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COBRA-SFS Modifications and Cask Model Optimization

January 1989

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COBRA-SFS MODIFICATIONS AND CASK MODEL OPTIMIZATION

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ABSTRACT

Spent-fuel storage systems are complex systems and developing a computational model for one can be a difficult task. The COBRA-SFS computer code provides many capabilities for modeling the details of these systems, but these capabilities can also allow users to specify a more complex model than necessary. This report provides important guidance to users that dramatically reduces the size of the model while maintaining the accuracy of the calculation. A series of model optimization studies was performed, based on the TN-24P spent-fuel storage cask, to determine the optimal model geometry. Expanded modeling capabilities of the code are also described. These include adding fluid shear stress terms and a detailed plenum model. The mathematical models for each code modification are described, along with the associated verification results.

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NOMENCLATURE

SYMBOLS AND NOTATIONS

α_m	- set of wall numbers that connect to wall node m
β_n	- set of wall numbers that connect to rod n
γ_n	- set of channel numbers for channels with a thermal connection to rod n
Δt	- time step
Δx	- axial step
ϵ	- surface emittance or a member of a set
ζ_n	- set of rod numbers with a thermal radiation connection to rod n
θ	- problem orientation, angle from vertical
κ_n	- set of rod numbers with a thermal radiation connection to wall n
λ_i	- set of rod numbers with a thermal connection to channel i
ξ_m	- set of channel numbers with a thermal connection to wall m
ρ	- density
σ	- Stephan-Boltzmann constant
σ_m	- set of wall numbers with a thermal radiation connection to wall m
τ_i	- set of wall numbers for walls that connect to channel i
ψ_i	- set of transverse gap connections to channel i
ℓ	- length of transverse momentum control volume
A	- area
C, c	- drag, axial loss coefficient, empirical coefficient, or specific heat
D_h	- hydraulic diameter
e_k	- multiplier (± 1) that gives the correct sign to the transverse connection terms
f	- friction factor
F_{ij}	- radiation exchange factor, surface i to j
g	- acceleration due to gravity
h, H	- fluid enthalpy, average film coefficient, or heat transfer coefficient
H_g	- fuel-cladding gap conductance
k, K	- thermal conductivity

P, p	- pressure
q'''	- volumetric heat generation in wall
R	- radial thermal resistance or radius
r	- radius
S	- transverse gap width
T	- temperature
T_c	- cladding temperature
T_w	- wall temperature
t	- time
u	- transverse velocity
v	- axial velocity
w_T	- crossflow due to turbulent exchange
y_c	- cladding thickness
z	- factor for effective fluid radial conduction length

SUPERSCRIPTS

n	- time step level or Nusselt number exponent
$*$	- donor cell quantity
—	- average value

SUBSCRIPTS

c	- cladding or convection
f	- friction or fuel
i	- channel number or generalized subscript for matrix notation
HTR	- heat transfer from a rod
HTW	- heat transfer from a wall
j	- axial level or generalized subscript for matrix notation
$\left. \begin{matrix} II \\ JJ \end{matrix} \right\}$	- refer to channel numbers on either side of a transfer gap
k	- transverse gap number
m	- wall number
n	- rod number
R	- rod

T - transverse
w - wall

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COBRA-SFS MODIFICATIONS AND CASK MODEL OPTIMIZATION

1.0 INTRODUCTION

The COBRA-SFS (Spent Fuel Storage) code is designed to perform thermal-hydraulic analysis of multiassembly spent-fuel storage systems. The objective of the COBRA-SFS user is to develop a COBRA-SFS model that is both accurate and efficient. This study examines methods and factors that will assist the user in optimizing the nodalization of a storage cask model. This report also describes new code modeling capabilities that have been added to allow a more detailed representation of a system. This study was conducted by the Pacific Northwest Laboratory (PNL)(a) for the U.S. Department of Energy (DOE).

The accuracy of a storage system analysis is highly dependent on node distribution and the quantity and location of temperature points on a given cask. Although COBRA-SFS can handle very large problems (consisting of hundreds of channel and rod nodes), there is a practical upper limit, generally dictated by computer memory requirements. Also, the larger the problem, the more expensive it is to run; thus, cost considerations provide a significant incentive to limit problem size. The level of detail provided by rod-and-channel modeling is not always required for flow and heat transfer problems in fuel assemblies. Experience with COBRA codes has shown that reasonable results can often be obtained with much coarser representations of the assembly geometry (Rector, Cuta, and Lombardo 1986).

One objective of this work is to provide the COBRA-SFS user with a guide to developing the optimal model for a particular spent-fuel cask. Model aspects that were explored include geometry considerations, such as assembly, slab, and axial nodalization, and optimization of the numerical solution parameters.

Certain aspects of the original COBRA-SFS code (cycle 0) limited the scope and accuracy of the thermal-hydraulic calculations. One limitation of the code

(a) Operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

was the absence of fluid shear stress terms in the momentum equations. As a result, open flow regions could only be modeled using large channel nodes that may not represent the velocity distribution within the region with the desired accuracy. Fluid shear stress terms have been added to allow finer nodalization and more detailed information in these regions.

Another limiting aspect of the code was the plenum models that were used to represent the upper and lower portions of storage casks. In using these models, it was assumed that all fluid entering a plenum region was uniformly mixed and that no temperature variation existed in the region. In addition, heat transfer from each region to ambient conditions was modeled using two one-dimensional heat transfer paths. The limitations of these plenum models have been identified in several previous cask analysis studies. A detailed plenum model was added to allow the calculation of temperature and flow distributions in the plenum regions.

The conclusions and recommendations based on this study are presented in Section 2.0. A brief description of the COBRA-SFS code is presented in Section 3.0. In Section 4.0, the results of the model optimization studies based on the TN-24P spent-fuel cask are presented, and general guidelines for model optimization are discussed. Modifications to the COBRA-SFS code are described in Sections 5.0, 6.0, and 7.0. Section 5.0 describes the addition of fluid shear stress terms to the momentum equations. Section 6.0 describes the addition of a detailed plenum model. Section 7.0 describes a series of additional code improvements including temperature-dependent solid thermal conductivity and axially varying solid material types.

2.0 CONCLUSIONS AND RECOMMENDATIONS

COBRA-SFS optimization is somewhat cask-specific; however, the conclusions and recommendations presented here, based on the TN-24P spent-fuel cask described in Section 4.0, apply in general to all COBRA-SFS cask models. It is recommended that all COBRA-SFS users investigate the benefits of optimization for their specific model based on the procedures detailed in this document.

2.1 CONCLUSIONS

The conclusions for this study are divided into two areas: 1) those related to the optimization of cask nodalization and 2) those related to the addition of new code modeling capabilities. The following conclusions were drawn from the cask model optimization study.

- Spent-fuel assemblies can be represented by coarse assembly models using composite channels and rods. The temperature predictions for the simulations using different combinations of coarse and detailed assembly models compared well with the completely detailed assembly model predictions. Therefore, combinations of coarse and detailed assembly models can be used in a multiassembly cask model to reduce the problem size by half of a fully detailed model, with less than 5% change in peak temperature prediction compared to the fully detailed analysis. This was true for all three backfills: helium, nitrogen, and low-pressure nitrogen (vacuum).
- In many cases, the number of slab nodes used in a cask model can be reduced. Circumferential temperature gradients in many spent-fuel cask shells can be neglected so that only radial nodes are required. Radial nodes of similar materials may be combined, except in casks where an interfacial gap is involved. When the basket is constructed of a high-conductivity material, the model can be more coarsely noded than for a low-conductivity material. The TN-24P cask basket temperature predictions varied by less than 2%, when the basket nodes were reduced by 66%.

- There is a limit to the minimum number of axial levels that will provide accurate temperature profiles. In this study, the 24-, 18-, and 12-axial level models all predicted temperature profiles within 5% of each other. However, when the 8-level model was applied, the temperature predictions differed by as much as 13% from the other axial model predictions. This effect was most apparent in the nitrogen backfill case, where convection is a major contributor to the overall heat transfer. It is important to know the sensitivity of a specified cask-to-axial noding to ensure that the predictions are accurate.
- By optimizing the parameters controlling the numerical solution, the computational time required for a cask simulation can be significantly reduced without affecting the accuracy of the solution. The optimum values for parameters ACCELW and ACCROD vary as a function of backfill media. The optimum value for ACCELW was determined to be 1.6 for the helium backfill case and 1.5 for the nitrogen case. The optimum value for ACCROD was found to be 0.6 for the helium and nitrogen cases, and 0.4 for the vacuum case. For all backfills the optimum value of ACCAX was determined to be 1.0.

The following conclusions were drawn from the addition of new code modeling capabilities:

- The fluid shear stress terms have been successfully added to the COBRA-SFS momentum equations. These terms allow the modeling of open flow regions with several channels. Verification runs have been performed for developing flows in a planar channel, cylindrical pipe, and square duct. The heat transfer terms were verified by comparing code results with analytically determined Nusselt numbers. In all cases, results show excellent agreement.
- An improved plenum model has been added that allows detailed modeling of fluid velocities and enthalpies in the plenum region. The model was verified by comparing the code results with data for natural circulation in a square cavity. The comparison shows very good agreement.

- Several other improvements have been made to the COBRA-SFS code, including temperature-dependent solid thermal conductivities, axially varying solid material types, solid heat generation transient tables, and dimensionless solid-to-fluid connections. The temperature-dependent conductivities were verified by comparing code results with the analytical solution for heat generation in a slab with linearly-varying thermal conductivity.

2.2 RECOMMENDATIONS

The following recommendations are offered:

- The results presented in this study were based on the TN-24P spent-fuel cask but apply in general to all COBRA-SFS cask models. For each code application, a limited optimization study should be performed based on the methods detailed in this report to determine the most efficient model. The study should include axial and assembly noding sensitivity investigations.
- One major feature of the COBRA-SFS code that has not yet been verified is its transient capability. It is recommended that a series of runs be performed and documented to verify this capability and extend its applicability to transient heat transfer systems.

3.0 COBRA-SFS DESCRIPTION

The COBRA-SFS code is a steady-state, lumped-parameter, finite-difference computer code that predicts flow and temperature distributions in spent-fuel storage systems and fuel assemblies under mixed and/or natural convection conditions. Derived from the COBRA family of codes (Rowe 1973; Stewart et al. 1977; George et al. 1980; Khan et al. 1981), which have been extensively evaluated against in-pile and out-of-pile data, COBRA-SFS retains all the important features of the COBRA codes and extends the range of application to problems with two-dimensional radiation and conduction heat transfer. This capability permits analyses of single- and multiassembly spent-fuel storage systems with unconsolidated or consolidated fuel, with a variety of fill media (Cuta, Rector, and Creer 1984; Lombardo et al. 1986a; Cuta and Creer 1986; Wiles et al. 1986; Rector, Cuta, and Lombardo 1986; Rector et al. 1986a; McKinnon et al. 1986; Wheeler et al. 1986).

COBRA-SFS provides finite-difference solutions to the equations governing mass, momentum, and energy conservation for incompressible flows. Analyses are conducted using a channel approach in which the flow areas of assemblies or storage systems are divided axially into discrete control volumes for which the conservation equations of mass, momentum, and energy are written. These equations are then solved using an iterative implicit method. The energy equations for the coolant, rod cladding, fuel, and structural members (slabs) are solved implicitly by iteration, but simultaneously in a plane. Axial conduction in the structural members is modeled. A nonparticipating gray body radiation heat transfer model also allows two-dimensional radiant heat exchange among all solid surfaces in an enclosure and is iteratively coupled to the rod and wall energy equations.

The flow field may be either user-prescribed or internally calculated as a function of the gravitational and dynamic pressure losses. Specifications of heat losses from the boundary may vary circumferentially and axially, and can include both radiation and convection heat transfer. Axial heat transfer from the channel model to plenum regions (regions above and below the fuel assemblies) also can be modeled.

In the following sections, the COBRA-SFS modeling capabilities are outlined, and a brief description of the conservation equations is given.

3.1 MODELING CAPABILITIES

COBRA-SFS allows simulations of a wide range of dry storage systems. In addition to the multiassembly cask analysis described in this report, applications have included analyses of single-assembly spent-fuel storage systems under multiple orientations and fill media (Lombardo et al. 1986a), multi-assembly systems with unconsolidated spent-fuel (Wiles et al. 1986; Rector et al. 1986a; McKinnon et al. 1986), and analyses of both single- and multi-assembly consolidated fuel storage systems (Cuta, Rector, and Creer 1984; Cuta and Creer 1986; and Rector et al. 1986b). The code contains thermal-hydraulic models for pressure drop, turbulent mixing, diversion crossflow, buoyancy-induced flow recirculation, and conduction and radiation heat transfer. A versatile fuel rod model allows simulation of consolidated fuel assemblies. The code's capabilities and limitations are outlined in Table 3.1.

3.2 CONSERVATION EQUATIONS

The COBRA-SFS code solves the conservation equations of mass, momentum, and energy in a fuel assembly or fuel storage system using finite-difference equations derived by performing suitable balances on finite control volumes. Empirical relationships are used where needed to close the set of equations. The conservation equations presented below are derived in more detail in Rector, Wheeler, and Lombardo (1986).

The fluid control volume for continuity, axial momentum, and energy is characterized by a flow cross-sectional area, A ; an axial length, Δx ; and a gap width, S , for the connection between itself and adjacent control volumes. Figure 3.1 shows the relationship of a channel control volume to a fuel storage system; a typical channel control volume is also displayed. Any series of control volumes connected axially is considered a channel. In the following equations, the finite-difference terms are presented with the corresponding word definitions given immediately below each equation. The list of symbols

in the Nomenclature section of this document should be referred to for explanation of the notation.

Continuity Equation (for channel i)

$$\bar{A} \frac{(\rho - \rho^n)}{\Delta t} j = \frac{v_{j-1} A_{j-1} \rho_{j-1}^*}{\Delta x_j} - \frac{v_j A_j \rho_j^*}{\Delta x_j} + \sum_{k \in \Psi_i} e_k (u_k S_k \rho_k^*)_j \quad (3.1)$$

$$\left[\text{mass storage} \right] = \left[\text{mass transported axially} \right] + \left[\text{mass transported laterally} \right]$$

The asterisk denotes donor cell values convected by the velocities u and v .

Fluid Energy Equation (for channel i)

$$\bar{A} \frac{[\rho h - (\rho h)^n]}{\Delta t} j = \frac{v_{j-1} A_{j-1} \rho_{j-1}^* h_{j-1}^*}{\Delta x_j} - \frac{v_j A_j \rho_j^* h_j^*}{\Delta x_j} + \sum_{k \in \Psi_i} e_k (u_k S_k \rho_k^* h_k^*)_j$$

$$\left[\text{energy storage} \right] = \left[\text{energy transported axially} \right] + \left[\text{energy transported laterally} \right]$$

$$+ \sum_{n \in \lambda_i} \frac{A_{HTR} H_R}{\Delta x_j} (T_c - T_n) + \sum_{m \in \gamma_i} \frac{A_{HTW} H_W}{\Delta x_j} (T_w - T_m)$$

$$+ [\text{rod heat flux}] + [\text{wall heat flux}]$$

$$+ \sum_{k \in \Phi_i} e_k S_k K_k \frac{T_{II} - T_{JJ}}{\ell_k Z_k} + \sum_{k \in \Psi_i} \frac{e_k w_T}{\Delta x_j} (h_{II} - h_{JJ})$$

$$+ \left[\begin{array}{c} \text{conductive heat} \\ \text{transfer laterally} \end{array} \right] + [\text{turbulent energy exchange}] \quad (3.2)$$

All other forms of energy transport that are not explicitly represented in Equation (3.2) (e.g., potential and kinetic energy) have been neglected.

Axial Momentum Equation (for channel i)

$$\bar{A} \frac{[\rho v - (\rho v)^n]}{\Delta t} \bigg|_j = \frac{A_{j-1} v_{j-1} v_{j-1}^* \rho_{j-1}^*}{\Delta x_j} - \frac{A_j v_j v_j^* \rho_j^*}{\Delta x_j} + \sum_{k \in \Psi_i} e_k (u_k S_k v_k^* \rho_k^*)_j$$

$$\left[\begin{array}{c} \text{axial} \\ \text{momentum} \\ \text{storage} \end{array} \right] = \left[\begin{array}{c} \text{axial momentum} \\ \text{transported} \\ \text{axially} \end{array} \right] + \left[\begin{array}{c} \text{axial momentum} \\ \text{transported} \\ \text{laterally} \end{array} \right]$$

$$+ \bar{A}_j \frac{P_{j-1} - P_j}{\Delta x_j} + \sum_{k \in \Psi_i} \frac{e_k w_T}{\Delta x_j} (v_{II} - v_{JJ})$$

$$\left[\begin{array}{c} \text{pressure} \\ \text{gradient} \end{array} \right] + \left[\begin{array}{c} \text{turbulent momentum} \\ \text{exchange} \end{array} \right]$$

$$- \frac{1}{2} \left(\frac{f}{D_h} + \frac{C}{\Delta x_j} \right) \rho_j v_j |v_j| A_j - A \rho g \cos \theta$$

$$- \left[\begin{array}{c} \text{irreversible friction} \\ \text{and form losses} \end{array} \right] - [\text{gravitational head}] \quad (3.3)$$

In the derivation of the axial momentum equation, it is assumed that all irreversible losses can be obtained by use of suitable friction factors and

loss coefficients applied to the bulk velocity. Also, it is assumed that pressure changes linearly along the control volume and the shear stress terms due to flow in the adjacent channels can be neglected.

Transverse Momentum Equation

$$S\Delta x_j \frac{[\rho^*u - (\rho^*u)^n]}{\Delta t} k = S_k v_{j-1} (\rho^*u)_{k,j-1}^* - S_k v_j (\rho^*u)_{k,j}^*$$

$$\left[\begin{array}{c} \text{lateral} \\ \text{momentum} \\ \text{storage} \end{array} \right] = \left[\begin{array}{c} \text{transverse momentum} \\ \text{transported axially} \end{array} \right]$$

$$+ (P_{II} - P_{JJ})_{j-1} \frac{S_k \Delta x_j}{\ell_k} - C_T u_k |u_k| \frac{\rho S \Delta x_j}{2\ell_k}$$

$$+ [\text{pressure gradient}] - \left[\begin{array}{c} \text{irreversible form and} \\ \text{friction loss} \end{array} \right] \quad (3.4)$$

The momentum control volume length, ℓ , and gap width, S , define a transverse momentum control volume as shown in Figure 3.2. Inside this control volume, the transverse velocity is normal to the gap; the flow is assumed to have no transverse component outside the transverse momentum control volume. A further assumption in the transverse momentum equation is that there are no applied body forces in the transverse direction. Therefore, natural convection in the transverse direction cannot be modeled.

Fuel Rod and Cladding Energy Equations

$$y_c \rho_c c_c \frac{T_c - T_c^n}{\Delta t} = H_R (T_c - T) + H_g \frac{R_f}{R_c} (T_{fs} - T_c)$$

$$\begin{aligned}
\left[\text{energy storage} \right] &= \left[\text{convective transfer to the fluid} \right] + \left[\text{heat transfer from fuel} \right] \\
&+ \sigma \sum_{n \in \zeta_n} F_{in} (T_c^4 - T_{c_n}^4) + \sigma \sum_{m \in k_m} F_{im} (T_c^4 - T_{w_n}^4) \\
&+ \left[\text{radiation heat transfer from rods} \right] + \left[\text{radiation heat transfer from walls} \right]
\end{aligned} \tag{3.5}$$

By assuming that 1) there is no heat transfer axially, 2) the heat is generated uniformly throughout the fuel at a given axial location, and 3) the fuel properties do not vary with the radial variation in temperature, the cladding temperature is obtained by performing a lumped energy balance on the cladding material at each axial level. The film coefficient, H_R , is given by user-specified correlations, and the gap conductance between fuel pellet and cladding, H_g , is assumed constant. F_{in} and F_{im} are gray body radiation exchange factors that account for multiple reflections within an enclosure. F_{in} is a coefficient for rod-to-rod heat transfer, while F_{im} is a coefficient for rod-to-slab heat transfer. Both are derived by assuming constant surface emissivity. The gray body exchange factors can be user-prescribed or calculated internally by specifying black body view factors and surface emissivity values.

Slab Energy Equations

$$\rho_w c_w t_w \frac{T_w - T_w^n}{\Delta t} = \sum_{\Delta \epsilon \psi_i} U (T - T_w) + \sigma \sum_{m \in \sigma_m}^{NW} F_{im} (T_w - T_m^4)$$

$$\begin{aligned}
[\text{energy storage}] &= [\text{heat transfer from adjacent channels}] + [\text{radiation heat transfer from walls}] \\
&+ \sigma \sum_{n \in \beta_n}^{NR} F_{in} (T_w^4 - T_{c_n}^4) + q'' \\
&+ [\text{radiation heat transfer from rods}] + [\text{heat generation}] \\
&+ U_{j-1} (T_w - T_{w_{j-1}}) + U_{j+1} (T_w - T_{w_{j+1}}) + \sum_{m \in \alpha_m} U (T_w - T_{w_m}) \\
&+ [\text{axial conduction heat transfer}] + [\text{heat transfer from adjacent walls}]
\end{aligned} \tag{3.6}$$

As before, F_{im} and F_{in} are the gray body exchange factors from wall node i to wall node m and rod node n , respectively. Axial heat transfer from the walls to a plenum region can be included at the top and bottom axial levels.

FIGURE 3.1. Channel Definition

FIGURE 3.2. Transverse Momentum Control Volume

TABLE 3.1. COBRA-SFS Capabilities and Limitations

Modeling Capabilities

- Steady state
- Triangular, square, or consolidated rod arrays
- Recirculating flows
- Zero net flow solution option
- Interassembly and intra-assembly heat transfer
- Nonparticipating radiation (planar)
- Variable axial grid spacing
- Multiple flow regions
- Fluid conduction and turbulent mixing
- Pressure drop model (network and channel)
- Variable material property rod model
- Prescribed heat flux
- Use of specified or prescribed flow regions
- Variable fluid properties

Program and I/O Control

- Constant prescribed flow
- Zero net flow option
- Restart and post-processing dump
- Decoupled hydrodynamics (no buoyancy)
- Fully coupled hydrodynamics
- Result execution and time monitoring
- Variable/constant fluid properties
- Pressure drop initialization scheme
- Data "roll" option to reduce memory for large problems

Limitations and Assumptions

- Incompressible flow
- One-dimensional boundary heat transfer

4.0 CASK MODEL OPTIMIZATION

The accuracy of a cask thermal-hydraulic analysis is dependent upon how the cask is noded; i.e., how the cask geometry is divided into nodes. In addition, the analysis cost and memory requirements are directly related to the number of nodes used in the model. Therefore, the objective of model development is to achieve the maximum level of accuracy with the minimum number of nodes.

4.1 MODEL DEVELOPMENT

A COBRA-SFS cask model is constructed by dividing the cask into a set of finite volumes or nodes. Three types of nodes are used in a typical cask model--channels, rods, and slabs. The channel nodes are used to represent the fluid regions of the cask, the rod nodes are used to represent the spent fuel rods, and the slab nodes are used to represent the solid structures of the cask such as the basket and cask shell.

In a COBRA-SFS cask model, the geometry in the channel region of the cask is assumed to be uniform in the axial direction. The first step in developing a COBRA-SFS model is to prepare a two-dimensional nodalization map of the cask cross section. To aid in preparing a nodalization map, the following points should be considered:

- Use symmetry to determine what portion of the cask must be modeled.
- Decide what information is required from the model.
- From what is known about the temperature distribution in the cask, arrange the nodes for maximum accuracy.

Each of these points is discussed in more detail below.

4.1.1 Cask Symmetry

In most cases, the entire cask cross section does not have to be modeled. Where symmetry exists, the cask may be modeled using a portion of the cross section with appropriately averaged operating and boundary conditions. Symmetry assumes that the cask may be divided into uniform sections, so that

negligible heat crosses the boundaries between the modeled section and other sections. Before symmetry can be assumed, the following conditions must be satisfied:

- The geometry is symmetric.
- The decay heat generation is symmetric.
- The boundary conditions are symmetric.

A symmetric geometry may be obtained by folding the cross section along symmetry lines that run through the center of the cask. For a cask with a square basket, this procedure may result in a one-half, one-fourth, or one-eighth section of the cask. Noding maps for the TN-24P cask are presented in Figure 4.1 for a one-half section and Figure 4.2 for a one-eighth section. Note that the one-eighth symmetry allows greater detail using fewer nodes.

The geometric symmetry may change as a function of cask orientation. When a cask is placed in a horizontal position, the assembly basket, if separate from the cask shell, may shift, changing the gap widths between the basket and shell. In addition, the fuel assemblies may shift their position within the basket and make contact on one side. If these changes are significant, a one-half symmetry must be used to represent the cask.

If the decay heat generation is not perfectly symmetric, two possible approaches are suggested. One is to average the heat generation for assemblies with the same relative position to the center of the cask for all sections. This approach has the advantage of maintaining the correct total power for the problem. If a conservative analysis is desired, the peak heat generation for each assembly location can be used.

For most cask problems it can be assumed that the boundary conditions are uniform around the cask. The resistance to thermal conduction around the circumference of the cask is generally quite low as compared to the thermal resistance to ambient temperature. One major exception to this is a cask in a horizontal position with a significant thermal contact to the supporting surface.

4.1.2 Model Requirements

The development of a cask model is influenced by the type of information desired from the analysis. If specific values such as the peak cladding temperature are desired, the cask may be modeled to give greater detail in the areas of interest and less detail in other areas of the cask. This is especially true of spent-fuel casks with baskets of high thermal conductivity. In such a case, the radial temperature profile of one assembly does not greatly affect that of an adjacent assembly. The assemblies where the peak temperature is not expected to occur may be noded with less detail. The primary concern for these assemblies would be to provide the correct average flow and temperature to the plenums and to provide the proper radial resistance to heat flow. Examples of this type of noding simplification will be presented in Section 4.3.

4.1.3 Effect of Temperature Distribution

The COBRA-SFS code, like most finite-difference codes, models heat transfer from one node to another by assuming a constant heat flux between node points. For nodes with the same thermal conductivity, this is characterized by a linear-temperature gradient between node centers. If the heat flux or temperature gradient through a series of node connections is constant, they can be replaced by a single node connection without loss in accuracy. Therefore, nodes may be minimized in areas of constant temperature gradient or heat flux. However, when the temperature gradient is significantly nonuniform, a single linear node connection will do a poor job of representing the heat transfer through that region. Instead, the region should be modeled using a series of finer node connections and nodes should be concentrated in areas where the temperature gradient or heat flux is most nonuniform.

Examples of this type of noding simplification will be presented in Sections 4.3 and 4.4.

4.2 BASE MODEL DESCRIPTION

Several sensitivity studies have been performed to demonstrate the effect of model nodalization on the solution accuracy and computational size. The Transnuclear TN-24P spent-fuel cask was selected as the basis for these studies.

A brief description of the cask is presented in Section 4.2.1. The cask model used in these studies is described in Section 4.2.2. More detailed information about both the cask and model may be found in (McKinnon et al. 1986).

4.2.1 TN-24P Cask Description

The TN-24P spent-fuel storage cask consists of a forged steel body for structural integrity and gamma shielding, surrounded by a resin layer for neutron shielding. The resin layer is enclosed in a smooth steel outer shell. The cask cross section is shown in Figure 4.3. The cask is 5.0 m (16 ft) long and 2.3 m (7.5 ft) in diameter and weighs approximately 100 tons when loaded with unconsolidated PWR spent fuel. The fuel basket within the cask is configured to hold 24 PWR spent-fuel assemblies and is composed of stacked, interlocking plates constructed of aluminum and boron. The cask is closed with a lid having two concentric metallic O-ring seals plus a protective cover sealed with one rubber O-ring gasket to seal the cask cavity from the environment.

4.2.2 TN-24P Base Model Description

A one-eighth section model of 18 uniform axial levels as depicted in Figure 4.4 was developed to analyze the TN-24P spent fuel cask. Each axial level comprised 51 wall nodes, 386 channels, and 450 rod nodes (Figure 4.2).

The wall nodes included 27 basket nodes, 12 cask body nodes, 4 neutron shield nodes, and 8 cask shell nodes. The four outermost shell nodes are zero-thickness nodes that represent the cask surface temperature for the purpose of accurately calculating the contribution of radiation and convection heat transfer to the environment.

One of the lines of symmetry used to define the one-eighth section model runs through two of the basket fuel tubes. Fuel assemblies in these locations were modeled with one rod surface node per rod, for a total of 120 rod surface nodes. This representation, along with the layout of the 136 fluid channels used to describe the flow, is shown in Figure 4.5. In the noding of the full fuel assemblies, the flexibility of the COBRA-SFS channel approach was used to selectively lump rods together and channels together to decrease the size of the computational model, as displayed in Figure 4.6. The 225

rods were represented by 105 lumped rods. The flow area within the assemblies was modeled by 57 channels.

Decay heat from the fuel assemblies is removed by conduction, convection, and radiation heat transfer. The following is a discussion of COBRA-SFS modeling of each of these modes for the TN-24P cask.

Fluid-fluid conduction between neighboring channels was modeled using a transverse control volume defined by a gap width, a centroid-to-centroid length, and an axial length. Axial fluid-fluid conduction was neglected.

Conduction heat transfer in the walls was modeled in the radial, circumferential, and axial directions via an input specification of thermal resistances between neighboring nodes. Each thermal resistance can reflect any combination of parallel and/or series resistance paths. An example of such a composite resistance in the TN-24P analyses is the polyethylene resin and copper fins, which formed the side neutron shield. In this region a resistance was calculated that represented the two parallel paths through the shield.

The contribution of convection heat transfer within the cask is dependent on the predicted flow field. For the TN-24P simulations, the flow field was obtained iteratively by adjusting the total pressure drop until 1) the pressure drop across all channels was equal and 2) the total net flow rate was zero. Therefore, the basket and the fuel assembly flow resistances were important convection parameters. The surface friction for all of the channels was approximated using a friction factor of $f = 100/Re$, which was derived for a square rod array with pitch-to-diameter ratios typical of PWRs (Sparrow and Loeffler 1959).

Convective heat transfer from the rod and wall surfaces to the fluid was prescribed using a film coefficient having the form $Nu = 3.66$ (Kays and Crawford 1980). This correlation is the analytical solution of the energy equation for a constant temperature wall and fully developed temperature and velocity profiles in a circular tube. Previous work (Wiles et al. 1986) that investigated the effect of various values of Nusselt number on COBRA-SFS temperature

predictions determined that a value of 3.66 gave the best overall results for the nitrogen and helium fill media.

Radiation heat transfer was treated on an assembly-by-assembly basis. In each basket fuel tube containing a pressurized water reactor (PWR) fuel assembly, rod-rod, rod-wall, and wall-wall radiative heat transfer were modeled by specification of gray body exchange factors. The exchange factors for the fuel rods and walls were calculated using one-quarter pin surface segments to define the radiation generation view factors and the cross-string correlation method of Hottel (Cox 1977). This is a more exact approach than the assumption of uniform radiosity around a rod surface. Radiation exchange in the empty basket enclosures, which consisted of either basket walls, or basket walls and the inner cask wall, was determined using wall-wall view factors input by the user. The COBRA-SFS code used these factors along with appropriate emissivities to calculate the gray body exchange factors.

The material properties used for the TN-24P model are presented in Table 4.1. All surface emissivities and the greater portion of the solid thermal conductivities were provided by Transnuclear, Inc. The thermal properties of the solids were assumed constant, and properties of the fill gas were specified as a function of temperature.

The effects of deviations from the base COBRA-SFS model are described in the following three sections. Section 4.3 focuses on assembly model nodalization. The slab nodalization concerns are addressed in Section 4.4 and, lastly, the axial nodalization sensitivity is described in Section 4.5.

4.3 ASSEMBLY NODALIZATION

The noding of the individual assemblies is discussed in this section. It is especially important to minimize the number of assembly nodes in the case of a multiassembly cask. If one node per fuel rod is used, the information can end up being more detailed than required, the cost prohibitive, and in some cases the problem will not fit on currently available computers. However, the analyst may require more detailed information from certain areas of the cask, or large temperature gradients may require a more detailed noding

scheme. The goal of the modeler is to balance cost and size versus accuracy and detail requirements.

The effect of seven different assembly node model sets on temperature distribution in the TN-24P spent-fuel storage cask is addressed. Axial and radial temperature profiles are provided for each model. The bottom data point of the axial temperature profiles represents the bulk temperature of the lower plenum and the top data point represents the bulk temperature of the upper plenum. Comparisons discussed in this section and Section 4.5 pertain only to the fuel assembly region of the COBRA-SFS models. Each assembly model is discussed separately, and then a brief discussion of all of the temperature predictions is provided.

Each assembly model set includes a pattern description within its section title. Two different pattern descriptors are used. For the first six model sets, the following is used:

(A/B Rod Nodes, D/E Channel Nodes)

where A = number of rod nodes in each of the two half assemblies

B = number of rod nodes in each full assembly

D = number channel nodes in the half assemblies

E = number of channel nodes in each full assembly.

For the last two assembly models, the format is as follows:

(A/B/C Rod Nodes, D/E/F Channel Nodes)

where A = number of rod assemblies in the center half assembly

B = number of rod nodes in the outer half assembly

C = number of rod nodes in each of the full assemblies

D, E, F = number of channel nodes in the corresponding assemblies.

4.3.1 Assembly Model Set #1 (120/105 Rod Nodes, 136/57 Channel Nodes)

A description of this assembly model set was given in Section 4.2. The design goal for this assembly model set was to provide detailed temperature

information for the hottest assembly. The TN-24P cask was modeled by a one-eighth section model (Figure 4.2). This required two assembly models, one for the two assemblies split in half, and another for the two whole assemblies. Using past experience and a knowledge of the spent-fuel loading pattern, it was determined that the center assembly would be the hottest. The center one-half assembly model was therefore developed with the detailed noding shown in Figure 4.5. This model was also applied to the remaining one-half assembly model for the sake of simplicity.

The full assembly model was not noded in as much detail in an effort to keep the computational model as small as possible. An initial test run was made with a detailed one node-one rod model to find out what temperature distribution in the full assembly would result. Based on the isotherms resulting from the test run, the noding pattern displayed in Figure 4.6 was selected. This scheme required only 105 rod nodes and 57 channel nodes, instead of the 225 rod nodes and 256 channel nodes a full assembly detailed model requires.

The comparisons of assembly model set #1 predicted axial temperatures with experimental data for three backfill cases of helium, nitrogen, and vacuum (low-pressure nitrogen) are presented in Figures 4.7 through 4.9. The axial temperature profiles correspond to the hottest instrumented rod location in the center assembly. The radial temperature profiles displayed in Figures 4.10 through 4.12, and in all other radial temperature profiles presented in this report, represent selected locations through the cask at the peak measured temperature axial level. For the helium and vacuum cases (Figures 4.7 and 4.9), the predicted temperatures are in very close agreement with the measured values. For the nitrogen case (Figure 4.8), the prediction is somewhat conservative, probably because of underprediction of the actual amount of natural convection heat transfer in the cask. In the following sections the effect of varying the assembly noding structure is described.

4.3.2 Assembly Model Set #2 (1/1 Rod Nodes, 1/1 Channel Nodes)

The simplest COBRA-SFS spent fuel assembly model would consist of 1 rod node representing all rods and 1 channel node representing the channel area.

Although this results in a much faster and smaller model, accuracy may be drastically reduced. Axial and radial temperature profiles for each of the backfill cases are displayed along with the post-test model results in Figures 4.13 through 4.18.

The loss of accuracy is clear for the coarsest assembly model. For most applications this model would be insufficient.

4.3.3 Assembly Model Set #3 (5/9 Rod Nodes, 5/9 Channel Nodes)

The effect of increasing the assembly model sizes from the minimum sizes is shown in the third model set. The half assemblies were modeled with 5 rod nodes and 5 channel nodes and the full assemblies were modeled with 9 rod nodes and 9 channel nodes as depicted in Figures 4.19 and 4.20. The effect of an increase in nodes per assembly is shown in the comparison of the axial and radial temperature profiles with the two previous models sets (Figures 4.21 through 4.26). However, this model still provides only a rough approximation.

4.3.4 Assembly Model Set #4 (28/49 Rod Nodes, 28/49 Channel Nodes)

The fourth set consisted of 28 rod and channel nodes in the half assemblies and 49 in the full assemblies (Figures 4.27 and 4.28). As expected, the comparison of model sets 2, 3, and 4 with the post-test set shows improved temperature predictions as the number of nodes increases, with the greatest improvement shown in the going from 5/9 nodes per assembly to 28/49 nodes per assembly (Figures 4.29 through 4.34).

4.3.5 Assembly Model Set #5 (120/225 Rod Nodes, 136/256 Channel Nodes)

This model set represents the fully detailed assembly model. In both the half assembly model and the full assembly model, each rod and each channel are modeled with one node (Figure 4.5 and Figure 4.35). A comparison of the axial and radial temperature profiles for model set No. 1 and the fully detailed model is provided in Figures 4.36 through 4.41. The change in temperature predictions is small (less than 5°C in the center assembly, and less than 10°C in the outer assembly), indicating that model set No. 1 was not under noded in the assembly regions. It is possible that a model smaller than model set No. 1 may have been acceptable, or a different assembly modeling approach

could have been applied. Some such approaches are addressed in the following assembly model descriptions.

4.3.6 Assembly Model Set #6 (120/1 Rod Nodes, 136/1 Channel Nodes)

This set combines the accuracy of a detailed assembly model for the center assembly, the minimizing of storage requirements in the full assemblies, and a decrease in required CPU time. This approach is designed to give detailed information in the center (hottest) assembly and provide an accurate prediction for the peak cladding temperature. For the sake of simplicity, both half assemblies were modeled in a detailed fashion. Comparisons of axial and radial temperature profiles with the detailed model set (assembly model set #5) for the three backfills are presented in Figures 4.42 through 4.47. For all three backfills, the agreement in the center assembly is fair. Peak temperature predictions were within 10°C for the nitrogen and vacuum case; however, the helium peak temperature underpredicted the assembly model set #5 temperatures by 22°C. If more detailed temperature information is required in the full assemblies, this model set would not be appropriate.

4.3.7 Assembly Model Set #7 (120/5/9 Rod Nodes, 136/5/9 Channel Nodes)

Assembly model set #7 consisted of three assembly models. The center half assembly was modeled with 120 rod nodes and 136 channel nodes, the other half assembly was modeled with 5 rod nodes and 5 channel nodes (Figure 4.19), and the full assemblies were modeled with 9 rod and 9 channel nodes. This decrease in computational size, as compared with assembly model set #6, is brought about by a major decrease in the number of nodes in the outer half assembly in conjunction with only a minor increase in the number of nodes in the two full assemblies. The predictions from this model set are displayed along with the detailed model set and assembly model set #6 predictions for the three backfills in Figures 4.48 through 4.53. This model set results in an overall improvement over the previous model set while at the same time requiring less CPU time. Peak temperature predictions were within 5°C of the detailed model predictions for all three backfill cases. The radial temperature profiles reflect the inability of this model to match the detailed temperature

predictions in the outer assemblies, underpredicting the temperatures by as much as 36°C.

4.3.8 Assembly Model Set #8 (120/49/28 Rod Nodes, 136/49/28 Channel Nodes)

This final model set was also a three-assembly model set. The center assembly was modeled in the detailed fashion described previously, while the other assemblies were modeled using the noding logic described for assembly model set #4 (Figures 4.27 and 4.28). In the center assembly the temperature predictions were within 5°C of the predictions from the detailed model for the three backfill cases (Figures 4.54 through 4.59). The outer assembly temperature predictions were within 15°C of the detailed model predictions. In many cases this model would suffice, but if detailed information in the outer assemblies is required this model may not be sufficient.

As expected, the accuracy of the temperature predictions is highly dependent on the quantity of assembly nodes. The more nodes, the more detailed the predictions. However, selective assembly noding strategies have been proven effective in producing peak temperatures in the hot assembly within 5°C of the detailed model. This allows the COBRA-SFS user to decrease the size and associated running time of the problem without sacrificing detail in selected regions. Other important considerations are the slab noding and axial noding models. The following section addresses the sensitivity of the temperature prediction to slab noding.

4.4 SOLID STRUCTURE MODELING

Solid structures in a cask, such as the assembly basket and cask shell, are modeled using finite volume nodes known as slabs. Each slab may be thermally connected to adjacent slabs, fluid channels, and contacting rods. Solid structure nodes are described in Section 3.0. The thermal connection between two adjacent slabs may be characterized by using either of two methods. The total solid conduction resistance can be specified directly as input. Alternatively, the user can define the geometry of the thermal connection by entering conduction geometry factors for the two adjacent slabs. The code

then calculates the solid resistance from the geometry factors and thermal conductivities of the slabs.

Methods of optimizing the slab nodalization for a cask are demonstrated using the TN-24P cask model. The solid structure noding for the TN-24P cask is shown in Figure 4.60. The assembly basket is represented by 27 slabs and the cask shell is represented by 20 slabs.

The cask shell is divided in both the radial and circumferential directions. In most cases the temperature gradient in the circumferential direction is negligibly small and the heat transfer can be characterized as one-dimensional in the radial direction. This was done for the TN-24P cask model, representing the cask shell with five radial nodes as shown in Figure 4.61. The peak clad temperature for this case was 281.6°C as compared to 282.0°C for the detailed cask shell case, a difference of 0.4°C.

For steady-state calculations, the number of radial nodes may also be reduced without loss in accuracy. For example, using three radial nodes to represent the steel body is no more accurate than one node. The only regions where the temperatures must be calculated are surfaces where radiation heat transfer occurs. This includes the inner and outer shell surfaces and interior gaps that are evacuated or gas filled.

Special care must be taken in modeling interior gaps. These gaps generally occur at material interfaces within the shell. The temperature drop across gaps can be extremely high and can affect the accuracy of the entire analyses. The parameters used to describe the gap, i.e., gap width and surface emissivities, must be known as accurately as possible to properly describe the heat transfer through the gap.

The number of slab nodes required to describe the assembly basket is dependent on basket material and how the basket is constructed. When a high conductivity material such as copper or aluminum is used, the temperature drop through the basket is small, and fewer nodes can be used without significantly affecting accuracy. When a relatively low conductivity material such as stainless steel is used, a larger variation in temperature gradient occurs and a more detailed noding may be required. An example of how the basket can

be modeled with different levels of detail is shown in Figure 4.62. The basket shown in Figure 4.62a is noded with a relatively high level of detail. When a coarser noding is desired, the nodes may be combined to form cruciforms as shown in Figure 4.62b. This results in five times fewer nodes than used in representing the basket.

4.5 AXIAL NODING STUDY

This section addresses the effect of axial node size on the temperature predictions. It is important to minimize the number of axial levels specified because the COBRA-SFS computer memory requirement is approximately proportional to the number of axial levels. Six axial modeling strategies were developed for the basic post-test COBRA-SFS TN-24P model. A description of each axial model and a temperature comparison with the 24 axial level model is provided for all cases.

4.5.1 Axial Level Model #1 (24 Uniform Levels)

Axial level model #1 was the most detailed model investigated. The spent-fuel region of the cask was modeled with 24 uniform levels of 16.9 cm. Three backfill cases--helium, nitrogen, and vacuum--were run using assembly model set #1 from the COBRA-SFS TN-24P post-test analysis. Axial temperature profiles for experimental data and COBRA-SFS predictions are presented in Figures 4.63 through 4.65.

4.5.2 Axial Level Model #2 (18 Uniform Levels)

An 18-level model was developed for the post-test COBRA-SFS TN-24P analysis. Each axial level comprised 22.5 cm of the spent-fuel region of the cask. Comparisons of the axial temperature profiles for this model and the detailed 24-axial-level model are provided in Figure 4.66 through 4.68. All three backfill cases relate only minor differences, less than 5°C, between the two models temperature predictions over the entire temperature profile.

4.5.3 Axial Level Model #3 (12 Uniform Levels)

The third model consisted of 12 uniform axial levels, each 33.8 cm in height. Temperature profiles for this model and the 24-level model are dis-

played in Figures 4.69 through 4.71. The comparisons of the temperature profiles are good in the lower and middle portion of the cask for the helium and vacuum backfills, with some differences ($< 20^{\circ}\text{C}$) in the upper portion of the temperature profiles. The nitrogen backfill case shows an overall fair agreement between the two models, with a maximum difference of 15°C in the upper portion of the profile.

4.5.4 Axial Level Model #4 (8 Uniform Levels)

Axial level model #4 consisted of 8 axial levels, each 50.6 cm in height. The axial temperature profiles for this model are displayed for the three backfills along with the detailed model predictions in Figures 4.72 through 4.74. The results reflect a failure of the model to accurately match the 24-axial-level model temperature distributions for a nitrogen backfill. The helium and vacuum backfill temperature predictions were within 5°C over the entire profile, however the nitrogen temperature predictions differed by as much as 15°C in the upper and lower portions of the cask.

4.5.5 Axial Level Model #5a (12 Nonuniform Levels)

The COBRA-SFS computer code has the capability of modeling casks using nonuniform axial node sizes. This feature was employed in an effort to match the detailed axial model temperature predictions by concentrating the axial nodes in areas where the temperature gradient was the steepest. In this model large axial nodes (67.6 cm) were used in the center of the model, where the temperature gradient is generally the flattest, and small nodes (16.9 cm) were applied in the upper and lower portions of the model, where the temperature gradient is the steepest. The axial noding pattern for this model is displayed in Figure 4.75. Comparisons of axial temperature profiles for this model and the detailed (24 levels, model #1) uniform axial node model are presented in Figure 4.76 through 4.79. This model affected an overall improvement in the predictions; however, some differences still existed in the upper portion of the temperature profiles. Temperature predictions were within 5°C of the 24-axial-level model for the helium and vacuum cases, while the nitrogen predictions differed by less than 10°C .

4.5.6 Axial Level Model #5b (12 Nonuniform Levels)

A variation of axial level model #5a was developed in an effort to decrease the discrepancy between temperature predictions in the upper portion of the profile. In this model, the nodes' sizes ranged from a high of 50.7 cm in the center to a low of 16.9 cm in the upper and lower locations of the model, with transition nodes 33.8 cm between. The axial model is displayed in Figure 4.79. Axial temperature profiles for the detailed axial model and this model are provided in Figures 4.80 through 4.82. In general the temperature predictions from this model matched the detailed model predictions more closely than model #5a. For the helium and vacuum cases, the predictions were within 3°C, and the nitrogen case predictions were within 8°C of the 24-axial-level model.

In summary, the application of axial model #3 (12 uniform levels) resulted in temperature predictions nearly identical to axial model #1 (24 uniform levels), while requiring nearly half the computational size and time. However, there is a definite point where a reduction in axial nodes reduces the temperature prediction accuracy significantly, as was seen in the results from axial model #4 (8 uniform levels). Lastly, variable axial noding is a successful method of further improving COBRA-SFS temperature predictions, as shown by the results from axial models 5a and 5b.

4.6 PARAMETER OPTIMIZATION

The numerical solution of a particular cask simulation is controlled by various calculational parameters specified in input group CALC. The computational time required for the simulation may be reduced if the values specified for these parameters are optimized. This is especially true for parameters associated with the energy solution. A typical COBRA-SFS cask simulation uses more than 80% of the total computational time for the energy solution.

Three parameters are associated with the control of the numerical solution of the energy equations. These are the acceleration factor for the solid structure energy equation (ACCELW), the damping factor for the rod energy solution (ACCROD), and the acceleration factor for the axial energy rebalancing (ACCAX). The factors are applied as

$$X^n = \alpha X^n + (1 - \alpha)X^{n-1} \quad (4.1)$$

where X = calculational variable

α = damping or acceleration factor

n = current iteration number.

A series of TN-24P runs was performed using the detailed cask model to determine the sensitivity of the run time to each of the three parameters. The results are presented below for each parameter.

4.6.1 Solid Structure Equation Acceleration Factor

The fluid and solid structure energy equations are solved simultaneously at each axial level. The acceleration factor for the fluid equations (ACCELH) is set to a permanent value of 1.2 in the current version of the COBRA-SFS code. The acceleration factor for the solid structure equations (ACCELW) is an input parameter on card CALC.2 with a default value of 1.2.

The values assigned to these parameters typically fall in the range of 1.0 to 2.0. Values at the low end of the range do not adequately accelerate the solution and require more computational time than necessary. However, values at the high end of the range tend to cause instabilities in the solution. Therefore, a series of runs were performed with ACCELW values ranging from 1.2 to 1.6 to obtain the run times associated with each. Cases were run for both nitrogen and helium backfills. The results are presented in Table 4.2. The runs were performed on a CRAY X/MP using the CTSS operating system.

For both the nitrogen and helium cases, the optimum value for ACCELW exceeds the default value of 1.2. The optimum value for nitrogen is 1.5 and the optimum value for helium is at least 1.6. The improvement in total computational time is over 6% in the nitrogen case and over 22% in the helium case. One reason that this improvement is not greater is the use of energy rebalancing for both the fluid and solid structure equations every fifth iteration in the axial level energy solution. Rebalancing optimizes the energy solution for large-scale enthalpy and temperature changes, and the optimization of ACCELW optimizes the detailed changes in the solution.

The optimum value for ACCELW is highly problem specific. However, experience shows that 1.4 appears to be an appropriate value for ACCELW for a wide range of cask models.

4.6.2 Rod Equation Damping Factor

The rod energy equations are solved simultaneously at each axial level while assuming a fixed fluid enthalpy and slab temperature distribution. The damping factor for the rod solution (ACCRD) is an input parameter on card CALC.2 with a default value of 0.5.

Rods may be thermally coupled either by rod-to-rod contact (as in the case of consolidated fuel) or by thermal radiation. If the rods are not coupled, only one iteration is required for the solution. If the rods are coupled by rod-to-rod contact, the solution may need to be accelerated by specifying a value for ACCRD of greater than one. The optimum value will be highly dependent on the rod-to-rod contact coefficient.

If the rods are coupled by thermal radiation, the solution may require damping due to the highly nonlinear nature of the problem. The amount of damping that is required is dependent on how tightly connected the rods are to the fluid enthalpy distribution. These connections, in turn, are dependent on the Nusselt number expression and the thermal conductivity of the fluid.

To determine the optimum values for ACCRD, a series of runs were performed using the detailed TN-24P cask model. Cases were run for nitrogen, helium, and vacuum backfill. A Nusselt number of 3.66 was specified for the helium and nitrogen cases and a value of 1.0 was specified for the vacuum case. The results are presented in Table 4.3.

As expected, the optimum value for ACCRD is dependent on the backfill medium considered. The optimum value for nitrogen is 0.6; for helium it is at least 0.8; and for vacuum it is 0.4. However, the change in total computational time is not large, less than 5% in all cases. Note also that the optimum value for ACCRD is not far from values which cause instability in the solution procedure. Therefore, it is recommended that a conservatively low value for ACCRD be used, especially for the nitrogen and vacuum cases.

4.6.3 Axial Rebalancing Factor

The energy solution for the cask is performed by solving for enthalpies and temperatures at each axial level while holding values on adjacent levels fixed. Using this method, the solution may develop slowly due to thermal connections in the axial direction. To accelerate the solution, an axial energy rebalancing solution was added that calculates the temperature increment required to reduce the total energy error for each axial level to zero. The axial rebalancing is applied on the axial upsweep of every third iteration.

The axial rebalancing factor (ACCAX) is a multiplier on the temperature increments that are to be added to the different axial levels. The factor ACCAX is an input parameter that is read on card CALC.2 and has a default value of 1.0. In some cases, such as those where no side boundary connection exists, axial energy rebalancing may not be desired. In that case, ACCAX should be set to a very small value. For most cask problems, however, ACCAX should have a value of at least 1.0.

To determine the optimum value for ACCAX, a series of runs were performed with parameter values of 0.9, 1.0, and 1.1. A backfill medium of nitrogen was used in all cases. The results are presented in Table 4.4. Since the primary goal in energy rebalancing is to reduce the total energy error, the fraction of error remaining after 20 iterations is used as the basis for comparison. The optimum value for ACCAX is 1.0.

FIGURE 4.1. TN-24P One-Half Section Cask Model

FIGURE 4.2. TN-24P One-Eighth Section Cask Model

FIGURE 4.3. TN-24P Cask Cross Section

FIGURE 4.4. COBRA-SFS TN-24P Axial Computational Cask Model

FIGURE 4.5. One-Half Fuel Assembly Rod & Channel Computational Model

FIGURE 4.6. Full Fuel Assembly Lumped Rod and Lumped Channel Computational Model

FIGURE 4.7. Axial Temperature Profiles of Experimental Data and COBRA-SFS Predictions for Assembly Model Set #1 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.8. Axial Temperature Profiles of Experimental Data and COBRA-SFS Predictions for Assembly Model Set #1 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.9. Axial Temperature Profiles of Experimental Data and COBRA-SFS Predictions for Assembly Model Set #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.10. Radial Temperature Profiles of Experimental Data and COBRA-SFS Predictions for Assembly Model Set #1 for the TN-24p Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.11. Radial Temperature Profiles of Experimental Data and COBRA-SFS Predictions for Assembly Model Set #1 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.12. Radial Temperature Profiles of Experimental Data and COBRA-SFS Predictions for Assembly Model Set #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.13. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #2 and #1 (Detailed Models) for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.14. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #2 and #1 for the TN-24P Spent-Fuel Cask Nitrogen Backfill Case

FIGURE 4.15. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #2 and #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.16. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #2 and #1 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.17. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #2 and #1 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.18. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #2 and #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.19. COBRA-SFS TN-24P Half Assembly Model Set #3 (5 rod and 5 channel nodes per assembly)

FIGURE 4.20. COBRA-SFS TN-24P Full Assembly Model Set #3 (9 rod and 9 channel nodes per assembly)

FIGURE 4.21. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.22. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.23. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.24. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.25. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.26. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.27. COBRA-SFS TN-24P Half Assembly Model Set #4 (28 rod and 28 channel nodes per assembly)

FIGURE 4.28. COBRA-SFS TN-24P Full Assembly Model Set #4 (49 rod and 49 channel nodes per assembly)

FIGURE 4.29. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #4, #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.30. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #4, #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.31. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #4, #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.32. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #4, #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.33. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #4, #3, #2, and #1 for the TN-24P Spent Fuel Cask, Nitrogen Backfill Case

FIGURE 4.34. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #4, #3, #2, and #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.35. COBRA-SFS TN-24P Full Assembly Model for Set #5

FIGURE 4.36. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #5 and #1 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.37. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #5 and #1 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.38. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #5 and #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.39. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #5 and #1 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.40. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #5 and #1 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.41. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #5 and #1 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.42. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #6 and #5 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.43. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #6 and #5 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.44. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #6 and #5 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.45. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #6 and #5 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.46. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #6 and #5 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.47. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #6 and #5 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.48. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #7, #6, and #5 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.49. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #7, #6, and #5 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.50. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #7, #6, and #5 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.51. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #7, #6, and #5 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.52. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #7, #6, and #5 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.53. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #7, #6, and #5 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.54. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #8 and #5 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.55. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #8 and #5 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.56. Axial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #8 and #5 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.57. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #8 and #5 for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.58. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #8 and #5 for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.59. Radial Temperature Profiles of COBRA-SFS Predictions for Assembly Model Sets #8 and #5 for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.60. TN-24P Solid Structure Noding

FIGURE 4.61. TN-24P Model with Reduced Shell Noding

a) Detailed Noding

b) Coarse Noding with Cruciforms

FIGURE 4.62. Solid Structure Basket Noding

FIGURE 4.63. Axial Temperature Profiles of Experimental Data and COBRA-SFS Predictions Using Axial Model Set #1 (24 levels) for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.64. Axial Temperature Profiles of Experimental Data and COBRA-SFS Predictions Using Axial Model Set #1 (24 levels) for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.65. Axial Temperature Profiles of Experimental Data and COBRA-SFS Predictions Using Axial Model Set #1 (24 levels) for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.66. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #2 (18 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.67. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #2 (18 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.68. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #2 (18 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.69. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #3 (12 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.70. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #3 (12 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.71. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #3 (12 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.72. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #4 (8 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.73. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #4 (8 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.74. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #4 (8 levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.75. COBRA-SFS Axial Model #5a, 12 Levels with Nonuniform Noding

FIGURE 4.76. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #5a (12 nonuniform levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.77. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #5a (12 nonuniform levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.78. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #5a (12 nonuniform levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

FIGURE 4.79. COBRA-SFS Axial Model #5b, 12 Levels with Nonuniform Noding

FIGURE 4.80. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #5b (12 nonuniform levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Helium Backfill Case

FIGURE 4.81. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #5b (12 nonuniform levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Nitrogen Backfill Case

FIGURE 4.82. Axial Temperature Profiles of COBRA-SFS Predictions for Axial Model Sets #5b (12 nonuniform levels) and #1 (24 levels) for the TN-24P Spent-Fuel Cask, Vacuum Backfill Case

TABLE 4.1. Material Properties

<u>Thermal Conductivities (Btu/ft-h-°F)</u>		<u>Surface Emissivities</u>	
Steel cask body	= 24.0	Fuel rods	= 0.8
Polyethylene resin	= 0.1	Fuel basket	= 0.8
Aluminum basket	= 119.0	Plated cask surfaces	= 0.9
Copper fins	= 218.0	Painted cask surfaces	= 0.9
Steel shell	= 24.0	Copper fin surface	= 0.5
Polypropylene	= 0.1		

TABLE 4.2. Parameter ACCELW Results

Nitrogen Cases:

<u>ACCELW</u>	<u>Computational Time, sec.</u>	<u>Number of Iterations</u>
1.2	1290.27	40
1.3	1245.62	40
1.4	1230.71	40
1.5	1208.17	40
1.6	1240.79	40

Helium Cases:

<u>ACCELW</u>	<u>Computational Time, sec.</u>	<u>Number of Iterations</u>
1.2	1164.34	33
1.3	1127.06	33
1.4	1024.70	30
1.5	1002.46	30
1.6	904.33	27

TABLE 4.3. Parameter ACCROD Results

Nitrogen Cases:

<u>ACCROD</u>	<u>Computational Time, sec.</u>
0.5	1290.27
0.6	1275.56
0.7	1364.05
0.8	did not converge

Helium Cases:

<u>ACCROD</u>	<u>Computational Time, sec.</u>
0.3	1164.34
0.4	1154.98
0.5	1132.58
0.6	1113.78

Vacuum Cases:

<u>ACCROD</u>	<u>Computational Time, sec.</u>
0.3	1464.77
0.4	1460.12
0.5	did not converge

TABLE 4.4. Parameter ACCAX Results

<u>ACCAX</u>	<u>Total Energy Error (20 iterations)</u>
0.9	0.40%
1.0	0.14%
1.1	-0.73%

5.0 FLOW SOLUTION IMPROVEMENTS

The COBRA-SFS thermal-hydraulic analysis of a spent fuel system is separated into two parts--a flow field solution and an energy solution. The flow field is determined by solving a set of finite-volume equations governing conservation of mass and momentum.

In the original release of the COBRA-SFS code, shear stress on the fluid resulted solely from adjacent solid surfaces, such as slabs or rods, and shear stress from adjacent fluid channels was neglected. This is appropriate for flow in rod bundles, where each channel is surrounded by solid surfaces. However, in many applications, the geometry includes large open flow areas that must be modeled. Using the original COBRA-SFS code with no fluid shear stress terms, such an area is modeled using a single channel.

To improve the modeling of open flow regions, fluid shear stress terms have been added to the momentum equations used in the COBRA-SFS code. The addition of these terms will allow more detailed modeling of large open flow regions with several channels. The modifications are described in Section 5.1. The input changes resulting from these modifications are described in Section 5.2. In Section 5.3, the results from a series of verification runs are compared with the analytical solutions.

5.1 DESCRIPTION OF MODIFICATIONS

The flow field of a spent fuel storage system is determined by solving a set of finite-volume equations governing conservation of mass and momentum. The conservation equations described below are taken from Rector, Wheeler, and Lombardo (1986). To determine the conservation equations, suitable balances are performed on the typical control volume shown in Figure 5.1. The axial length of the control volume is denoted by Δx . The axial flow area at the upper and lower surfaces is denoted by A and the axial velocity by U .

Lateral flow between adjacent subchannel control volumes passes through a region between separated solid surfaces. The width of the gap between surfaces is S and the lateral velocity is V . Each channel can have an arbitrary

number of lateral flow connections (three in the case of Figure 5.1) to adjacent channels, and the gap width (S) may vary from connection to connection.

In deriving the axial momentum equation, the shear stress on the fluid from adjacent channels was neglected. Applying conservation of momentum to the control volume shown in Figure 5.2 gives the following finite-volume form of the axial momentum equation

$$\begin{aligned} \Delta x A \left(\frac{\rho U}{\Delta t} - \frac{(\rho U)^n}{\Delta t} \right)_j + \left(\rho^* U_j \right)^* A_j U_j - \left(\rho^* U_{j-1} \right)^* A_j U_{j-1} + \\ \left[\text{axial momentum storage} \right] + \left[\text{axial momentum transported axially} \right] + \\ \sum_{k \in \Psi_j} e_{ik} (\rho^* U)_k V_k S_k \Delta x + F_T \\ \left[\text{axial momentum transported laterally} \right] + \left[\text{turbulent momentum exchange} \right] \\ P_{j-1} A_{j-1} - P_j A_j - \bar{P} (A_{j-1} - A_j) + F_s - F_g \\ [\text{pressure forces}] - [\text{wall drag forces}] - [\text{body forces}] \end{aligned} \quad (5.1)$$

In the original version of COBRA-SFS, the shear forces are limited to wall interfaces and are expressed in terms of empirical wall friction factor correlations and local form loss coefficients. This term is expressed as

$$F_s = \frac{1}{2} \left(\frac{f \Delta x}{D_h} + K \right) \rho U |U| A \quad (5.2)$$

where D_h is the hydraulic diameter, f is the Darcy-Weisbach friction factor, and K is the form loss coefficient to account for local obstructions such as grid spacers.

When fluid shear is considered, axial momentum is transferred between each channel and every adjacent channel through gap connections. This term is expressed as

$$F_f = \sum_{k \in \Psi_i} e_{ik} (U_{ii} - U_{jj}) \frac{S}{L} \mu_k \Delta x \quad (5.3)$$

where k is the gap connection, e_{ik} is a switch function indicating the direction of momentum transfer, and ii and jj are channel numbers on either side of gap k . The gap viscosity, μ_k , is assumed to be the average viscosity of the two adjacent channels.

The values for gap width, S , and transverse control volume, L , depend on the flow geometry being modeled. For rod bundles, the transverse control volume is defined as a rectangle with the width equal to the gap distance between rods and the length equal to the distance between channel centroids. A typical rod bundle transverse control volume is shown in Figure 5.3. When a large flow area is divided into channels, as shown in Figure 5.4, the dimensions of the transverse control volume depend on the geometry of the model. If the model fits a Cartesian coordinate system, the gap width S corresponds to the interface between the two channels and the length L is the channel centroid-to-centroid distance.

When a large flow region is divided into a large number of channels, the wall shear forces exerted on the outer channels should be expressed as a linear function of channel velocity, not friction factor or form loss coefficients as in Equation (5.2). For example, a rectangular channel adjacent to a wall is shown in Figure 5.5. The length from the wall to the channel centroid is assumed to be

$$L = A/2P \quad (5.4)$$

where the channel area is A and the sum of slab perimeters contacting the channel is P . The wall shear forces can then be expressed as

$$F_s = \mu \frac{P}{L} U_j \Delta x = 2\mu \frac{P^2}{A} U_j \Delta x \quad (5.5)$$

In deriving the transverse momentum equation, the shear stress on the fluid from adjacent axial levels and adjacent transverse flow connections was assumed to be negligible. Applying conservation of momentum to the control volume shown in Figure 5.3 gives the following finite-volume form of the transverse momentum equation

$$\begin{aligned} & \Delta x S_k \left(\frac{\rho V - (\rho V)^n}{\Delta t} \right) + \rho^* v_{jk}^* S_k \bar{u}_j - \rho^* v_{j-1} S_k \bar{u}_{j-1} \\ & \left[\text{transverse momentum} \right]_{\text{storage}} + \left[\text{transverse momentum} \right]_{\text{transported axially}} \\ & = \frac{\Delta x S_k}{L_k} g_c (P_{ii} - P_{jj})_{j-1} - F_s \\ & = [\text{pressure forces}] - [\text{wall shear forces}] \end{aligned} \quad (5.6)$$

In the original version of COBRA-SFS, the shear forces were exerted only by the walls and fuel rods and were expressed in terms of empirical local form loss coefficients. The shear force per unit length, F_s , was expressed as

$$F_s = - 1/2 K_G |V| V \frac{\Delta x S \rho}{L} \quad (5.7)$$

where K is the form loss coefficient.

When fluid shear is considered, transverse momentum is transferred in the axial direction and laterally between adjacent crossflows. In the axial direction, momentum is transferred to the transverse control volumes above and below the current axial level, as shown in Figure 5.6. This term is expressed as

$$F_{ax} = S \ell \left[\frac{2\mu_{j-\frac{1}{2}}(v_j - v_{j-1})}{\Delta x_j + \Delta x_{j+1}} + \frac{2\mu_{j+\frac{1}{2}}(v_j - v_{j+1})}{\Delta x_j + \Delta x_{j+1}} \right] \quad (5.8)$$

where the viscosities $\mu_{j-\frac{1}{2}}$ and $\mu_{j+\frac{1}{2}}$ are defined as

$$\mu_{j-\frac{1}{2}} = (\mu_{ii,j} + \mu_{jj,j} + \mu_{ii,j-1} + \mu_{jj,j-1})/4$$

$$\mu_{j+\frac{1}{2}} = (\mu_{ii,j} + \mu_{jj,j} + \mu_{ii,j+1} + \mu_{jj,j+1})/4$$

and ii and jj are the indices of the channels connected by the transverse control volume.

The location and orientation of transverse connections between channels was not specified in the original COBRA-SFS input. To properly calculate momentum transferred laterally between adjacent transverse control volumes, F_{lat} , a factor describing the connection must be provided. An example is shown in Figure 5.7. This term is expressed as

$$F_{lat} = \Sigma \ell \Delta x \bar{\mu} \left[\frac{2(v_k - v_n)}{S_k + S_n} \right] \quad (5.9)$$

where n is the index of a transverse control volume connected to control volume k and $\bar{\mu}$ is defined as

$$\bar{\mu} = (\mu_{ii,k} + \mu_{jj,k} + \mu_{ii,n} + \mu_{jj,n})/4$$

A maximum of two other crossflows may be coupled to each crossflow in this manner.

5.2 INPUT CHANGES

Modifications to the flow solution described in Section 5.1 required changes in the COBRA-SFS input structure. These changes are described below on a line-by-line basis. The input description format used here is similar to that used in the COBRA-SFS users' manual (Rector et al. 1986b).

CHAN.1 AGROUP, NASSEM, NDX, NAZONE, ISHEAR, NSHEAR
 FORMAT(A4,1X,5I5)

<u>Columns</u>	<u>Variable</u>	<u>Description</u>
1-4	AGROUP	Enter CHAN.
6-10	NASSEM	Number of assemblies.
11-15	NDX	Number of axial nodes.
16-20	NAZONE	Flag for variable axial node sizes: = 0; uniform axial nodes. > 0; number of regions in variable axial node size table (read on CHAN.3).
21-25	ISHEAR	Flag for fluid shear stress: = 0; fluid shear stress not considered = 1; fluid shear stress included.
26-30	NSHEAR	Number of crossflow pairs connected by fluid shear in the lateral direction (read on CHAN.8). (This is meaningful only if ISHEAR = 1.)

The flag for fluid shear stress (ISHEAR[CHAN.1]) determines whether the fluid shear terms are calculated and included in the flow solution. For situations involving rod bundles or separated channels, fluid shear may not be an important consideration. For situations with open flow areas that are divided into channels, the fluid shear terms must be included in the flow solution.

When ISHEAR[CHAN.1] is set equal to one, certain fluid shear terms are automatically calculated. These include the transfer of axial momentum through

the transverse control volume and the transfer of transverse momentum to adjacent axial levels. The third type of fluid shear terms, the transfer of transverse momentum laterally between adjacent crossflows, requires additional information. The number of crossflow pairs that are connected by fluid shear is specified in NSHEAR [CHAN.1]. The individual pairs are read on CHAN.8, which is described later in this section.

CHAN.4 NASS,ITYPA,NCHANA,INTAPE,IFREE
 FORMAT(5I5)

<u>Columns</u>	<u>Variable</u>	<u>Description</u>
1-5	NASS	Assembly number.
6-10	ITYPA	Assembly type number (corresponding to a channel geometry description entered on CHAN.6).
11-15	NCHANA	Number of channels in assembly NASS.
16-20	INTAPE	Flag for I/O unit source of the channel input (CHAN.6) for assembly NASS: = 0; read from the input file = N; read from the I/O unit N.
21-25	IFREE	Flag for specifying wall shear boundary condition for assembly NASS = 0; wall shear specified by friction factor correlation = 1; laminar zero slip wall boundary condition

Two methods are available for specifying the shear forces exerted by solid structures such as slabs and rods on fluid flowing in channels. These methods are specified using the flag IFREE CHAN.4 for each assembly. One method (IFREE[CHAN.4] = 0) is to specify the shear forces in terms of empirical wall friction factor correlations and local form loss coefficients. In this case, the friction term is based on the hydraulic diameter of the channel, which is calculated using the wetted perimeter (PW[CHAN.6]) and the channel

area. This method is appropriate for assemblies where each channel contacts solid surfaces, as in a rod bundle.

The other method (IFREE[CHAN.4] = 1) is to specify a laminar zero slip wall boundary condition. The fluid at the wall is assumed to have zero velocity. The shear stress is calculated assuming a linear velocity profile between the wall and the center of the adjacent channel. The wetted perimeter of each channel is the sum of slab perimeters (WID[SLAB.4]) contacting that channel. This method is appropriate for assemblies that consist of a large open flow area where only the outside channels contact a solid surface.

CHAN.8 (III(L),JJJ(L),L = 1, NSHEAR[CHAN.1])
 Read only if NSHEAR > 0
 FORMAT (12I5)

<u>Columns</u>	<u>Variable</u>	<u>Description</u>
1-5,11-15 etc.	III(L)	Identification numbers of transverse connections that are connected by fluid shear in the lateral direction.
6-10,16-20 etc.	JJJ(L)	

When NSHEAR[CHAN.1] is set equal to a value greater than zero, pairs of crossflows that are connected by fluid shear are specified in card CHAN.8. Six pairs may be specified in each line. The crossflow connections are read from card CHAN.6 for each channel. The connections are numbered sequentially as they are read. The distance between crossflow centroids and width of the connection are automatically calculated from the crossflow information provided in CHAN.6.

5.3 VERIFICATION ASSESSMENT

A series of verification cases was performed to assess the fluid shear stress terms added to the COBRA-SFS code. The first few cases represent simple flow problems that demonstrate the effect of fluid-fluid and wall-fluid shear stresses. A comparison of code results and analytical solution is presented

for each case. In addition, the solid-to-fluid heat transfer terms added to the code were verified by comparing analytically determined Nusselt numbers with code results.

5.3.1 Flow in Plane Channel

A series of simulations of developing forced-convection laminar flow in a plane channel was performed for Reynolds numbers of 50 and 200. The plane channel model used is shown in Figure 5.8. Symmetry was assumed and half of the channel was modeled using ten channels. The axial length was divided into 30 levels with constant spacing. The output for the $Re = 50$ case is presented in Appendix A.

The predicted cross channel profiles and centerline velocity as a function of distance from the entrance are shown in Figures 5.9 and 5.10 for Reynolds numbers of 50 and 200, respectively. The analytical solution for fully developed flow in a plane channel is a parabolic velocity profile with a centerline velocity of 1.5 times the bulk velocity. Both predictions show this analytical value being approached asymptotically.

5.3.2 Flow in Cylindrical Pipe

A simulation of two-dimensional, forced-convection laminar flow in a cylindrical pipe was performed for a Reynolds number of 100. The cylindrical pipe model used is shown in Figure 5.11. The pipe cross section was divided into 10 channels. The length was represented by 30 axial levels. A uniform inlet flow was assumed. The output for this case is presented in Appendix B.

The cross-section velocity development and centerline velocity are shown in Figure 5.12. The fully developed, analytical velocity profile for this geometry is a parabolic profile given by

$$\frac{U}{\bar{U}} = 2[1 - (r/R)^2] \quad (5.10)$$

where r is the distance from the center of the pipe, R is the inner radius of the pipe, and $\bar{U}$ is the bulk velocity. The prediction shows the analytical centerline value of $U/\bar{U} = 2$ being asymptotically approached.

5.3.3 Flow in a Square Duct

Entry flow development in a square duct was chosen for analysis because a reliable data base for centerline velocity is available. The test case was a 1/4-symmetry model using a 5 x 5 channel grid with flow at $Re = 200$. The square duct model used is shown in Figure 5.13. The duct length was modeled using 30 axial levels. Constant cell spacing was used. The output for this case is presented in Appendix C. Cross-stream velocity profile results are shown in Figure 5.14, and the centerline flow development profile is compared to the experimental data of Kreid (1967) and Goldstein and Kreid (1967) in Figure 5.15.

Because the code computes velocity at the channel centroid, it is impossible to obtain velocity at the duct center using symmetry modeling. Thus both Figures 5.14 and 5.15 show velocity extrapolated to the centerline as the flow attains a near-parabolic cross-stream profile upon full development. Figure 5.15 shows that the computed results underpredict the centerline velocity by a maximum of 5% to 7% during the early stages of development and 1% to 3% at full development. This underprediction may be caused by the assumed uniform velocity entrance condition.

5.3.4 Thermal-Entry-Length Pipe Heat Transfer

To evaluate the free field heat transfer terms added to COBRA-SFS, two simulations were performed for a developing thermal profile in a pipe with a uniform surface temperature. The simulations used models with 10 and 20 channels, respectively. The code results are compared with analytical values presented in (Kays and Crawford 1980). Since the analytical values are based on a fully developed velocity profile at the inlet, an entry length is used to develop the velocity profile before the surface temperature is changed. A total of 30 axial levels were used, 15 for the developing flow region and 15 for the developing thermal region.

The comparison of results with analytical values from Kays and Crawford (1980) are presented in Table 5.1. The location is expressed in terms of x^+ , which is defined as

$$x^+ = \frac{x/r_o}{Re Pr} \quad (5.11)$$

The dimensionless temperature is defined as

$$\theta_m(x^+) = \frac{t_o - t_m}{t_o - t_e} \quad (5.12)$$

where t_o is the surface temperature, t_e is the entry temperature, and t_m is the mixed mean temperature at x^+ . The heat transfer in the entry length can be expressed in terms of a mean Nusselt number, Nu_m . The relationship between the mean Nusselt number and the dimensionless temperature can be expressed as

$$Nu_m = 1/2x^+ \ln 1/\theta_m \quad (5.13)$$

The results show very good comparison with analytical results, especially for higher values of x^+ . When the 20-channel model is used, the error in the mean Nusselt number is less than 3% for values of x^+ above 0.01. The discrepancy at $x^+ = 0.01$ may be due to the use of only one axial level to represent the development in that region.

5.3.5 Thermal-Entry-Length for Square Duct

A simulation was performed for a developing thermal profile in a square duct with a uniform surface temperature. The case used a 1/4-symmetry model using a 5 x 5 channel grid with $Re = 200$. The code results are compared with an analytical expression for the Nusselt number presented in Kays and Crawford (1980). Since the analytical expression is based on a fully developed velocity profile at the inlet, an entry length is used to develop the velocity profile before the surface temperature is changed. A total of 30 axial levels were used, 15 for the developing flow region and 15 for the developing thermal region.

The comparison of COBRA-SFS results with values from the analytical expression in Kays and Crawford (1980) is presented in Table 5.2. The expression for mean Nusselt number for a square duct is given as

$$Nu_m = 2.98 + 0.11/x^+ \quad (5.14)$$

The Nusselt number determined from the COBRA-SFS solution is calculated using the expression

$$Nu_m = 1/2x^+ \ln 1/\theta_m \quad (5.15)$$

The results show very good comparison with analytical results, especially for higher values of x^+ . The error for values at $x^+ = 0.10$ and greater is less than 1%.

FIGURE 5.1. Subchannel Control Volume

FIGURE 5.2. Axial Momentum Balance on a Subchannel Control Volume

FIGURE 5.3. Transverse Momentum Balance on a Control Volume

FIGURE 5.4. Transverse Control Volume for Open Flow Region

FIGURE 5.5. Control Volume for Wall Shear Stress

FIGURE 5.6. Axial Transfer of Transverse Momentum

FIGURE 5.7. Lateral Transfer of Transverse Momentum

FIGURE 5.8. Plane Channel Model Geometry

FIGURE 5.9. Velocity Profiles for a Two-Dimensional Planar Channel with Uniform Inlet Velocity and Constant Cell Spacing, $Re = 50$ Case

FIGURE 5.10. Velocity Profiles for a Two-Dimensional Planar Channel with Uniform Inlet Velocity and Constant Cell Spacing, $Re = 200$ Case

FIGURE 5.11. Cylindrical Pipe Model Geometry

FIGURE 5.12. Velocity Profiles for a Two-Dimensional, Cylindrical-Channel Flow with Uniform Inlet Velocity and Constant Cell Spacing, $Re = 100$ Case

FIGURE 5.13. Square Duct Model Geometry

FIGURE 5.14. Velocity Profiles for a Three-Dimensional Cartesian Square Channel with Uniform Inlet Velocity, $Re = 200$ Case

FIGURE 5.15. Centerline Velocity Profile for a Square Channel with Uniform Inlet Velocity, $Re = 200$ Case

TABLE 5.1. Nusselt Numbers and Mean Temperatures for Constant Surface Temperature Pipe

x^+	θ_m			Nu_m		
	Kays (1966)	COBRA-SFS		Kays (1966)	COBRA-SFS	
		10 Channel	20 Channel		10 Channel	20 Channel
0	1.0	1.0	1.0	∞	∞	∞
0.01	0.836	0.851	0.850	8.99	8.07	8.13
0.04	0.626	0.637	0.634	5.87	5.64	5.70
0.08	0.457	0.467	0.462	4.89	4.76	4.83
0.10	0.394	0.404	0.398	4.66	4.53	4.61

TABLE 5.2. Nusselt Numbers for Square Duct with Constant Surface Temperature

x^+	Nu_m		
	Kays (1966)	COBRA-SFS	% Error
0	∞	∞	∞
0.05	5.18	4.87	-6.0
0.10	4.08	4.05	-0.7
0.15	3.71	3.71	0.0

6.0 PLENUM MODEL IMPROVEMENTS

A simplified sketch of a typical spent fuel dry storage cask is shown in Figure 6.1. Convection heat transfer within the cask removes decay heat by circulating fluid up through the heated spent fuel assemblies and down through the cooler regions of the cask. A COBRA-SFS model of this cask, shown in Figure 6.2, is divided into three regions: an upper plenum, a channel region, and a lower plenum. The upper and lower plenum models consist of single node regions where the fluid is uniformly mixed. A set of thermal connections is used to describe heat transfer between the plenum regions and a boundary temperature.

Certain assumptions are implied when a single-node plenum is used. One assumption is that there is negligible flow resistance in the plenum regions as compared to the channel region. Another is that the temperature distribution in the plenum is sufficiently uniform to not affect the heat transfer from the plenum or the temperature distribution of the fluid entering the channel region.

For many spent fuel storage applications, a single-node mixed-plenum model adequately describes the heat transfer and fluid flow in the plenum region. However, some applications require a more detailed model to accurately describe the plenum region. Improvements have been made to the COBRA-SFS code to allow detailed modeling of the plenum. The modifications are described in Section 6.1. The input changes resulting from these modifications are described in Section 6.2. In Section 6.3, the results from verification runs are compared with analytical solutions.

6.1 DESCRIPTION OF MODIFICATIONS

Detailed plenum model modifications added to COBRA-SFS can be grouped into two categories: changes to the flow solution and changes to the plenum heat transfer model. Descriptions of these changes are presented below.

6.1.1 Flow Solution Modifications

A sketch of a typical COBRA-SFS single node plenum model is shown in Figure 6.3. The plenum is connected to the bottom axial level of the channel region so that flows enter and exit through the bottom of the channel node as shown. A detailed model of the plenum is created by extending the channel region to the bottom of the cask as shown in Figure 6.4. The plenum is divided into as many axial levels as necessary to obtain the proper resolution for the flow and temperature distributions. The plenum in the example has been divided into four axial levels.

To model the plenum in this fashion requires the addition of a new flow boundary condition option. The COBRA-SFS code currently allows three primary types of flow boundary conditions. These are:

- specified inlet flow
- specified pressure drop
- uniform pressure drop for specified total flow.

In all three cases, flow is allowed to pass through one or both ends of the channel region. Even when zero inlet flow is specified for each channel, the flows at the channel region outlet are free to move as long as the net sum is zero. A fourth flow boundary condition option has been added that specifies zero flow for both ends of each channel. The implementation of this boundary condition is described below.

The COBRA-SFS flow field solution routine is divided into two parts: a tentative flow solution and a pressure solution. The tentative flow solution is achieved by sweeping the bundle from inlet to exit. In each sweep, the bundle tentative axial flows ($\tilde{m}$) and crossflows ($\tilde{w}$) are computed by evaluating the two linearized momentum equations with current values for pressures and other variables. After all tentative flows and crossflows have been computed at all axial levels, the flows and pressures are adjusted to satisfy continuity by a Newton-Raphson method. The resulting flow field from this pressure solution is then used in the energy equation to obtain an enthalpy and fluid properties distribution for the next axial sweep.

The tentative axial flows ($\tilde{m}$) are calculated by solving a set of linearized momentum equations of the form

$$[A] \tilde{m}_j = -g_c A_j (\tilde{P}_j - \tilde{P}_{j-1}) + B \quad (6.1)$$

where $[A]$ is the coefficient matrix, $\tilde{P}$ are the previous iterate values for pressure and B is the source term.

When the zero flow option is selected, the inlet flows are set equal to zero. The outlet flows at the top axial level are made to have very small values by modifying the set of linearized momentum equations. The diagonal elements of matrix $[A]$, designated A_{ii} , are added to an extremely large value while the source term remains unchanged. This results in tentative axial flows that are negligibly small while not affecting the calculation of crossflows.

During the pressure solution both the pressure and flow fields are adjusted to satisfy continuity. Estimated pressure changes ($\delta P'$) are calculated using a Newton-Raphson method. The new axial flows are calculated using the expression

$$m'_j = \tilde{m}_j + \frac{\partial \tilde{m}_j}{\partial P_{j-1}} \delta P'_{j-1} \quad (6.2)$$

The derivative term is defined as

$$\frac{\partial \tilde{m}_j}{\partial P_{j-1}} = \frac{g_c A_j}{A_{ii}} \quad (6.3)$$

Because the diagonal term, A_{ii} , has been set to an extremely large number, the changes in the pressure field will have a negligible effect on the tentative axial flows at the top axial level.

When crossflows along the top or bottom of the channel region are adjacent to a free surface, transverse shear stress from the surface can be neglected. If, however, the crossflows are adjacent to a solid no-slip surface, shear stress terms must be included. For example, the force due to transverse shear stress in the axial direction is expressed as

$$F_{ax} = S\ell \left[\frac{2\mu_j V_j}{\Delta x_j} + \frac{2\mu_{j+1/2} (V_j - V_{j+1})}{\Delta x_j + \Delta x_{j+1}} \right] \quad (6.4)$$

for the bottom axial level. This expression is similar to Equation (5.8) except that the adjacent transverse velocities have a specified value of zero and the axial distance is one-half the width of the current axial level.

6.1.2 Plenum Heat Transfer Modifications

The change from a single node to a detailed plenum also affects the models used to represent heat transfer from the plenum. When single node plenums are used, each plenum has an axial and radial one-dimensional thermal connection between the fluid in the plenum and a boundary temperature. Different boundary temperatures may be specified for each direction. The connection, similar to that used in the side boundary specification, may consist of one or a series of regions, with each region having a different expression for heat transfer. These expressions take the form

$$q''_{\text{boundary}} = C_1 \left[C_2 (T_i - T_{i+1})^{C_3} \right] (T_i - T_{i+1}) + \sigma \left(\frac{1}{\epsilon_i} + \frac{1}{\epsilon_{i+1}} - 1 \right)^{-1} (T_i^4 - T_{i+1}^4) \quad (6.5)$$

where C_n = user defined constants

T_i = temperature for boundary region i

σ = Stefan-Boltzmann constant

ϵ_i = surface emissivity for boundary region i .

In addition, each plenum region can have thermal connections to solid structure nodes of the channel region in the axial level adjacent to the plenum. These connections are used to represent axial heat transfer from the cask body or heat transfer from the basket to the bottom or top of the cask.

The fluid enthalpies and flow rates entering the plenum as well as temperatures of the solid structure nodes connected to the plenum are computed in the energy solution for the axial level adjacent to the plenum. These values are then held fixed while the plenum equations are solved. The resulting plenum structure temperatures and plenum fluid enthalpy are held fixed for the next iteration of the rod, fluid, and slab energy solution.

When a detailed plenum model is used, the radial plenum heat transfer path is replaced by solid structure nodes and the side heat transfer model for the channel region, since the channel region now extends to the top and bottom surfaces of the flow region. This offers a great deal more detail because each one-dimensional heat transfer region can be represented by several solid structure nodes. In addition, heat transfer can be modeled in the axial and circumferential directions in addition to the radial direction.

The axial heat transfer from the plenum is still modeled using a series of one-dimensional heat transfer regions. However, instead of connecting to the single node plenum, the innermost surface connects to each individual channel node in the top or bottom axial level by fluid conduction, as shown in Figure 6.5. The heat removed from channel i is given by the expression

$$Q_i = \frac{2A_i k_i}{\Delta x} (T_i - T_1) = U_i (T_i - T_1) \quad (6.6)$$

where A_i is the cross-sectional area of channel i

k_i is the fluid thermal conductivity

T_i is the fluid temperature

T_1 is the top or bottom surface temperature.

The total heat transfer from an axial level can be expressed as

$$\begin{aligned}
 Q &= \sum Q_i = \sum U_i (T_i - T_1) \\
 &= U_{total} (\tilde{T} - T_1)
 \end{aligned}
 \tag{6.7}$$

$$\begin{aligned}
 \text{where } U_{total} &= \sum U_i \\
 \tilde{T} &= \frac{\sum U_i T_i}{U_{total}}
 \end{aligned}$$

The fluid temperatures are held constant while the temperature distribution through each end of the cask is computed. The surface temperatures are then used as boundary conditions for the fluid and slab energy solution.

6.2 INPUT CHANGES

As a result of the modifications to the plenum model described in Section 6.1, changes have been made to the COBRA-SFS input structure. These changes are described below on a line-by-line basis. The input description used here is similar to that used in the COBRA-SFS user's manual (Rector et al. 1986b). (Variable description is given only for new data available with this option.)

OPER.1 AGROUP, IHH, IG, ITDP, NRPF, NP, NH, NG, NGPRFL, NHX, NQ, NQPRFL, NDPA, NRAMPH, NAXP
 FORMAT(A4, 1X, 14I5)

<u>Columns</u>	<u>Variable</u>	<u>Description</u>
16-20	ITDP	Flag for flow or pressure drop boundary conditions: = 0; specified flow boundary conditions. = 1; uniform pressure drop (specified in DPS on OPER.2). = 2; pressure drop resulting in uniform inlet mass flux. = 3; uniform pressure drop calculated for total mass flow rate (FTOTAL on OPER.2).

= 4; zero flow at both top and bottom boundaries.

The boundary condition for the flow field solution is specified by variable ITDP. The options include a specified inlet flow distribution (ITDP=0), a pressure drop across the channel region (ITDP=1), and total flow rate for the problem (ITDP=3). An additional flow boundary condition option (ITDP=4) has been added that specifies zero flow at the top and bottom surfaces of the channel region for each individual channel. When this option is used, the inlet mass flux (GIN), system pressure drop (DPS), and total flow rate (FTOTAL), which are read on OPER.2, are ignored.

When the zero flow boundary condition is used, the entire fluid volume is represented by the channel region and is divided into axial levels. For example, a natural circulation system can be modeled using 20 axial levels in the channel region and an upper and lower plenum region. If the zero flow option is used, each plenum region may be divided into four axial levels, resulting in a total of 28 axial levels and no common plenum regions. This change would affect several other input variables, including the number of axial nodes (NDX[CHAN.1]), the axial length of the channel region (Z[CHAN.2]), and all the tables based on axial position such as channel and gap variations (AXL[VARY.2]) and GAPXL[VARY.5]), side boundary temperatures (ZENDT[BDRY.3]) and axial power distribution (AXIAL[OPER.17]).

BDRY.6 IPLENR(N),AWPS(N),AWPAX(N),NPSID(N),NPAX(N),TAMPB(1,N),TAMPB(2,N),
QPSRC(1,N),QPSRC(2,N)

Read only if NPR > 0 on BDRY.1
FORMAT(I5,2F5.3,2I5,4F.3)

Columns	Variable	Description
1-5	IPLENR(N)	Flag for plenum region under consideration: = 1; lower plenum. = 2; upper plenum.
6-10	AWPS(N)	Nomical plenum radial heat transfer area (in. ²).

Columns	Variable	Description
11-15	AWPAX(N)	Nominal plenum axial heat transfer area (in. ²).
16-20	NPSID(N)	Number of radial plenum boundary regions.
21-25	NPAX(N)	Number of axial plenum boundary regions.
26-30	TAMPB(1,N)	Plenum radial boundary temperature, (F).
31-35	TAMPB(2,N)	Plenum axial boundary temperature, (F).
36-40	QPSRC(1,N)	Optional plenum radial boundary heat flux, (Btu/h-ft ²) (applied to the outermost plenum radial region only).
41-45	QPSRC(2,N)	Optional plenum axial boundary heat flux, (Btu/h-ft ²) (applied to the outermost plenum axial region only).

Input lines BDRY.6 through BDRY.8 describe the heat transfer model from the plenum regions. When the common plenum regions are used, heat is removed through one-dimensional heat transfer paths in the radial and axial directions. When the zero flow option is specified (ITDP[OPER.1]=4), the radial plenum heat transfer path is replaced by the channel region side thermal boundary model. The values for AWPX(N), NPSID(N), TAMPB(1,N), and QPSRC(1,N) are not used.

The number of connections in the axial heat transfer path (NPAX) is also redefined. When the common plenum regions are used, the first connection describes the heat transferred between the mixed fluid in the plenum and the bottom surface. When the zero flow option is specified, the heat transfer is assumed to be by fluid conduction between the mid-point of each channel node in the bottom axial level and the bottom surface. Therefore, since the fluid-to-surface region does not need to be specified, the value for NPAX(N) will be one less when the zero flow option is specified.

BDRY.7 I,SPERP(K,1,IPL(N)),NPTYP(I,1,IPL(N)),NPWN,(IPINTP(I,J),MATYPP(K,J),
AREAXCP(K,J),DXPLEN(J),J=1,NPWN),i=1,NPSID(N)[BDRY.6]

Read only if NPSID(N) > 0 on BDRY.6

FORMAT(I5,F5.3,2I5,3(2I5,2F5.3))

Columns	Variable	Description
1-5	I	Plenum radial region number. (Note: Regions must be numbered sequentially from 1 to NPSID(N).)
6-10	SPERP(I,1,IPL(N))	Plenum radial region heat transfer area multiplier, (normalized to AWPS(N) on BDRY.6).
11-15	NPTYP(I,1,IPL(N))	Thermal connection type for connections between solid structure nodes and plenum radial region I. (Note: This must correspond to a boundary connection type defined on BDRY.2.)
16-20	NPWN	Number of solid structure nodes connected to plenum radial region I.
21-25, 41-45, 61-65	IPINTP(I,J)	Identification number of the Jth solid node connected to plenum radial region I.
26-30, 46-50, 66-70	MATYPP(I,J)	Identification number of the material type for the connection between node IPINTP(I,J) and plenum axial region I.
31-35 51-55 71-75	AREAXCP(I,J)	Heat transfer area for connection J from solid node IPINTP(I,J) to plenum region I. (Default is node IPINTP(I,J) cross sectional area for axial conduction; WALLCX, specified on SLAB.3.)
36-40 56-60 76-80	DXPLEN(I,J)	Length (in.) for heat transfer from node IPINTP(I,J) to the center of plenum radial region I. INote: Up to 3 sets of values for IPINTP, MATYPP, AREAXCP, and DXPLEN may be read on a line. If NPWN is greater than 3, repeat this line starting at column 21 as many times as necessary to define NPWN sets of values.

*** BDRY.7 is read NPSID(N)[BDRY.6] times ***

Input line BDRY.7 describes the radial regions for the plenum heat transfer model. When the zero flow boundary option is specified (ITDP[OPER.1]=4), the

radial heat transfer path is replaced by the channel region side thermal boundary model and input line BDRY.7 is not read.

6.3 VERIFICATION ASSESSMENT

A detailed plenum model and shear stress terms were added to COBRA-SFS to accurately model buoyant convection flow in an open square cavity. Verification cases, representing simple flow problems, were run to assess the new plenum model.

The COBRA-SFS simulation was performed with the fluid shear stress terms included. The wall shear was modeled using the laminar zero slip wall boundary condition. The heat transfer at the wall was modeled by laminar conduction. The zero flow boundary condition described in Section 6.1 was applied to the flow section.

Both vertical walls of the test simulation geometry were assumed to be constant-temperature boundaries of 155°F and 70°F, respectively. The top and bottom surfaces were assumed adiabatic. The simulation was run with constant cell spacing (10 cells in the horizontal direction and 28 cells in the vertical direction). The convecting medium was air. The geometry of the problem is shown in Figure 6.6. The output for this case is presented in Appendix D.

A comparison of COBRA-SFS results and experimental data is shown in Figure 6.7. The experimental results of Eckert and Carlson (1961) in a 10:1-aspect-ratio cavity were chosen to verify the new models. The temperature distribution at the three axial levels is displayed. In general, the agreement between the data of Eckert and Carlson and the COBRA-SFS predictions are excellent.

FIGURE 6.11. Cut-Away Sketch of a Typical Spent Fuel Cask

FIGURE 6.2. Typical COBRA-SFS Cask Model

FIGURE 6.3. COBRA-SFS Plenum Model

FIGURE 6.4. Detailed Plenum Model

FIGURE 6.5. Detailed Plenum Heat Transfer Model

FIGURE 6.6. Geometry of a Square Cavity

FIGURE 6.7. Natural Convection in a Two-Dimensional Cavity

FIGURE 2.7. Natural Conversion in 2D-dimensional Cavity

7.0 ADDITIONAL CODE FEATURES

In addition to the flow solution improvements described in Section 5.0 and plenum model improvements described in Section 6.0, several other features have been added to optimize the usefulness of the COBRA-SFS code. Each feature is described and the associated input modifications are presented. These features include:

- temperature-dependent solid thermal conductivities (Section 7.1)
- solid heat generation transient tables (Section 7.2)
- axially varying solid material types (Section 7.3)
- solid-to-fluid connection (Section 7.4).

7.1 TEMPERATURE-DEPENDENT SOLID THERMAL CONDUCTIVITIES

The thermal conductivity of most solid materials varies as a function of temperature. The original version of COBRA-SFS used a single value of thermal conductivity for each material. The code has been modified to allow temperature-dependent thermal conductivity for each solid material type to be expressed as a polynomial:

$$k = C_0 + C_1 \times T + C_2 \times T^2 + C_3 \times T^3 \quad (7.1)$$

where C_0 , C_1 , C_2 , and C_3 are user-specified constants and T is the temperature in °R.

The flow and temperature equations are solved iteratively at each time step. At each iteration, the solid thermal conductivity for each slab node is updated to reflect the current temperature.

The coefficients for the thermal conductivity expression are specified in the solid material property card:

PROP.3 (AMAT(I), ANAME(I), CPSOL(I), RHOSOL(I), CON0(I), CON1(I), CON2(I), CON3(I),
NQVT(I), i=1, NSPROP[PROP.1])

Read only if NSPROP > 0 on PROP.1

FORMAT (I5, A5, 6E10.0, I5)

Columns	Variable	Description
1-5	AMAT(I)	Solid material type identification number.
6-10	ANAME(I)	Solid material name (for user convenience).
11-20	CPSOL(I)	Specific heat (Btu/lbm-°F) (for transient calculations).
21-30	RHOSOL(I)	Density (lbm/ft ³) (for transient calculations).
31-40	CON0(I)	Coefficients of an expression for solid thermal conductivity (Btu/h-ft-°F) that has the form: $k = \text{CON0}(I) + \text{CON1}(I)*T + \text{CON2}(I)*T^2 + \text{CON3}(I)*T^3$ where T is the temperature in °R.
41-50	CON1(I)	
51-60	CON2(I)	
61-70	CON3(I)	
71-75	NQVT(I)	Transient heating rate forcing function. Corresponds to profiles read in OPER.14 and 15.

Note that this is compatible with the old input format for PROP.3. Constant thermal conductivity is specified with the coefficient CON0(I) in columns 31-40, the rest are defaulted to zero.

The temperature-dependent thermal conductivity modifications were verified by comparing COBRA-SFS results with an analytical solution from Arpaci (1966) for a plate with uniform heat generation and a thermal conductivity of the form:

$$k = k_R (1 + \beta T) \quad (7.2)$$

where k_R is the thermal conductivity at reference temperature, T_R . A half-symmetrical section of the plate was modeled using ten equally-spaced slab nodes.

The results of the comparison are presented in Figure 7.1 for four values of β . In all four cases, the comparison between code results and the analytical

solution is excellent, indicating that the temperature-dependent thermal conductivity has been installed correctly.

7.2 SOLID HEAT GENERATION TRANSIENT TABLES

The original version of COBRA-SFS did not provide for variation of slab heat generation as a function of time. In many situations, slab heat generation will vary with time as in the case of decaying gamma heating in cask structures. For this reason, a modification was made to allow specification of the transient heat generation profile as a function of material type. The only input modification is in Card PROP.3 (which is shown in Section 7.1). The variable NQVT[PROP.3] specifies one of the transient profiles read on Cards OPER.14 and 15.

7.3 AXIALLY VARYING MATERIAL TYPES

In the original version of COBRA-SFS, the assumption is made that the problem geometry, including solid material types, is uniform in the axial direction. The solid material type is specified solely as a function of slab node location in the cross-sectional plane. However, there are many situations where a slab node will consist of different solid material types at different axial locations. For this reason, an option was added to specify material types as a function of axial level. The material type for each node is used to determine material properties such as thermal conductivity.

The input modifications for axially varying material types is presented below:

SLAB.1 AGROUP,NKSS,NKSF,NWK,NMAT

FORMAT(A4,1X,1315)

<u>Columns</u>	<u>Variable</u>	<u>Description</u>
1-4	AGROUP	Enter SLAB.
6-10	NKSS	Number of solid-to-solid thermal connection types.

11-15	NKSF	Number of solid-to-fluid thermal connection types.
16-20	NWK	Number of solid structure nodes.
21-25	NMAT	Number of axial material type profiles.

The variable NMAT[SLAB.1] is specified only if there are slab locations with axially varying material types. The variable specifies the number of material type profiles to be read in cards SLAB.6 and SLAB.7.

SLAB.3. (KW,MATTYP(KW,1),WALLXC(KW),QSLAB(KW),NAXK(KW),NSLAB,(KWAL(L,KW),
ICON(L,KW),L=1,NSLAB)

Read only if NWK > 0 on SLAB.1

FORMAT(2I5,2D5.3,2I5,5(I5,I5))

Columns	Variable	Description
1-5	KW	Solid structure node identification number.
6-10	MATTYP(KW,1)	Solid node material type identification number (corresponding to a material type specified on PROP.3) or, if greater than NSPROP[PROP.1], an axial material type profile (corresponding to a profile specified on SLAB.6 and 7).
11-15	WALLXC(KW)	Solid node cross-sectional area (in. ²) for axial conduction. (Enter zero if axial conduction will not be calculated for this problem.)
16-20	QSLAB(KW)	Solid node volumetric heat generation rate (Btu/h-ft ³).
21-25	NAXK(KW)	Identification number of the axial heat generation profile table [specified on OPER.16] to be applied to QSLAB(KW). (Default is 1.)
26-30	NSLAB	Number of thermal connections to adjacent solid nodes with index numbers greater than KW.
31-35, 41-45, etc.	KWAL(L,KW)	Identification number of the Lth solid node adjacent to node KW, where KWAL(L,KW) > KW.

The only change in SLAB.3 is that the variable MATTYP[SLAB.3] specifies not only constant material types (if less than NSPROP[PROP.1]) but also axial

material profiles (if greater than NSPROP[PROP.1]. The profile number corresponds to variable MAT on SLAB.6.

SLAB.6. MAT,NSET

Read only if NMAT > 0 on SLAB.1

FORMAT (2I5)

Columns	Variable	Description
1-5	MAT	Axial material type profile identification number. (Used in SLAB.3. Must be greater than NSPROP [PROP.1].)
6-10	NSET	Number of sets of material type information.

SLAB.7. (KAX(N),KMAT(N),N=1,NSET[SLAB.6])

Read only if NMAT > 0 on SLAB.1

FORMAT (4(5X,2I5))

Columns	Variable	Description
6-10 21-25 36-40 51-55	KAX(N)	Number of axial nodes in axial set N, starting from the bottom level. (The total number of nodes must be equal to NDX[CHAN.1].) $\sum_{N=1}^{NSET} KAX(N) = NDX[CHAN.1]$
11-15 26-30 41-45 56-60	KMAT(N)	Material type for axial set N. (Corresponds to material type specified in PROP.3.)

SLAB.7 is repeated until all NSET sets are read.

SLAB.6 and SLAB.7 are read NMAT[SLAB.1] times.

The axial material type profiles are read in SLAB.6 and SLAB.7. Card SLAB.6 provides the identification number of the profile (MAT) and the number of material type sets (NSET). Card SLAB.7 provides the material type

information in terms of consecutive sets, where each set consists of a number of axial levels and a material type.

7.4 SOLID-TO-FLUID CONNECTIONS

The thermal connection between a solid node and subchannel consists of two parts, the thermal resistance between the center of the solid node and the wetted surface and the resistance between the surface and center of the subchannel. In the original version of COBRA-SFS, the thermal resistance in the solid node must be specified directly. Since modifications have been made to allow varying material types and temperature dependent conductivity for solid nodes, this method for specifying resistance will be inadequate for many situations. For this reason, an option was added to specify the resistance in terms of a geometry shape factor, similar to those used in the solid-to-solid thermal connections. The thermal conductivity of the node is determined based on material type and temperature, and is then used to calculate the thermal resistance.

The input modification for this feature is located on Card SLAB.4.

SLAB.4. (IC,RDIMF(IC)RWAL(IC),WID(IC),IC=1,NSKF[SLAB.1])

Read only if NKSF > 0 on SLAB.1

FORMAT(I5,2E5.0,e105)

<u>Columns</u>	<u>Variable</u>	<u>Description</u>
1-5	IC	Solid-to-fluid thermal connection type identification number.
6-10	RDIMF(IC)	Geometry factor from the solid structure node to the node surface that faces the channel. (Not used if RWAL is specified for connection IC.)
11-15	RWAL(IC)	Thermal resistance (s-ft-°F/Btu) from the solid structure node to the node surface that faces the channel. (Not used if RDIMF is specified for connection IC.)
16-25	WID(IC)	Perimeter of solid node that faces the channel (in.).

*** SLAB.4 is read in NKSF[SLAB.1] times. ***

Either a geometry factor (RDIMF[SLAB.4]) or thermal resistance (RWAL[SLAB.4]) may be used to describe the connection between slab node center and the wetted surface.

FIGURE 7.7. Relationship between $R_{wal}/(k \cdot A)$ and L/A for various values of $RDIMF[SLAB.4]$.

FIGURE 7.1. Temperature Profiles for Heat-Generating Plate with Linearly Varying Thermal Conductivity

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APPENDIX A

DEVELOPING FLOW IN A PLANAR CHANNEL OUTPUT

APPENDIX A

DEVELOPING FLOW IN A PLANAR CHANNEL OUTPUT

cobra dimension parameters:

id= 6	ie= 40	lif= 15
ih= 9	lip= 8	iq= 7
ir= 9	lit= 3	iu= 6
liw= 6	ix= 8	liz= 15
la= 15	lb= 1	llc= 1
ld= 1	le= 1	lf= 1
ma= 20	mc= 40	me= 31
mg= 50	mh= 6	mi= 12
mj= 1	mk= 3	ml= 9
lmn= 20	mn= 6	mp= 20
mq= 1	mr= 20	ms= 30
mt= 1	mw= 40	mx= 31
my= 4	nd= 9	no= 2
nv= 2	lnz= 10	

1***** the following is an image listing of the cobra-sfs input cards *****

radx generated input is not included

0	1	2	3	4	5	6	7	8
1234567890123456789012345678901234567890123456789012345678901234567890								
2	1	fluid shear sample problem no. 1						
3	prop	2	1					
4		0.0	50.	18.07	0.332	1.000	0.016	37.52
5		0.0	100.	67.97	0.364	0.998	0.016	37.52
6	1	none	1.0	1.0	1.0	1.0		
7	chan	1	30	1				
8		150.	90.					
9	1	1	10	0	1			
10	1	0	0	0	0			
11	1	1.0	1.0	0.0	2	1.0	1.0	
12	2	1.0	1.0	0.0	3	1.0	1.0	
13	3	1.0	1.0	0.0	4	1.0	1.0	
14	4	1.0	1.0	0.0	5	1.0	1.0	
15	5	1.0	1.0	0.0	6	1.0	1.0	
16	6	1.0	1.0	0.0	7	1.0	1.0	
17	7	1.0	1.0	0.0	8	1.0	1.0	
18	8	1.0	1.0	0.0	9	1.0	1.0	
19	9	1.0	1.0	0.0	10	1.0	1.0	
20	10	1.0	1.0	0.0				
21								
22	slab	0	1	1				
23	1	1	1.0	0.0				

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24      1      0.0      1.0
25      1      1      1      1
26
27      oper      1      0
28      0.0      70.      .00900      0.0      50.
29      calc      0
30      .001      .50
31
32      outp      1
33      endd
0      0      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890

```

input for case 1 fluid shear sample problem no. 1

date 01/05/89 time

summary of input options

group	n1	n2	n3	n4	n5	n6	n7	n8	n9	n10	n11	n12	n13	n14	n15
prop	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
chan	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0
slab	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
oper	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
calc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
outp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
endd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

fluid property table

pliq (psia)	temliq (f)	hliq (btu/lbm)	conliq (btu/hr-ft-f)	cpliq (btu/lbm-f)	vliq (ft ³ /lbm)	visliq (lbm/hr-ft)
0.0000	50.0000	18.0700	0.3320	1.0000	0.0160	37.5200
0.0000	100.0000	67.9700	0.3640	0.9980	0.0160	37.5200

solid property table

type	material	cp _{sol} (btu/hr-f)	rho _{sol} (lbm/ft ³)	thermal conductivity (btu/hr-ft-f)
1	none	1.0000	1.0000	1.000E+00 + 1.000E+00*t + 0.000E+00*t**2 + 0.000E+00*t**3

assembly number 1 input description

axial heat flux profile number 1 heat transfer correlation number 0
heat flux vs. time profile number 0 inlet flow vs. time profile number 0

subchannel input data for assembly number 1

loc. ch. no.	gib. ch. no.	frictn factor	area (sq-in)	wetted perim. (in)	heated perim. (in)	hydraulic diameter (in)	(adjacent channel no., momentum control volume width and length)
1	1	0	1.0000	1.0000	0.0000	4.0000	(2, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
2	2	0	1.0000	1.0000	0.0000	4.0000	(3, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
3	3	0	1.0000	1.0000	0.0000	4.0000	(4, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
4	4	0	1.0000	1.0000	0.0000	4.0000	(5, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
5	5	0	1.0000	1.0000	0.0000	4.0000	(6, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
6	6	0	1.0000	1.0000	0.0000	4.0000	(7, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
7	7	0	1.0000	1.0000	0.0000	4.0000	(8, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
8	8	0	1.0000	1.0000	0.0000	4.0000	(9, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
9	9	0	1.0000	1.0000	0.0000	4.0000	(10, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
10	10	0	1.0000	1.0000	0.0000	4.0000	(0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)

solid-to-fluid thermal connection type table

connection type	geometry factor	slab-fluid resistance (ft-f-s/btu)	slab wetted perimeter (in)
1	0.000	0.000	0.083

calculation parameters

lateral resistance factor	0.5000
s/l parameter	0.5000
turbulent momentum factor	0.0000
channel orientation (degrees)	90.0000
channel length (inches)	150.0000
number of axial nodes	30
total transient time (seconds)	0.0000
number of time steps	0
nominal time step (seconds)	*****
roll option (0 - no roll)	0

data for implicit solution

external iteration limit	20
convergence factors	
internal (dp/p)	0.00100
energy (dh/h)	0.00100
acceleration factors	
crossflow solution	1.60000
lateral delta-p	0.80000
flow	0.50000
density	1.00000
slab energy	1.20000

axial noding

node no.	integral height (in.)	nodal length (in.)	node no.	integral height (in.)	nodal length (in.)	node no.	integral height (in.)	nodal length (in.)
1	0.0- 5.0	5.000	2	5.0- 10.0	5.000	3	10.0- 15.0	5.000
4	15.0- 20.0	5.000	5	20.0- 25.0	5.000	6	25.0- 30.0	5.000
7	30.0- 35.0	5.000	8	35.0- 40.0	5.000	9	40.0- 45.0	5.000
10	45.0- 50.0	5.000	11	50.0- 55.0	5.000	12	55.0- 60.0	5.000
13	60.0- 65.0	5.000	14	65.0- 70.0	5.000	15	70.0- 75.0	5.000
16	75.0- 80.0	5.000	17	80.0- 85.0	5.000	18	85.0- 90.0	5.000
19	90.0- 95.0	5.000	20	95.0- 100.0	5.000	21	100.0- 105.0	5.000
22	105.0- 110.0	5.000	23	110.0- 115.0	5.000	24	115.0- 120.0	5.000
25	120.0- 125.0	5.000	26	125.0- 130.0	5.000	27	130.0- 135.0	5.000
28	135.0- 140.0	5.000	29	140.0- 145.0	5.000	30	145.0- 150.0	5.000

operating conditions

system pressure	=	0.0 psia
inlet enthalpy	=	38.0 btu/lbm
inlet temperature	=	70.000 degrees f
nominal mass flux	=	0.009 million lbm/ft2-hr
nominal power density	=	0.0000 million btu/hr-ft3
exit enthalpy	=	50.0 btu/lbm
uniform inlet temperature		

0 uniform inlet mass velocity
1

parameter summary

parameter	description	dimensioned for	amount used
ld	max. no. of solid material property types	6	1
lf	max. no. of boundary thermal connection types	15	0
lip	max. no. of radial boundary regions	8	1
iq	max. no. of circumferential boundary nodes	7	0
lit	max. no. of assembly types	3	1
lu	max. no. of assemblies	6	1
iw	max. no. of loss coeff. profiles, friction factor or heat transfer corr.	6	0
iz	max. no. of slab-slab and slab-fluid connection types	15	1
ma	max. no. of channels with area variations	20	0
mc	max. no. of channels	40	10
me	mx if not using roll option; 3 if roll is used	31	31
mg	max. no. of channel gap connections	50	9
mh	max. no. of slab-slab solid connections	6	0
mj	max. no. of assembly groupings in network model	1	0
mk	max. no. of loss coefficients	3	0
ml	max. no. of axial locations for gap and area variations	9	0
lmm	max. no. of points in selected profile tables	20	0
mn	max. no. of fuel nodes in a rod	6	1
mp	max. no. of entries in property, axial heat flux or transient tables	20	2
mq	max. no. of channel groups that have local axial losses	1	0
mr	max. no. of fuel rods	20	0
ms	max. no. of gaps that can have gap spacing variations	30	0
mt	max. no. of fuel types	1	0
mv	max. no. of axial heat flux profiles	1	1
mw	max. no. of slab nodes	40	1
mx	max. no. of axial nodes plus one	31	31
my	max. no. of axial fuel type divisions	4	0
nd	max. no. of fluid channels connected to a wall node	9	1
no	max. no. of boundary temperature types	2	0
nv	max. no. of user-defined radiation groups	2	0
lnz	max. no. of surfaces in a user-defined radiation group	10	0
la	no. of radiation surfaces in enclosure type 1	15	0
lb	no. of radiation surfaces in enclosure type 2	1	0
llc	no. of radiation surfaces in enclosure type 3	1	0
ld	no. of radiation surfaces in enclosure type 4	1	0
le	no. of radiation surfaces in enclosure type 5	1	0
lf	no. of radiation surfaces in enclosure type 6	1	0

total heat generation in the problem is 0.00000 btu/sec or 0.00000 kw

data from iterative solution using the recirculation module

time = 0.0000 dt = ***** implicit dt = 0.0000 explicit dt = 8.9968 mode = 0

iteration no.	sweep no.	peak clad				total flow (lbm/s)	pressure drop (psi)	error			
		temp(f)	level	rod	ass.			total energy	flow	fluid energy	rod energy
1	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.2338	0.0000	0.0000
2	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.2009	0.0000	0.0000
3	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.1060	0.0000	0.0000
4	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0582	0.0000	0.0000
5	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0349	0.0000	0.0000
6	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0222	0.0000	0.0000
7	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0146	0.0000	0.0000
8	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0098	0.0000	0.0000
9	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0067	0.0000	0.0000
10	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0046	0.0000	0.0000
11	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0031	0.0000	0.0000
12	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0021	0.0000	0.0000
13	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0015	0.0000	0.0000
14	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0010	0.0000	0.0000
15	1	0.0	0	0	0	0.174E+00	0.0000000	0.0000	0.0007	0.0000	0.0000

cobra-sfs code results

case 1 fluid shear sample problem no. 1

date 01/05/89 time

calculated fluid conditions at time = 0.0000 seconds

channel 1

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000114	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000096	38.03	70.00	62.5000	0.0128477	0.0066602	0.0296011	1.00000
10.0	0.0000085	38.03	70.00	62.5000	0.0094237	0.0048852	0.0217121	1.00000
15.0	0.0000076	38.03	70.00	62.5000	0.0071913	0.0037280	0.0165688	1.00000
20.0	0.0000070	38.03	70.00	62.5000	0.0058563	0.0030359	0.0134930	1.00000
25.0	0.0000065	38.03	70.00	62.5000	0.0050852	0.0026362	0.0117163	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0046272	0.0023987	0.0106611	1.00000

35.0	0.0000057	38.03	70.00	62.5000	0.0043323	0.0022459	0.0099816	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0041229	0.0021373	0.0094992	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0039618	0.0020538	0.0091281	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0038312	0.0019861	0.0088271	1.00000
55.0	0.0000043	38.03	70.00	62.5000	0.0037219	0.0019294	0.0085753	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0036286	0.0018811	0.0083603	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0035479	0.0018392	0.0081743	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0034772	0.0018026	0.0080114	1.00000
75.0	0.0000032	38.03	70.00	62.5000	0.0034147	0.0017702	0.0078675	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0033590	0.0017413	0.0077392	1.00000
85.0	0.0000027	38.03	70.00	62.5000	0.0033091	0.0017154	0.0076242	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0032640	0.0016921	0.0075202	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0032230	0.0016708	0.0074259	1.00000
100.0	0.0000020	38.03	70.00	62.5000	0.0031857	0.0016514	0.0073398	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0031514	0.0016337	0.0072609	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0031199	0.0016174	0.0071883	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0030908	0.0016023	0.0071212	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0030639	0.0015883	0.0070592	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0030389	0.0015753	0.0070015	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0030156	0.0015633	0.0069478	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0029938	0.0015520	0.0068978	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0029735	0.0015415	0.0068510	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0029544	0.0015316	0.0068069	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0029289	0.0015183	0.0067481	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 2
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000112	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000097	38.03	70.00	62.5000	0.0169192	0.0087709	0.0389817	1.00000
10.0	0.0000085	38.03	70.00	62.5000	0.0157376	0.0081584	0.0362595	1.00000
15.0	0.0000076	38.03	70.00	62.5000	0.0145039	0.0075188	0.0334170	1.00000
20.0	0.0000070	38.03	70.00	62.5000	0.0134378	0.0069662	0.0309607	1.00000
25.0	0.0000065	38.03	70.00	62.5000	0.0125780	0.0065205	0.0289798	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0118992	0.0061685	0.0274157	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0113605	0.0058893	0.0261745	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0109257	0.0056639	0.0251728	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0105676	0.0054783	0.0243478	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0102673	0.0053226	0.0236558	1.00000
55.0	0.0000043	38.03	70.00	62.5000	0.0100113	0.0051899	0.0230661	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0097904	0.0050754	0.0225571	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0095976	0.0049754	0.0221129	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0094278	0.0048874	0.0217216	1.00000
75.0	0.0000032	38.03	70.00	62.5000	0.0092769	0.0048091	0.0213739	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0091419	0.0047391	0.0210628	1.00000
85.0	0.0000027	38.03	70.00	62.5000	0.0090203	0.0046761	0.0207827	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0089101	0.0046190	0.0205290	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0088099	0.0045671	0.0202980	1.00000
100.0	0.0000020	38.03	70.00	62.5000	0.0087183	0.0045196	0.0200869	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0086341	0.0044759	0.0198931	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0085567	0.0044358	0.0197145	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0084850	0.0043986	0.0195495	1.00000

120.0	0.0000012	38.03	70.00	62.5000	0.0084186	0.0043642	0.0193966	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0083570	0.0043322	0.0192544	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0082995	0.0043024	0.0191220	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0082458	0.0042746	0.0189984	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0081956	0.0042486	0.0188826	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0081474	0.0042236	0.0187715	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0080972	0.0041976	0.0186559	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 3

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000109	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000097	38.03	70.00	62.5000	0.0179195	0.0092895	0.0412866	1.00000
10.0	0.0000086	38.03	70.00	62.5000	0.0179376	0.0092988	0.0413282	1.00000
15.0	0.0000077	38.03	70.00	62.5000	0.0176521	0.0091509	0.0406705	1.00000
20.0	0.0000070	38.03	70.00	62.5000	0.0172431	0.0089388	0.0397280	1.00000
25.0	0.0000065	38.03	70.00	62.5000	0.0168076	0.0087131	0.0387247	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0163896	0.0084963	0.0377615	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0160037	0.0082963	0.0368726	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0156528	0.0081144	0.0360640	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0153353	0.0079498	0.0353325	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0150486	0.0078012	0.0346720	1.00000
55.0	0.0000043	38.03	70.00	62.5000	0.0147898	0.0076671	0.0340758	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0145561	0.0075459	0.0335373	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0143446	0.0074363	0.0330500	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0141528	0.0073368	0.0326081	1.00000
75.0	0.0000032	38.03	70.00	62.5000	0.0139783	0.0072464	0.0322061	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0138191	0.0071638	0.0318393	1.00000
85.0	0.0000027	38.03	70.00	62.5000	0.0136734	0.0070883	0.0315036	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0135397	0.0070190	0.0311954	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0134166	0.0069551	0.0309117	1.00000
100.0	0.0000020	38.03	70.00	62.5000	0.0133029	0.0068962	0.0306498	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0131977	0.0068417	0.0304074	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0131001	0.0067911	0.0301825	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0130093	0.0067440	0.0299734	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0129247	0.0067002	0.0297785	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0128457	0.0066592	0.0295965	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0127718	0.0066209	0.0294263	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0127026	0.0065850	0.0292667	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0126374	0.0065512	0.0291165	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0125751	0.0065189	0.0289730	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0125174	0.0064890	0.0288401	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 4

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000107	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000

5.0	0.0000096	38.03	70.00	62.5000	0.0181175	0.0093921	0.0417426	1.00000
10.0	0.0000086	38.03	70.00	62.5000	0.0186334	0.0096595	0.0429312	1.00000
15.0	0.0000077	38.03	70.00	62.5000	0.0188796	0.0097872	0.0434986	1.00000
20.0	0.0000071	38.03	70.00	62.5000	0.0189376	0.0098173	0.0436322	1.00000
25.0	0.0000065	38.03	70.00	62.5000	0.0188850	0.0097900	0.0435110	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0187736	0.0097322	0.0432543	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0186322	0.0096589	0.0429285	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0184762	0.0095781	0.0425692	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0183145	0.0094942	0.0421967	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0181524	0.0094102	0.0418231	1.00000
55.0	0.0000044	38.03	70.00	62.5000	0.0179934	0.0093278	0.0414567	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0178395	0.0092480	0.0411023	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0176922	0.0091716	0.0407629	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0175521	0.0090990	0.0404399	1.00000
75.0	0.0000032	38.03	70.00	62.5000	0.0174193	0.0090302	0.0401341	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0172940	0.0089652	0.0398453	1.00000
85.0	0.0000027	38.03	70.00	62.5000	0.0171758	0.0089039	0.0395730	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0170645	0.0088462	0.0393166	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0169598	0.0087919	0.0390753	1.00000
100.0	0.0000020	38.03	70.00	62.5000	0.0168612	0.0087408	0.0388482	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0167684	0.0086928	0.0386345	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0166811	0.0086475	0.0384332	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0165988	0.0086048	0.0382437	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0165213	0.0085646	0.0380650	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0164481	0.0085267	0.0378965	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0163791	0.0084909	0.0377375	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0163139	0.0084571	0.0375872	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0162520	0.0084250	0.0374447	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0161932	0.0083946	0.0373092	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0161421	0.0083681	0.0371914	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 5

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft ²)	velocity (ft/sec)	area (sq-in)
0.0	0.0000105	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000096	38.03	70.00	62.5000	0.0180977	0.0093819	0.0416971	1.00000
10.0	0.0000086	38.03	70.00	62.5000	0.0187782	0.0097346	0.0432649	1.00000
15.0	0.0000078	38.03	70.00	62.5000	0.0192694	0.0099892	0.0443966	1.00000
20.0	0.0000071	38.03	70.00	62.5000	0.0195860	0.0101534	0.0451261	1.00000
25.0	0.0000066	38.03	70.00	62.5000	0.0197773	0.0102525	0.0455669	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0198868	0.0103093	0.0458191	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0199434	0.0103387	0.0459497	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0199647	0.0103497	0.0459986	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0199611	0.0103478	0.0459903	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0199397	0.0103368	0.0459412	1.00000
55.0	0.0000044	38.03	70.00	62.5000	0.0199056	0.0103191	0.0458626	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0198625	0.0102967	0.0457632	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0198132	0.0102711	0.0456495	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0197597	0.0102434	0.0455263	1.00000
75.0	0.0000032	38.03	70.00	62.5000	0.0197037	0.0102144	0.0453974	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0196465	0.0101847	0.0452655	1.00000
85.0	0.0000028	38.03	70.00	62.5000	0.0195889	0.0101549	0.0451328	1.00000

90.0	0.0000025	38.03	70.00	62.5000	0.0195316	0.0101252	0.0450008	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0194751	0.0100959	0.0448707	1.00000
100.0	0.0000020	38.03	70.00	62.5000	0.0194199	0.0100673	0.0447434	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0193660	0.0100393	0.0446193	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0193138	0.0100123	0.0444990	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0192633	0.0099861	0.0443826	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0192146	0.0099609	0.0442704	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0191677	0.0099366	0.0441625	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0191227	0.0099132	0.0440587	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0190794	0.0098908	0.0439590	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0190379	0.0098692	0.0438632	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0189984	0.0098488	0.0437724	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0189660	0.0098320	0.0436976	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 6
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000103	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000095	38.03	70.00	62.5000	0.0180331	0.0093483	0.0415482	1.00000
10.0	0.0000086	38.03	70.00	62.5000	0.0187436	0.0097167	0.0431853	1.00000
15.0	0.0000078	38.03	70.00	62.5000	0.0193277	0.0100195	0.0445310	1.00000
20.0	0.0000071	38.03	70.00	62.5000	0.0197657	0.0102465	0.0455402	1.00000
25.0	0.0000066	38.03	70.00	62.5000	0.0200868	0.0104130	0.0462799	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0203254	0.0105367	0.0468297	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0205078	0.0106313	0.0472501	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0206505	0.0107052	0.0475788	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0207635	0.0107638	0.0478391	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0208531	0.0108103	0.0480456	1.00000
55.0	0.0000044	38.03	70.00	62.5000	0.0209240	0.0108470	0.0482089	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0209795	0.0108758	0.0483369	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0210225	0.0108980	0.0484357	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0210550	0.0109149	0.0485107	1.00000
75.0	0.0000033	38.03	70.00	62.5000	0.0210790	0.0109274	0.0485661	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0210960	0.0109362	0.0486053	1.00000
85.0	0.0000028	38.03	70.00	62.5000	0.0211073	0.0109420	0.0486313	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0211139	0.0109454	0.0486464	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0211167	0.0109469	0.0486528	1.00000
100.0	0.0000021	38.03	70.00	62.5000	0.0211163	0.0109467	0.0486520	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0211135	0.0109452	0.0486455	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0211087	0.0109427	0.0486344	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0211023	0.0109394	0.0486197	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0210947	0.0109355	0.0486021	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0210861	0.0109310	0.0485823	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0210768	0.0109262	0.0485609	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0210669	0.0109211	0.0485382	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0210567	0.0109158	0.0485147	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0210471	0.0109108	0.0484924	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0210413	0.0109078	0.0484791	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 7
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000102	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000095	38.03	70.00	62.5000	0.0179722	0.0093168	0.0414080	1.00000
10.0	0.0000086	38.03	70.00	62.5000	0.0186692	0.0096781	0.0430138	1.00000
15.0	0.0000078	38.03	70.00	62.5000	0.0192788	0.0099941	0.0444184	1.00000
20.0	0.0000071	38.03	70.00	62.5000	0.0197651	0.0102463	0.0455389	1.00000
25.0	0.0000066	38.03	70.00	62.5000	0.0201454	0.0104434	0.0464151	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0204486	0.0106006	0.0471136	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0206987	0.0107302	0.0476898	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0209112	0.0108404	0.0481793	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0210954	0.0109358	0.0486038	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0212569	0.0110196	0.0489759	1.00000
55.0	0.0000044	38.03	70.00	62.5000	0.0213994	0.0110934	0.0493042	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0215256	0.0111588	0.0495949	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0216376	0.0112169	0.0498530	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0217372	0.0112686	0.0500826	1.00000
75.0	0.0000033	38.03	70.00	62.5000	0.0218261	0.0113147	0.0502874	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0219056	0.0113559	0.0504705	1.00000
85.0	0.0000028	38.03	70.00	62.5000	0.0219767	0.0113927	0.0506344	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0220406	0.0114258	0.0507815	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0220980	0.0114556	0.0509139	1.00000
100.0	0.0000021	38.03	70.00	62.5000	0.0221498	0.0114825	0.0510332	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0221966	0.0115067	0.0511410	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0222389	0.0115287	0.0512385	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0222774	0.0115486	0.0513271	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0223123	0.0115667	0.0514076	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0223442	0.0115832	0.0514810	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0223733	0.0115983	0.0515481	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0223999	0.0116121	0.0516095	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0224245	0.0116249	0.0516660	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0224477	0.0116369	0.0517196	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0224711	0.0116490	0.0517735	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 8
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000101	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000095	38.03	70.00	62.5000	0.0179262	0.0092930	0.0413021	1.00000
10.0	0.0000086	38.03	70.00	62.5000	0.0186019	0.0096432	0.0428587	1.00000
15.0	0.0000078	38.03	70.00	62.5000	0.0192129	0.0099599	0.0442664	1.00000
20.0	0.0000072	38.03	70.00	62.5000	0.0197146	0.0102200	0.0454224	1.00000
25.0	0.0000066	38.03	70.00	62.5000	0.0201180	0.0104292	0.0463519	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0204489	0.0106007	0.0471143	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0207302	0.0107465	0.0477624	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0209772	0.0108746	0.0483314	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0211988	0.0109894	0.0488419	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0214002	0.0110938	0.0493060	1.00000
55.0	0.0000044	38.03	70.00	62.5000	0.0215845	0.0111894	0.0497306	1.00000

60.0	0.0000041	38.03	70.00	62.5000	0.0217538	0.0112772	0.0501208	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0219098	0.0113580	0.0504802	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0220539	0.0114327	0.0508121	1.00000
75.0	0.0000033	38.03	70.00	62.5000	0.0221872	0.0115018	0.0511192	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0223107	0.0115659	0.0514039	1.00000
85.0	0.0000028	38.03	70.00	62.5000	0.0224254	0.0116254	0.0516682	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0225321	0.0116807	0.0519141	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0226315	0.0117322	0.0521430	1.00000
100.0	0.0000021	38.03	70.00	62.5000	0.0227242	0.0117802	0.0523566	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0228108	0.0118251	0.0525560	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0228918	0.0118671	0.0527426	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0229676	0.0119064	0.0529173	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0230387	0.0119432	0.0530811	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0231054	0.0119778	0.0532348	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0231681	0.0120103	0.0533793	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0232271	0.0120409	0.0535152	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0232828	0.0120698	0.0536436	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0233358	0.0120973	0.0537656	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0233856	0.0121231	0.0538805	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 9

assembly 1

A.11

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000101	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000095	38.03	70.00	62.5000	0.0178964	0.0092775	0.0412333	1.00000
10.0	0.0000086	38.03	70.00	62.5000	0.0185550	0.0096189	0.0427508	1.00000
15.0	0.0000078	38.03	70.00	62.5000	0.0191615	0.0099333	0.0441482	1.00000
20.0	0.0000072	38.03	70.00	62.5000	0.0196665	0.0101951	0.0453115	1.00000
25.0	0.0000066	38.03	70.00	62.5000	0.0200772	0.0104080	0.0462580	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0204181	0.0105847	0.0470433	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0207115	0.0107368	0.0477193	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0209729	0.0108723	0.0483215	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0212113	0.0109960	0.0488709	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0214318	0.0111103	0.0493789	1.00000
55.0	0.0000044	38.03	70.00	62.5000	0.0216372	0.0112167	0.0498521	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0218293	0.0113163	0.0502947	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0220094	0.0114097	0.0507097	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0221787	0.0114974	0.0510996	1.00000
75.0	0.0000033	38.03	70.00	62.5000	0.0223379	0.0115800	0.0514666	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0224880	0.0116578	0.0518125	1.00000
85.0	0.0000028	38.03	70.00	62.5000	0.0226297	0.0117312	0.0521388	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0227634	0.0118006	0.0524469	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0228899	0.0118661	0.0527383	1.00000
100.0	0.0000021	38.03	70.00	62.5000	0.0230095	0.0119281	0.0530139	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0231227	0.0119868	0.0532748	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0232300	0.0120424	0.0535219	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0233317	0.0120951	0.0537562	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0234281	0.0121451	0.0539784	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0235196	0.0121926	0.0541892	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0236065	0.0122376	0.0543893	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0236890	0.0122804	0.0545795	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0237676	0.0123211	0.0547606	1.00000

145.0	0.0000002	38.03	70.00	62.5000	0.0238425	0.0123600	0.0549331	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0239121	0.0123960	0.0550934	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 10
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000101	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000094	38.03	70.00	62.5000	0.0178816	0.0092698	0.0411993	1.00000
10.0	0.0000086	38.03	70.00	62.5000	0.0185310	0.0096065	0.0426954	1.00000
15.0	0.0000078	38.03	70.00	62.5000	0.0191338	0.0099190	0.0440844	1.00000
20.0	0.0000072	38.03	70.00	62.5000	0.0196384	0.0101805	0.0452468	1.00000
25.0	0.0000066	38.03	70.00	62.5000	0.0200505	0.0103942	0.0461963	1.00000
30.0	0.0000061	38.03	70.00	62.5000	0.0203938	0.0105721	0.0469873	1.00000
35.0	0.0000057	38.03	70.00	62.5000	0.0206908	0.0107261	0.0476716	1.00000
40.0	0.0000053	38.03	70.00	62.5000	0.0209571	0.0108642	0.0482851	1.00000
45.0	0.0000050	38.03	70.00	62.5000	0.0212018	0.0109910	0.0488489	1.00000
50.0	0.0000047	38.03	70.00	62.5000	0.0214298	0.0111092	0.0493744	1.00000
55.0	0.0000044	38.03	70.00	62.5000	0.0216439	0.0112202	0.0498676	1.00000
60.0	0.0000041	38.03	70.00	62.5000	0.0218457	0.0113248	0.0503325	1.00000
65.0	0.0000038	38.03	70.00	62.5000	0.0220364	0.0114237	0.0507718	1.00000
70.0	0.0000035	38.03	70.00	62.5000	0.0222168	0.0115172	0.0511876	1.00000
75.0	0.0000033	38.03	70.00	62.5000	0.0223879	0.0116059	0.0515817	1.00000
80.0	0.0000030	38.03	70.00	62.5000	0.0225502	0.0116900	0.0519557	1.00000
85.0	0.0000028	38.03	70.00	62.5000	0.0227045	0.0117700	0.0523111	1.00000
90.0	0.0000025	38.03	70.00	62.5000	0.0228511	0.0118460	0.0526489	1.00000
95.0	0.0000023	38.03	70.00	62.5000	0.0229906	0.0119183	0.0529703	1.00000
100.0	0.0000021	38.03	70.00	62.5000	0.0231234	0.0119872	0.0532762	1.00000
105.0	0.0000018	38.03	70.00	62.5000	0.0232498	0.0120527	0.0535675	1.00000
110.0	0.0000016	38.03	70.00	62.5000	0.0233702	0.0121151	0.0538449	1.00000
115.0	0.0000014	38.03	70.00	62.5000	0.0234849	0.0121746	0.0541093	1.00000
120.0	0.0000012	38.03	70.00	62.5000	0.0235942	0.0122313	0.0543611	1.00000
125.0	0.0000010	38.03	70.00	62.5000	0.0236985	0.0122853	0.0546012	1.00000
130.0	0.0000008	38.03	70.00	62.5000	0.0237978	0.0123368	0.0548301	1.00000
135.0	0.0000006	38.03	70.00	62.5000	0.0238926	0.0123859	0.0550485	1.00000
140.0	0.0000004	38.03	70.00	62.5000	0.0239831	0.0124329	0.0552571	1.00000
145.0	0.0000002	38.03	70.00	62.5000	0.0240695	0.0124776	0.0554562	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0241494	0.0125191	0.0556403	1.00000

slab temperature summary time = 0.0000 seconds
(assembled no. - channel no.)

axial zone (inches)	(1)	(
0.0 - 5.0	70.00	
5.0 - 10.0	70.00	
10.0 - 15.0	70.00	
15.0 - 20.0	70.00	

20.0 - 25.0	70.00
25.0 - 30.0	70.00
30.0 - 35.0	70.00
35.0 - 40.0	70.00
40.0 - 45.0	70.00
45.0 - 50.0	70.00
50.0 - 55.0	70.00
55.0 - 60.0	70.00
60.0 - 65.0	70.00
65.0 - 70.0	70.00
70.0 - 75.0	70.00
75.0 - 80.0	70.00
80.0 - 85.0	70.00
85.0 - 90.0	70.00
90.0 - 95.0	70.00
95.0 - 100.0	70.00
100.0 - 105.0	70.00
105.0 - 110.0	70.00
110.0 - 115.0	70.00
115.0 - 120.0	70.00
120.0 - 125.0	70.00
125.0 - 130.0	70.00
130.0 - 135.0	70.00
135.0 - 140.0	70.00
140.0 - 145.0	70.00
145.0 - 150.0	70.00

crossflow between adjacent channels at time = 0.0000 seconds

assembly number	1	1	1	1	1	1	1	1	1
axial zone	1 2	2 3	3 4	4 5	5 6	6 7	7 8	8 9	9 10
0.0 - 5.0	0.01083	0.01189	0.01055	0.00874	0.00697	0.00536	0.00389	0.00253	0.00125
5.0 - 10.0	0.00822	0.01105	0.01101	0.00977	0.00814	0.00643	0.00476	0.00314	0.00156
10.0 - 15.0	0.00536	0.00832	0.00900	0.00841	0.00723	0.00583	0.00437	0.00290	0.00145
15.0 - 20.0	0.00320	0.00576	0.00675	0.00661	0.00585	0.00479	0.00363	0.00242	0.00121
20.0 - 25.0	0.00185	0.00391	0.00496	0.00509	0.00463	0.00386	0.00294	0.00198	0.00099
25.0 - 30.0	0.00110	0.00273	0.00373	0.00400	0.00374	0.00316	0.00244	0.00164	0.00082
30.0 - 35.0	0.00071	0.00200	0.00293	0.00327	0.00313	0.00269	0.00209	0.00142	0.00071
35.0 - 40.0	0.00050	0.00155	0.00239	0.00276	0.00271	0.00237	0.00186	0.00127	0.00064
40.0 - 45.0	0.00039	0.00125	0.00201	0.00240	0.00240	0.00213	0.00169	0.00116	0.00059
45.0 - 50.0	0.00031	0.00103	0.00172	0.00211	0.00216	0.00195	0.00156	0.00108	0.00055
50.0 - 55.0	0.00026	0.00088	0.00150	0.00188	0.00196	0.00179	0.00145	0.00101	0.00051
55.0 - 60.0	0.00022	0.00075	0.00131	0.00168	0.00179	0.00165	0.00135	0.00095	0.00048
60.0 - 65.0	0.00019	0.00066	0.00116	0.00152	0.00164	0.00153	0.00126	0.00089	0.00046
65.0 - 70.0	0.00017	0.00058	0.00104	0.00137	0.00150	0.00142	0.00118	0.00084	0.00043
70.0 - 75.0	0.00015	0.00051	0.00093	0.00125	0.00138	0.00133	0.00111	0.00079	0.00041
75.0 - 80.0	0.00013	0.00046	0.00084	0.00114	0.00128	0.00124	0.00105	0.00075	0.00039
80.0 - 85.0	0.00012	0.00041	0.00076	0.00104	0.00118	0.00116	0.00099	0.00071	0.00037
85.0 - 90.0	0.00011	0.00037	0.00069	0.00096	0.00110	0.00108	0.00093	0.00067	0.00035
90.0 - 95.0	0.00010	0.00034	0.00063	0.00089	0.00102	0.00101	0.00088	0.00064	0.00033
95.0 - 100.0	0.00009	0.00031	0.00058	0.00082	0.00095	0.00095	0.00083	0.00061	0.00032
100.0 - 105.0	0.00008	0.00028	0.00054	0.00076	0.00089	0.00090	0.00078	0.00058	0.00030
105.0 - 110.0	0.00008	0.00026	0.00050	0.00071	0.00083	0.00084	0.00074	0.00055	0.00029
110.0 - 115.0	0.00007	0.00024	0.00046	0.00066	0.00078	0.00079	0.00070	0.00052	0.00028
115.0 - 120.0	0.00006	0.00022	0.00043	0.00061	0.00073	0.00075	0.00066	0.00049	0.00026

120.0 - 125.0	0.00006	0.00021	0.00040	0.00057	0.00069 *	0.00071	0.00063	0.00047	0.00025
125.0 - 130.0	0.00006	0.00019	0.00037	0.00054	0.00064	0.00067	0.00060	0.00045	0.00024
130.0 - 135.0	0.00005	0.00018	0.00035	0.00050	0.00061	0.00063	0.00057	0.00043	0.00023
135.0 - 140.0	0.00005	0.00017	0.00033	0.00047	0.00057	0.00060	0.00054	0.00041	0.00022
140.0 - 145.0	0.00005	0.00016	0.00031	0.00045	0.00055	0.00057	0.00051	0.00039	0.00021
145.0 - 150.0	0.00006	0.00018	0.00032	0.00044	0.00052	0.00053	0.00048	0.00036	0.00019

iterations = 15

input transient time completed

common dumped to tape 8

1***** computational time summary *****

subroutine energy.....	0.30 sec
subroutine moment.....	0.44 sec
subroutine reheat.....	0.00 sec
subroutine recirc (pressure loop)....	0.31 sec
subroutine result.....	0.17 sec
subroutine setup.....	0.06 sec
other subroutines.....	0.32 sec
total cpu time.....	1.60 sec

APPENDIX B

DEVELOPING FLOW IN A CYLINDRICAL PIPE OUTPUT

APPENDIX B

NATURAL CIRCULATION IN A SQUARE CAVITY OUTPUT

cobra dimension parameters:

id= 6	ie= 40	lif= 15
ih= 9	lip= 8	iq= 7
ir= 9	lit= 3	iu= 6
liw= 6	ix= 8	liz= 15
la= 15	lb= 1	llc= 1
ld= 1	le= 1	lf= 1
ma= 20	mc= 40	me= 31
mg= 50	mh= 6	mi= 12
mj= 1	mk= 3	ml= 9
lmn= 20	mn= 6	mp= 20
mq= 1	mr= 20	ms= 30
mt= 1	mw= 40	mx= 31
my= 4	nd= 9	no= 2
nv= 2	lnz= 10	

1***** the following is an image listing of the cobra-sfs input cards *****

```

radx generated input is not included
0      0      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890

2      1      fluid shear sample problem no. 2
3      prop      2      1
4      0.0      50.      18.07      0.332      1.000      0.016      37.52
5      0.0      100.      67.97      0.364      0.998      0.016      37.52
6      1 none      1.0      1.0      1.0      1.0
7      chan      1      30      1
8      150.      90.
9      1      1      10      0      1
10     1      0      0      0      0
11     1 3.14 1.0 0.0 2 6.28 1.0
12     2 9.42 1.0 0.0 312.57 1.0
13     315.71 1.0 0.0 418.85 1.0
14     421.99 1.0 0.0 525.13 1.0
15     528.27 1.0 0.0 631.42 1.0
16     634.59 1.0 0.0 737.70 1.0
17     740.84 1.0 0.0 843.98 1.0
18     847.12 1.0 0.0 950.27 1.0
19     953.41 1.0 0.0 1056.55 1.0
20     1059.69 1.0 0.0
21
22     slab      0      1      1
23     1      1      1.0      0.0

```

```

24      1      0.0      62.83
25      1      1      10      1
26
27      oper      1      0
28      0.0      70.      .00450      0.0      50.
29      calc      0
30      .001      .40
31
32      outp      1
33      endd
0      0      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890

```

linput for case 1 fluid shear sample problem no. 1 date 01/05/89 time

```

summary of input options
group n1 n2 n3 n4 n5 n6 n7 n8 n9 n10 n11 n12 n13 n14 n15
prop 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0
chan 1 30 0 1 0 0 0 0 0 0 0 0 0 0 0
slab 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0
oper 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
calc 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
outp 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
endd 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

```

fluid property table

pliq (psia)	temliq (f)	hliq (btu/lbm)	conliq (btu/hr-ft-f)	cpliq (btu/lbm-f)	vliq (ft3/lbm)	visliq (lbm/hr-ft)
0.0000	50.0000	18.0700	0.3320	1.0000	0.0160	37.5200
0.0000	100.0000	67.9700	0.3640	0.9980	0.0160	37.5200

solid property table

type	material	cp _{sol} (btu/hr-f)	rho _{sol} (lbm/ft3)	thermal conductivity (btu/hr-ft-f)
1	none	1.0000	1.0000	1.000E+00 + 1.000E+00*t + 0.000E+00*t**2 + 0.000E+00*t**3

assembly number 1 input description

```

axial heat flux profile number 1 heat transfer correlation number 0
heat flux vs. time profile number 0 inlet flow vs. time profile number 0

```

subchannel input data for assembly number 1

loc. ch. no.	glb. ch. no.	frictn factor type	area (sq-in)	wetted perim. (in)	heated perim. (in)	hydraulic diameter (in)	(adjacent channel no., momentum control volume width and length)
1	1	0	3.1400	1.0000	0.0000	12.5600	{ 2, 6.280, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
2	2	0	9.4200	1.0000	0.0000	37.6800	{ 3, 12.570, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
3	3	0	15.7100	1.0000	0.0000	62.8400	{ 4, 18.850, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
4	4	0	21.9900	1.0000	0.0000	87.9600	{ 5, 25.130, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
5	5	0	28.2700	1.0000	0.0000	113.0800	{ 6, 31.420, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
6	6	0	34.5900	1.0000	0.0000	138.3600	{ 7, 37.700, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
7	7	0	40.8400	1.0000	0.0000	163.3600	{ 8, 43.980, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
8	8	0	47.1200	1.0000	0.0000	188.4800	{ 9, 50.270, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
9	9	0	53.4100	1.0000	0.0000	213.6400	{ 10, 56.550, 1.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}
10	10	0	59.6900	1.0000	0.0000	238.7600	{ 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000} { 0, 0.000, 0.000}

solid-to-fluid thermal connection type table

connection type	geometry factor	slab-fluid resistance (ft-f-s/btu)	slab wetted perimeter (in)
1	0.000	0.000	5.236

calculation parameters

lateral resistance factor	0.5000
s/l parameter	0.5000
turbulent momentum factor	0.0000
channel orientation (degrees)	90.0000
channel length (inches)	150.0000
number of axial nodes	30
total transient time (seconds)	0.0000
number of time steps	0
nominal time step (seconds)	*****
roll option (0 - no roll)	0

data for implicit solution

external iteration limit	20
convergence factors	
internal (dp/p)	0.00100
energy (dh/h)	0.00100
acceleration factors	
crossflow solution	1.60000
lateral delta-p	0.80000
flow	0.40000
density	1.00000
slab energy	1.20000

axial noding

node no.	integral height (in.)	nodal length (in.)	node no.	integral height (in.)	nodal length (in.)	node no.	integral height (in.)	nodal length (in.)
1	0.0- 5.0	5.000	2	5.0- 10.0	5.000	3	10.0- 15.0	5.000
4	15.0- 20.0	5.000	5	20.0- 25.0	5.000	6	25.0- 30.0	5.000
7	30.0- 35.0	5.000	8	35.0- 40.0	5.000	9	40.0- 45.0	5.000
10	45.0- 50.0	5.000	11	50.0- 55.0	5.000	12	55.0- 60.0	5.000
13	60.0- 65.0	5.000	14	65.0- 70.0	5.000	15	70.0- 75.0	5.000
16	75.0- 80.0	5.000	17	80.0- 85.0	5.000	18	85.0- 90.0	5.000
19	90.0- 95.0	5.000	20	95.0- 100.0	5.000	21	100.0- 105.0	5.000
22	105.0- 110.0	5.000	23	110.0- 115.0	5.000	24	115.0- 120.0	5.000
25	120.0- 125.0	5.000	26	125.0- 130.0	5.000	27	130.0- 135.0	5.000
28	135.0- 140.0	5.000	29	140.0- 145.0	5.000	30	145.0- 150.0	5.000

operating conditions

system pressure	=	0.0 psia
inlet enthalpy	=	38.0 btu/lbm
inlet temperature	=	70.000 degrees f
nominal mass flux	=	0.005 million lbm/ft2-hr
nominal power density	=	0.0000 million btu/hr-ft3
exit enthalpy	=	50.0 btu/lbm
uniform inlet temperature		

0 uniform inlet mass velocity
1

parameter summary

parameter	description	dimensioned for	amount used
id	max. no. of solid material property types	6	1
if	max. no. of boundary thermal connection types	15	0
lip	max. no. of radial boundary regions	8	1
iq	max. no. of circumferential boundary nodes	7	0
lit	max. no. of assembly types	3	1
iu	max. no. of assemblies	6	1
iw	max. no. of loss coeff. profiles, friction factor or heat transfer corr.	6	0
iz	max. no. of slab-slab and slab-fluid connection types	15	1
ma	max. no. of channels with area variations	20	0
mc	max. no. of channels	40	10
me	mx if not using roll option; 3 if roll is used	31	31
mg	max. no. of channel gap connections	50	9
mh	max. no. of slab-slab solid connections	6	0
mj	max. no. of assembly groupings in network model	1	0
mk	max. no. of loss coefficients	3	0
ml	max. no. of axial locations for gap and area variations	9	0
lmm	max. no. of points in selected profile tables	20	0
mn	max. no. of fuel nodes in a rod	6	1
mp	max. no. of entries in property, axial heat flux or transient tables	20	2
mq	max. no. of channel groups that have local axial losses	1	0
mr	max. no. of fuel rods	20	0
ms	max. no. of gaps that can have gap spacing variations	30	0
mt	max. no. of fuel types	1	0
mv	max. no. of axial heat flux profiles	1	1
mw	max. no. of slab nodes	40	1
mx	max. no. of axial nodes plus one	31	31
my	max. no. of axial fuel type divisions	4	0
nd	max. no. of fluid channels connected to a wall node	9	1
no	max. no. of boundary temperature types	2	0
nv	max. no. of user-defined radiation groups	2	0
lnz	max. no. of surfaces in a user-defined radiation group	10	0
la	no. of radiation surfaces in enclosure type 1	15	0
lb	no. of radiation surfaces in enclosure type 2	1	0
llc	no. of radiation surfaces in enclosure type 3	1	0
ld	no. of radiation surfaces in enclosure type 4	1	0
le	no. of radiation surfaces in enclosure type 5	1	0
lf	no. of radiation surfaces in enclosure type 6	1	0

total heat generation in the problem is 0.00000 btu/sec or 0.00000 kw

data from iterative solution using the recirculation module
time = 0.0000 dt = ***** implicit dt = 0.0000 explicit dt = ***** mode = 0

iteration sweep	no.	peak clad temp(t) level rod ass.	total flow (lbm/s)	pressure drop(psi)	total energy	flow energy	fluid rod energy	error
1	1	0.0	0.273E+01	0.0000000	0.0000	0.1802	0.0000	0.0000
2	1	0.0	0.273E+01	0.0000000	0.0000	0.1517	0.0000	0.0000
3	1	0.0	0.273E+01	0.0000000	0.0000	0.0749	0.0000	0.0000
4	1	0.0	0.273E+01	0.0000000	0.0000	0.0466	0.0000	0.0000
5	1	0.0	0.273E+01	0.0000000	0.0000	0.0298	0.0000	0.0000
6	1	0.0	0.273E+01	0.0000000	0.0000	0.0189	0.0000	0.0000
7	1	0.0	0.273E+01	0.0000000	0.0000	0.0124	0.0000	0.0000
8	1	0.0	0.273E+01	0.0000000	0.0000	0.0084	0.0000	0.0000
9	1	0.0	0.273E+01	0.0000000	0.0000	0.0058	0.0000	0.0000
10	1	0.0	0.273E+01	0.0000000	0.0000	0.0040	0.0000	0.0000
11	1	0.0	0.273E+01	0.0000000	0.0000	0.0028	0.0000	0.0000
12	1	0.0	0.273E+01	0.0000000	0.0000	0.0020	0.0000	0.0000
13	1	0.0	0.273E+01	0.0000000	0.0000	0.0014	0.0000	0.0000
14	1	0.0	0.273E+01	0.0000000	0.0000	0.0010	0.0000	0.0000

channel 1

assembly 1

calculated fluid conditions at time = 0.0000 seconds

cobras-efs code results

case 1

fluid shear sample problem no. 1

date 01/05/89 time

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000088	38.03	70.00	62.5000	0.0272569	0.0045000	0.0200000	3.14000
5.0	0.0000083	38.03	70.00	62.5000	0.0302081	0.0049872	0.0221654	3.14000
10.0	0.0000076	38.03	70.00	62.5000	0.0332640	0.0054917	0.0244077	3.14000
15.0	0.0000070	38.03	70.00	62.5000	0.0356876	0.0058919	0.0261861	3.14000
20.0	0.0000065	38.03	70.00	62.5000	0.0375426	0.0061981	0.0275472	3.14000
25.0	0.0000061	38.03	70.00	62.5000	0.0390357	0.0064446	0.0286427	3.14000
30.0	0.0000058	38.03	70.00	62.5000	0.0403107	0.0066551	0.0295783	3.14000
35.0	0.0000055	38.03	70.00	62.5000	0.0414409	0.0068417	0.0304076	3.14000
40.0	0.0000051	38.03	70.00	62.5000	0.0424607	0.0070101	0.0311559	3.14000

45.0	0.0000049	38.03	70.00	62.5000	0.0433877	0.0071631	0.0318361	3.14000
50.0	0.0000046	38.03	70.00	62.5000	0.0442333	0.0073027	0.0324566	3.14000
55.0	0.0000043	38.03	70.00	62.5000	0.0450066	0.0074304	0.0330240	3.14000
60.0	0.0000040	38.03	70.00	62.5000	0.0457149	0.0075473	0.0335437	3.14000
65.0	0.0000038	38.03	70.00	62.5000	0.0463646	0.0076546	0.0340204	3.14000
70.0	0.0000035	38.03	70.00	62.5000	0.0469612	0.0077531	0.0344582	3.14000
75.0	0.0000033	38.03	70.00	62.5000	0.0475097	0.0078436	0.0348606	3.14000
80.0	0.0000031	38.03	70.00	62.5000	0.0480142	0.0079269	0.0352308	3.14000
85.0	0.0000028	38.03	70.00	62.5000	0.0484788	0.0080036	0.0355717	3.14000
90.0	0.0000026	38.03	70.00	62.5000	0.0489068	0.0080743	0.0358857	3.14000
95.0	0.0000024	38.03	70.00	62.5000	0.0493013	0.0081394	0.0361752	3.14000
100.0	0.0000021	38.03	70.00	62.5000	0.0496651	0.0081995	0.0364422	3.14000
105.0	0.0000019	38.03	70.00	62.5000	0.0500008	0.0082549	0.0366885	3.14000
110.0	0.0000017	38.03	70.00	62.5000	0.0503107	0.0083061	0.0369159	3.14000
115.0	0.0000015	38.03	70.00	62.5000	0.0505968	0.0083533	0.0371258	3.14000
120.0	0.0000013	38.03	70.00	62.5000	0.0508612	0.0083970	0.0373198	3.14000
125.0	0.0000010	38.03	70.00	62.5000	0.0511055	0.0084373	0.0374991	3.14000
130.0	0.0000008	38.03	70.00	62.5000	0.0513314	0.0084746	0.0376648	3.14000
135.0	0.0000006	38.03	70.00	62.5000	0.0515403	0.0085091	0.0378181	3.14000
140.0	0.0000004	38.03	70.00	62.5000	0.0517338	0.0085410	0.0379601	3.14000
145.0	0.0000002	38.03	70.00	62.5000	0.0519136	0.0085707	0.0380921	3.14000
150.0	0.0000000	38.03	70.00	62.5000	0.0520784	0.0085979	0.0382129	3.14000

calculated fluid conditions at time = 0.0000 seconds
channel 2
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000089	38.03	70.00	62.5000	0.0817708	0.0045000	0.0200000	9.42000
5.0	0.0000083	38.03	70.00	62.5000	0.0907857	0.0049961	0.0222049	9.42000
10.0	0.0000076	38.03	70.00	62.5000	0.1000016	0.0055033	0.0244590	9.42000
15.0	0.0000070	38.03	70.00	62.5000	0.1072392	0.0059016	0.0262292	9.42000
20.0	0.0000065	38.03	70.00	62.5000	0.1127397	0.0062043	0.0275745	9.42000
25.0	0.0000061	38.03	70.00	62.5000	0.1171394	0.0064464	0.0286507	9.42000
30.0	0.0000058	38.03	70.00	62.5000	0.1208701	0.0066517	0.0295631	9.42000
35.0	0.0000055	38.03	70.00	62.5000	0.1241522	0.0068323	0.0303659	9.42000
40.0	0.0000051	38.03	70.00	62.5000	0.1270910	0.0069941	0.0310847	9.42000
45.0	0.0000049	38.03	70.00	62.5000	0.1297430	0.0071400	0.0317333	9.42000
50.0	0.0000046	38.03	70.00	62.5000	0.1321459	0.0072722	0.0323210	9.42000
55.0	0.0000043	38.03	70.00	62.5000	0.1343291	0.0073924	0.0328550	9.42000
60.0	0.0000040	38.03	70.00	62.5000	0.1363171	0.0075018	0.0333413	9.42000
65.0	0.0000038	38.03	70.00	62.5000	0.1381307	0.0076016	0.0337848	9.42000
70.0	0.0000035	38.03	70.00	62.5000	0.1397879	0.0076928	0.0341902	9.42000
75.0	0.0000033	38.03	70.00	62.5000	0.1413044	0.0077762	0.0345611	9.42000
80.0	0.0000031	38.03	70.00	62.5000	0.1426937	0.0078527	0.0349009	9.42000
85.0	0.0000028	38.03	70.00	62.5000	0.1439679	0.0079228	0.0352125	9.42000
90.0	0.0000026	38.03	70.00	62.5000	0.1451378	0.0079872	0.0354987	9.42000
95.0	0.0000024	38.03	70.00	62.5000	0.1462127	0.0080464	0.0357616	9.42000
100.0	0.0000021	38.03	70.00	62.5000	0.1472013	0.0081008	0.0360034	9.42000
105.0	0.0000019	38.03	70.00	62.5000	0.1481112	0.0081508	0.0362259	9.42000
110.0	0.0000017	38.03	70.00	62.5000	0.1489491	0.0081969	0.0364309	9.42000
115.0	0.0000015	38.03	70.00	62.5000	0.1497214	0.0082394	0.0366197	9.42000
120.0	0.0000013	38.03	70.00	62.5000	0.1504334	0.0082786	0.0367939	9.42000
125.0	0.0000010	38.03	70.00	62.5000	0.1510904	0.0083148	0.0369546	9.42000

130.0	0.0000008	38.03	70.00	62.5000	0.1516968	0.0083482	0.0371029	9.42000
135.0	0.0000006	38.03	70.00	62.5000	0.1522569	0.0083790	0.0372399	9.42000
140.0	0.0000004	38.03	70.00	62.5000	0.1527750	0.0084075	0.0373666	9.42000
145.0	0.0000002	38.03	70.00	62.5000	0.1532567	0.0084340	0.0374844	9.42000
150.0	0.0000000	38.03	70.00	62.5000	0.1537008	0.0084584	0.0375931	9.42000

calculated fluid conditions at time = 0.0000 seconds
channel 3
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000089	38.03	70.00	62.5000	0.1363715	0.0045000	0.0200000	15.71000
5.0	0.0000083	38.03	70.00	62.5000	0.1519360	0.0050136	0.0222827	15.71000
10.0	0.0000076	38.03	70.00	62.5000	0.1674110	0.0055242	0.0245522	15.71000
15.0	0.0000070	38.03	70.00	62.5000	0.1793026	0.0059166	0.0262962	15.71000
20.0	0.0000065	38.03	70.00	62.5000	0.1881935	0.0062100	0.0276001	15.71000
25.0	0.0000061	38.03	70.00	62.5000	0.1952001	0.0064412	0.0286277	15.71000
30.0	0.0000058	38.03	70.00	62.5000	0.2010478	0.0066342	0.0294853	15.71000
35.0	0.0000055	38.03	70.00	62.5000	0.2061074	0.0068011	0.0302273	15.71000
40.0	0.0000051	38.03	70.00	62.5000	0.2105642	0.0069482	0.0308810	15.71000
45.0	0.0000049	38.03	70.00	62.5000	0.2145240	0.0070789	0.0314617	15.71000
50.0	0.0000046	38.03	70.00	62.5000	0.2180601	0.0071956	0.0319803	15.71000
55.0	0.0000043	38.03	70.00	62.5000	0.2212299	0.0073002	0.0324452	15.71000
60.0	0.0000040	38.03	70.00	62.5000	0.2240805	0.0073942	0.0328632	15.71000
65.0	0.0000038	38.03	70.00	62.5000	0.2266514	0.0074791	0.0332403	15.71000
70.0	0.0000035	38.03	70.00	62.5000	0.2289761	0.0075558	0.0335812	15.71000
75.0	0.0000033	38.03	70.00	62.5000	0.2310829	0.0076253	0.0338902	15.71000
80.0	0.0000031	38.03	70.00	62.5000	0.2329964	0.0076884	0.0341708	15.71000
85.0	0.0000028	38.03	70.00	62.5000	0.2347374	0.0077459	0.0344262	15.71000
90.0	0.0000026	38.03	70.00	62.5000	0.2363244	0.0077983	0.0346589	15.71000
95.0	0.0000024	38.03	70.00	62.5000	0.2377732	0.0078461	0.0348714	15.71000
100.0	0.0000021	38.03	70.00	62.5000	0.2390978	0.0078898	0.0350657	15.71000
105.0	0.0000019	38.03	70.00	62.5000	0.2403104	0.0079298	0.0352435	15.71000
110.0	0.0000017	38.03	70.00	62.5000	0.2414219	0.0079665	0.0354065	15.71000
115.0	0.0000015	38.03	70.00	62.5000	0.2424418	0.0080001	0.0355561	15.71000
120.0	0.0000013	38.03	70.00	62.5000	0.2433787	0.0080310	0.0356935	15.71000
125.0	0.0000010	38.03	70.00	62.5000	0.2442400	0.0080595	0.0358198	15.71000
130.0	0.0000008	38.03	70.00	62.5000	0.2450326	0.0080856	0.0359360	15.71000
135.0	0.0000006	38.03	70.00	62.5000	0.2457625	0.0081097	0.0360431	15.71000
140.0	0.0000004	38.03	70.00	62.5000	0.2464360	0.0081319	0.0361418	15.71000
145.0	0.0000002	38.03	70.00	62.5000	0.2470622	0.0081526	0.0362337	15.71000
150.0	0.0000000	38.03	70.00	62.5000	0.2476477	0.0081719	0.0363196	15.71000

calculated fluid conditions at time = 0.0000 seconds
channel 4
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000089	38.03	70.00	62.5000	0.1908854	0.0045000	0.0200000	21.99000
5.0	0.0000083	38.03	70.00	62.5000	0.2137364	0.0050387	0.0223942	21.99000
10.0	0.0000076	38.03	70.00	62.5000	0.2353856	0.0055491	0.0246625	21.99000

15.0	0.0000070	38.03	70.00	62.5000	0.2513863	0.0059263	0.0263390	21.99000
20.0	0.0000065	38.03	70.00	62.5000	0.2629802	0.0061996	0.0275537	21.99000
25.0	0.0000061	38.03	70.00	62.5000	0.2718563	0.0064088	0.0284837	21.99000
30.0	0.0000058	38.03	70.00	62.5000	0.2790479	0.0065784	0.0292372	21.99000
35.0	0.0000054	38.03	70.00	62.5000	0.2850874	0.0067207	0.0298700	21.99000
40.0	0.0000051	38.03	70.00	62.5000	0.2902561	0.0068426	0.0304116	21.99000
45.0	0.0000049	38.03	70.00	62.5000	0.2947257	0.0069480	0.0308799	21.99000
50.0	0.0000046	38.03	70.00	62.5000	0.2986178	0.0070397	0.0312876	21.99000
55.0	0.0000043	38.03	70.00	62.5000	0.3020263	0.0071201	0.0316448	21.99000
60.0	0.0000040	38.03	70.00	62.5000	0.3050266	0.0071908	0.0319591	21.99000
65.0	0.0000038	38.03	70.00	62.5000	0.3076799	0.0072534	0.0322371	21.99000
70.0	0.0000035	38.03	70.00	62.5000	0.3100363	0.0073089	0.0324840	21.99000
75.0	0.0000033	38.03	70.00	62.5000	0.3121372	0.0073584	0.0327041	21.99000
80.0	0.0000031	38.03	70.00	62.5000	0.3140172	0.0074028	0.0329011	21.99000
85.0	0.0000028	38.03	70.00	62.5000	0.3157050	0.0074425	0.0330780	21.99000
90.0	0.0000026	38.03	70.00	62.5000	0.3172249	0.0074784	0.0332372	21.99000
95.0	0.0000024	38.03	70.00	62.5000	0.3185973	0.0075107	0.0333810	21.99000
100.0	0.0000021	38.03	70.00	62.5000	0.3198398	0.0075400	0.0335112	21.99000
105.0	0.0000019	38.03	70.00	62.5000	0.3209672	0.0075666	0.0336293	21.99000
110.0	0.0000017	38.03	70.00	62.5000	0.3219923	0.0075908	0.0337367	21.99000
115.0	0.0000015	38.03	70.00	62.5000	0.3229263	0.0076128	0.0338346	21.99000
120.0	0.0000013	38.03	70.00	62.5000	0.3237788	0.0076329	0.0339239	21.99000
125.0	0.0000010	38.03	70.00	62.5000	0.3245580	0.0076512	0.0340055	21.99000
130.0	0.0000008	38.03	70.00	62.5000	0.3252714	0.0076681	0.0340803	21.99000
135.0	0.0000006	38.03	70.00	62.5000	0.3259252	0.0076835	0.0341488	21.99000
140.0	0.0000004	38.03	70.00	62.5000	0.3265258	0.0076976	0.0342117	21.99000
145.0	0.0000002	38.03	70.00	62.5000	0.3270848	0.0077108	0.0342703	21.99000
150.0	0.0000000	38.03	70.00	62.5000	0.3276237	0.0077235	0.0343267	21.99000

calculated fluid conditions at time = 0.0000 seconds

channel 5
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000090	38.03	70.00	62.5000	0.2453993	0.0045000	0.0200000	28.27000
5.0	0.0000083	38.03	70.00	62.5000	0.2763374	0.0050673	0.0225214	28.27000
10.0	0.0000076	38.03	70.00	62.5000	0.3034045	0.0055637	0.0247274	28.27000
15.0	0.0000070	38.03	70.00	62.5000	0.3221096	0.0059067	0.0262519	28.27000
20.0	0.0000065	38.03	70.00	62.5000	0.3348874	0.0061410	0.0272933	28.27000
25.0	0.0000061	38.03	70.00	62.5000	0.3441348	0.0063106	0.0280469	28.27000
30.0	0.0000058	38.03	70.00	62.5000	0.3512169	0.0064404	0.0286241	28.27000
35.0	0.0000054	38.03	70.00	62.5000	0.3568426	0.0065436	0.0290826	28.27000
40.0	0.0000051	38.03	70.00	62.5000	0.3614064	0.0066273	0.0294546	28.27000
45.0	0.0000048	38.03	70.00	62.5000	0.3651582	0.0066961	0.0297603	28.27000
50.0	0.0000046	38.03	70.00	62.5000	0.3682734	0.0067532	0.0300142	28.27000
55.0	0.0000043	38.03	70.00	62.5000	0.3708829	0.0068011	0.0302269	28.27000
60.0	0.0000040	38.03	70.00	62.5000	0.3730868	0.0068415	0.0304065	28.27000
65.0	0.0000038	38.03	70.00	62.5000	0.3749625	0.0068759	0.0305594	28.27000
70.0	0.0000035	38.03	70.00	62.5000	0.3765704	0.0069053	0.0306904	28.27000
75.0	0.0000033	38.03	70.00	62.5000	0.3779582	0.0069308	0.0308035	28.27000
80.0	0.0000030	38.03	70.00	62.5000	0.3791635	0.0069529	0.0309018	28.27000
85.0	0.0000028	38.03	70.00	62.5000	0.3802167	0.0069722	0.0309876	28.27000
90.0	0.0000026	38.03	70.00	62.5000	0.3811418	0.0069892	0.0310630	28.27000
95.0	0.0000024	38.03	70.00	62.5000	0.3819586	0.0070042	0.0311296	28.27000

100.0	0.0000021	38.03	70.00	62.5000	0.3826831	0.0070174	0.0311886	28.27000
105.0	0.0000019	38.03	70.00	62.5000	0.3833285	0.0070293	0.0312412	28.27000
110.0	0.0000017	38.03	70.00	62.5000	0.3839057	0.0070399	0.0312882	28.27000
115.0	0.0000015	38.03	70.00	62.5000	0.3844236	0.0070494	0.0313305	28.27000
120.0	0.0000013	38.03	70.00	62.5000	0.3848900	0.0070579	0.0313685	28.27000
125.0	0.0000010	38.03	70.00	62.5000	0.3853112	0.0070656	0.0314028	28.27000
130.0	0.0000008	38.03	70.00	62.5000	0.3856924	0.0070726	0.0314339	28.27000
135.0	0.0000006	38.03	70.00	62.5000	0.3860383	0.0070790	0.0314621	28.27000
140.0	0.0000004	38.03	70.00	62.5000	0.3863527	0.0070847	0.0314877	28.27000
145.0	0.0000002	38.03	70.00	62.5000	0.3866465	0.0070901	0.0315116	28.27000
150.0	0.0000000	38.03	70.00	62.5000	0.3869598	0.0070959	0.0315372	28.27000

calculated fluid conditions at time = 0.0000 seconds
channel 6
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000091	38.03	70.00	62.5000	0.3002604	0.0045000	0.0200000	34.59000
5.0	0.0000083	38.03	70.00	62.5000	0.3394119	0.0050868	0.0226078	34.59000
10.0	0.0000076	38.03	70.00	62.5000	0.3693614	0.0055356	0.0246027	34.59000
15.0	0.0000070	38.03	70.00	62.5000	0.3876384	0.0058095	0.0258201	34.59000
20.0	0.0000065	38.03	70.00	62.5000	0.3986543	0.0059746	0.0265539	34.59000
25.0	0.0000061	38.03	70.00	62.5000	0.4056380	0.0060793	0.0270191	34.59000
30.0	0.0000058	38.03	70.00	62.5000	0.4102787	0.0061488	0.0273282	34.59000
35.0	0.0000054	38.03	70.00	62.5000	0.4134450	0.0061963	0.0275391	34.59000
40.0	0.0000051	38.03	70.00	62.5000	0.4156266	0.0062290	0.0276844	34.59000
45.0	0.0000048	38.03	70.00	62.5000	0.4171285	0.0062515	0.0277845	34.59000
50.0	0.0000046	38.03	70.00	62.5000	0.4181533	0.0062669	0.0278527	34.59000
55.0	0.0000043	38.03	70.00	62.5000	0.4188404	0.0062772	0.0278985	34.59000
60.0	0.0000040	38.03	70.00	62.5000	0.4192873	0.0062839	0.0279282	34.59000
65.0	0.0000038	38.03	70.00	62.5000	0.4195631	0.0062880	0.0279466	34.59000
70.0	0.0000035	38.03	70.00	62.5000	0.4197170	0.0062903	0.0279569	34.59000
75.0	0.0000033	38.03	70.00	62.5000	0.4197842	0.0062913	0.0279613	34.59000
80.0	0.0000030	38.03	70.00	62.5000	0.4197902	0.0062914	0.0279617	34.59000
85.0	0.0000028	38.03	70.00	62.5000	0.4197534	0.0062908	0.0279593	34.59000
90.0	0.0000026	38.03	70.00	62.5000	0.4196872	0.0062898	0.0279549	34.59000
95.0	0.0000024	38.03	70.00	62.5000	0.4196014	0.0062886	0.0279492	34.59000
100.0	0.0000021	38.03	70.00	62.5000	0.4195031	0.0062871	0.0279426	34.59000
105.0	0.0000019	38.03	70.00	62.5000	0.4193974	0.0062855	0.0279356	34.59000
110.0	0.0000017	38.03	70.00	62.5000	0.4192882	0.0062839	0.0279283	34.59000
115.0	0.0000015	38.03	70.00	62.5000	0.4191782	0.0062822	0.0279210	34.59000
120.0	0.0000013	38.03	70.00	62.5000	0.4190693	0.0062806	0.0279137	34.59000
125.0	0.0000010	38.03	70.00	62.5000	0.4189630	0.0062790	0.0279066	34.59000
130.0	0.0000008	38.03	70.00	62.5000	0.4188600	0.0062775	0.0278998	34.59000
135.0	0.0000006	38.03	70.00	62.5000	0.4187609	0.0062760	0.0278932	34.59000
140.0	0.0000004	38.03	70.00	62.5000	0.4186651	0.0062745	0.0278868	34.59000
145.0	0.0000002	38.03	70.00	62.5000	0.4185778	0.0062732	0.0278810	34.59000
150.0	0.0000000	38.03	70.00	62.5000	0.4185522	0.0062728	0.0278793	34.59000

calculated fluid conditions at time = 0.0000 seconds
channel 7
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000092	38.03	70.00	62.5000	0.3545139	0.0045000	0.0200000	40.84000
5.0	0.0000083	38.03	70.00	62.5000	0.3988231	0.0050624	0.0224997	40.84000
10.0	0.0000075	38.03	70.00	62.5000	0.4249835	0.0053945	0.0239756	40.84000
15.0	0.0000070	38.03	70.00	62.5000	0.4366372	0.0055424	0.0246330	40.84000
20.0	0.0000065	38.03	70.00	62.5000	0.4409178	0.0055968	0.0248745	40.84000
25.0	0.0000061	38.03	70.00	62.5000	0.4417547	0.0056074	0.0249217	40.84000
30.0	0.0000058	38.03	70.00	62.5000	0.4409537	0.0055972	0.0248765	40.84000
35.0	0.0000054	38.03	70.00	62.5000	0.4393668	0.0055771	0.0247870	40.84000
40.0	0.0000051	38.03	70.00	62.5000	0.4374307	0.0055525	0.0246778	40.84000
45.0	0.0000048	38.03	70.00	62.5000	0.4353810	0.0055265	0.0245621	40.84000
50.0	0.0000046	38.03	70.00	62.5000	0.4333456	0.0055006	0.0244473	40.84000
55.0	0.0000043	38.03	70.00	62.5000	0.4313918	0.0054758	0.0243371	40.84000
60.0	0.0000040	38.03	70.00	62.5000	0.4295520	0.0054525	0.0242333	40.84000
65.0	0.0000038	38.03	70.00	62.5000	0.4278393	0.0054308	0.0241367	40.84000
70.0	0.0000035	38.03	70.00	62.5000	0.4262556	0.0054106	0.0240473	40.84000
75.0	0.0000033	38.03	70.00	62.5000	0.4247972	0.0053921	0.0239651	40.84000
80.0	0.0000030	38.03	70.00	62.5000	0.4234572	0.0053751	0.0238895	40.84000
85.0	0.0000028	38.03	70.00	62.5000	0.4222275	0.0053595	0.0238201	40.84000
90.0	0.0000026	38.03	70.00	62.5000	0.4210993	0.0053452	0.0237564	40.84000
95.0	0.0000024	38.03	70.00	62.5000	0.4200644	0.0053321	0.0236981	40.84000
100.0	0.0000021	38.03	70.00	62.5000	0.4191148	0.0053200	0.0236445	40.84000
105.0	0.0000019	38.03	70.00	62.5000	0.4182431	0.0053089	0.0235953	40.84000
110.0	0.0000017	38.03	70.00	62.5000	0.4174423	0.0052988	0.0235501	40.84000
115.0	0.0000015	38.03	70.00	62.5000	0.4167062	0.0052894	0.0235086	40.84000
120.0	0.0000013	38.03	70.00	62.5000	0.4160292	0.0052808	0.0234704	40.84000
125.0	0.0000010	38.03	70.00	62.5000	0.4154061	0.0052729	0.0234353	40.84000
130.0	0.0000008	38.03	70.00	62.5000	0.4148323	0.0052656	0.0234029	40.84000
135.0	0.0000006	38.03	70.00	62.5000	0.4143034	0.0052589	0.0233730	40.84000
140.0	0.0000004	38.03	70.00	62.5000	0.4138139	0.0052527	0.0233454	40.84000
145.0	0.0000002	38.03	70.00	62.5000	0.4133586	0.0052469	0.0233197	40.84000
150.0	0.0000000	38.03	70.00	62.5000	0.4129847	0.0052422	0.0232986	40.84000

calculated fluid conditions at time = 0.0000 seconds

channel 8
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000093	38.03	70.00	62.5000	0.4090278	0.0045000	0.0200000	47.12000
5.0	0.0000083	38.03	70.00	62.5000	0.4459872	0.0049066	0.0218072	47.12000
10.0	0.0000075	38.03	70.00	62.5000	0.4540267	0.0049951	0.0222003	47.12000
15.0	0.0000069	38.03	70.00	62.5000	0.4489695	0.0049394	0.0219530	47.12000
20.0	0.0000065	38.03	70.00	62.5000	0.4401216	0.0048421	0.0215204	47.12000
25.0	0.0000061	38.03	70.00	62.5000	0.4309900	0.0047416	0.0210739	47.12000
30.0	0.0000058	38.03	70.00	62.5000	0.4226323	0.0046497	0.0206652	47.12000
35.0	0.0000054	38.03	70.00	62.5000	0.4152718	0.0045687	0.0203053	47.12000
40.0	0.0000051	38.03	70.00	62.5000	0.4088746	0.0044983	0.0199925	47.12000
45.0	0.0000048	38.03	70.00	62.5000	0.4033328	0.0044373	0.0197215	47.12000
50.0	0.0000046	38.03	70.00	62.5000	0.3985247	0.0043844	0.0194864	47.12000
55.0	0.0000043	38.03	70.00	62.5000	0.3943369	0.0043384	0.0192817	47.12000
60.0	0.0000040	38.03	70.00	62.5000	0.3906714	0.0042980	0.0191024	47.12000
65.0	0.0000038	38.03	70.00	62.5000	0.3874463	0.0042626	0.0189447	47.12000

70.0	0.0000035	38.03	70.00	62.5000	0.3845941	0.0042312	0.0188053	47.12000
75.0	0.0000033	38.03	70.00	62.5000	0.3820597	0.0042033	0.0186814	47.12000
80.0	0.0000030	38.03	70.00	62.5000	0.3797978	0.0041784	0.0185708	47.12000
85.0	0.0000028	38.03	70.00	62.5000	0.3777710	0.0041561	0.0184717	47.12000
90.0	0.0000026	38.03	70.00	62.5000	0.3759484	0.0041361	0.0183825	47.12000
95.0	0.0000024	38.03	70.00	62.5000	0.3743041	0.0041180	0.0183021	47.12000
100.0	0.0000021	38.03	70.00	62.5000	0.3728164	0.0041016	0.0182294	47.12000
105.0	0.0000019	38.03	70.00	62.5000	0.3714669	0.0040868	0.0181634	47.12000
110.0	0.0000017	38.03	70.00	62.5000	0.3702400	0.0040733	0.0181034	47.12000
115.0	0.0000015	38.03	70.00	62.5000	0.3691221	0.0040610	0.0180488	47.12000
120.0	0.0000013	38.03	70.00	62.5000	0.3681017	0.0040497	0.0179989	47.12000
125.0	0.0000010	38.03	70.00	62.5000	0.3671687	0.0040395	0.0179532	47.12000
130.0	0.0000008	38.03	70.00	62.5000	0.3663144	0.0040301	0.0179115	47.12000
135.0	0.0000006	38.03	70.00	62.5000	0.3655312	0.0040215	0.0178732	47.12000
140.0	0.0000004	38.03	70.00	62.5000	0.3648111	0.0040135	0.0178380	47.12000
145.0	0.0000002	38.03	70.00	62.5000	0.3641381	0.0040061	0.0178051	47.12000
150.0	0.0000000	38.03	70.00	62.5000	0.3635177	0.0039993	0.0177747	47.12000

calculated fluid conditions at time = 0.0000 seconds
channel 9
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000094	38.03	70.00	62.5000	0.4636285	0.0045000	0.0200000	53.41000
5.0	0.0000083	38.03	70.00	62.5000	0.4526211	0.0043932	0.0195252	53.41000
10.0	0.0000075	38.03	70.00	62.5000	0.44164070	0.0043017	0.0190630	53.41000
15.0	0.0000069	38.03	70.00	62.5000	0.3835238	0.0037225	0.0165444	53.41000
20.0	0.0000065	38.03	70.00	62.5000	0.3587448	0.0034820	0.0154755	53.41000
25.0	0.0000061	38.03	70.00	62.5000	0.3407536	0.0033074	0.0146994	53.41000
30.0	0.0000058	38.03	70.00	62.5000	0.3274589	0.0031783	0.0141259	53.41000
35.0	0.0000054	38.03	70.00	62.5000	0.3172955	0.0030797	0.0136875	53.41000
40.0	0.0000051	38.03	70.00	62.5000	0.3092706	0.0030018	0.0133413	53.41000
45.0	0.0000048	38.03	70.00	62.5000	0.3027668	0.0029387	0.0130608	53.41000
50.0	0.0000046	38.03	70.00	62.5000	0.2973865	0.0028864	0.0128287	53.41000
55.0	0.0000043	38.03	70.00	62.5000	0.2928613	0.0028425	0.0126334	53.41000
60.0	0.0000040	38.03	70.00	62.5000	0.2890036	0.0028051	0.0124670	53.41000
65.0	0.0000038	38.03	70.00	62.5000	0.2856776	0.0027728	0.0123236	53.41000
70.0	0.0000035	38.03	70.00	62.5000	0.2827828	0.0027447	0.0121987	53.41000
75.0	0.0000033	38.03	70.00	62.5000	0.2802432	0.0027201	0.0120891	53.41000
80.0	0.0000030	38.03	70.00	62.5000	0.2780000	0.0026983	0.0119924	53.41000
85.0	0.0000028	38.03	70.00	62.5000	0.2760070	0.0026789	0.0119064	53.41000
90.0	0.0000026	38.03	70.00	62.5000	0.2742273	0.0026617	0.0118296	53.41000
95.0	0.0000024	38.03	70.00	62.5000	0.2726312	0.0026462	0.0117608	53.41000
100.0	0.0000021	38.03	70.00	62.5000	0.2711942	0.0026322	0.0116988	53.41000
105.0	0.0000019	38.03	70.00	62.5000	0.2698962	0.0026196	0.0116428	53.41000
110.0	0.0000017	38.03	70.00	62.5000	0.2687202	0.0026082	0.0115920	53.41000
115.0	0.0000015	38.03	70.00	62.5000	0.2676520	0.0025978	0.0115460	53.41000
120.0	0.0000013	38.03	70.00	62.5000	0.2666796	0.0025884	0.0115040	53.41000
125.0	0.0000010	38.03	70.00	62.5000	0.2657924	0.0025798	0.0114658	53.41000
130.0	0.0000008	38.03	70.00	62.5000	0.2649817	0.0025719	0.0114308	53.41000
135.0	0.0000006	38.03	70.00	62.5000	0.2642399	0.0025647	0.0113988	53.41000
140.0	0.0000004	38.03	70.00	62.5000	0.2635605	0.0025581	0.0113695	53.41000
145.0	0.0000002	38.03	70.00	62.5000	0.2629261	0.0025520	0.0113421	53.41000
150.0	0.0000000	38.03	70.00	62.5000	0.2622654	0.0025456	0.0113136	53.41000

calculated fluid conditions at time = 0.0000 seconds
channel 10
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000095	38.03	70.00	62.5000	0.5181424	0.0045000	0.0200000	59.69000
5.0	0.0000082	38.03	70.00	62.5000	0.3274091	0.0028435	0.0126378	59.69000
10.0	0.0000075	38.03	70.00	62.5000	0.2230108	0.0019368	0.0086081	59.69000
15.0	0.0000069	38.03	70.00	62.5000	0.1747620	0.0015178	0.0067457	59.69000
20.0	0.0000065	38.03	70.00	62.5000	0.1524747	0.0013242	0.0058854	59.69000
25.0	0.0000061	38.03	70.00	62.5000	0.1407541	0.0012224	0.0054330	59.69000
30.0	0.0000058	38.03	70.00	62.5000	0.1334400	0.0011589	0.0051507	59.69000
35.0	0.0000054	38.03	70.00	62.5000	0.1282474	0.0011138	0.0049503	59.69000
40.0	0.0000051	38.03	70.00	62.5000	0.1242760	0.0010793	0.0047970	59.69000
45.0	0.0000048	38.03	70.00	62.5000	0.1211092	0.0010518	0.0046747	59.69000
50.0	0.0000046	38.03	70.00	62.5000	0.1185163	0.0010293	0.0045747	59.69000
55.0	0.0000043	38.03	70.00	62.5000	0.1163517	0.0010105	0.0044911	59.69000
60.0	0.0000040	38.03	70.00	62.5000	0.1145167	0.0009946	0.0044203	59.69000
65.0	0.0000038	38.03	70.00	62.5000	0.1129416	0.0009809	0.0043595	59.69000
70.0	0.0000035	38.03	70.00	62.5000	0.1115754	0.0009690	0.0043067	59.69000
75.0	0.0000033	38.03	70.00	62.5000	0.1103801	0.0009586	0.0042606	59.69000
80.0	0.0000030	38.03	70.00	62.5000	0.1093266	0.0009495	0.0042199	59.69000
85.0	0.0000028	38.03	70.00	62.5000	0.1083922	0.0009414	0.0041839	59.69000
90.0	0.0000026	38.03	70.00	62.5000	0.1075590	0.0009341	0.0041517	59.69000
95.0	0.0000024	38.03	70.00	62.5000	0.1068125	0.0009277	0.0041229	59.69000
100.0	0.0000021	38.03	70.00	62.5000	0.1061412	0.0009218	0.0040970	59.69000
105.0	0.0000019	38.03	70.00	62.5000	0.1055351	0.0009166	0.0040736	59.69000
110.0	0.0000017	38.03	70.00	62.5000	0.1049865	0.0009118	0.0040524	59.69000
115.0	0.0000015	38.03	70.00	62.5000	0.1044883	0.0009075	0.0040332	59.69000
120.0	0.0000013	38.03	70.00	62.5000	0.1040350	0.0009035	0.0040157	59.69000
125.0	0.0000010	38.03	70.00	62.5000	0.1036215	0.0008999	0.0039997	59.69000
130.0	0.0000008	38.03	70.00	62.5000	0.1032438	0.0008967	0.0039852	59.69000
135.0	0.0000006	38.03	70.00	62.5000	0.1028983	0.0008937	0.0039718	59.69000
140.0	0.0000004	38.03	70.00	62.5000	0.1025830	0.0008909	0.0039596	59.69000
145.0	0.0000002	38.03	70.00	62.5000	0.1022925	0.0008884	0.0039484	59.69000
150.0	0.0000000	38.03	70.00	62.5000	0.1019264	0.0008852	0.0039343	59.69000

slab temperature summary time = 0.0000 seconds
(assemblies no. - channel no.)

axial zone (inches)	(1)	(
0.0 - 5.0	70.00	
5.0 - 10.0	70.00	
10.0 - 15.0	70.00	
15.0 - 20.0	70.00	
20.0 - 25.0	70.00	
25.0 - 30.0	70.00	

30.0 - 35.0 70.00
 35.0 - 40.0 70.00
 40.0 - 45.0 70.00
 45.0 - 50.0 70.00
 50.0 - 55.0 70.00
 55.0 - 60.0 70.00
 60.0 - 65.0 70.00
 65.0 - 70.0 70.00
 70.0 - 75.0 70.00
 75.0 - 80.0 70.00
 80.0 - 85.0 70.00
 85.0 - 90.0 70.00
 90.0 - 95.0 70.00
 95.0 - 100.0 70.00
 100.0 - 105.0 70.00
 105.0 - 110.0 70.00
 110.0 - 115.0 70.00
 115.0 - 120.0 70.00
 120.0 - 125.0 70.00
 125.0 - 130.0 70.00
 130.0 - 135.0 70.00
 135.0 - 140.0 70.00
 140.0 - 145.0 70.00
 145.0 - 150.0 70.00

B.13

crossflow between adjacent channels at time = 0.0000 seconds

assembly number	1	1	1	1	1	1	1	1	1
axial zone	1 2	2 3	3 4	4 5	5 6	6 7	7 8	8 9	9 10
0.0 - 5.0	-0.00708	-0.02872	-0.06608	-0.12093	-0.19518	-0.28915	-0.39549	-0.48419	-0.45776
5.0 - 10.0	-0.00734	-0.02946	-0.06660	-0.11857	-0.18353	-0.25542	-0.31820	-0.33749	-0.25056
10.0 - 15.0	-0.00582	-0.02319	-0.05174	-0.09014	-0.13504	-0.17891	-0.20688	-0.19474	-0.11580
15.0 - 20.0	-0.00445	-0.01765	-0.03899	-0.06682	-0.09749	-0.12393	-0.13420	-0.11297	-0.05349
20.0 - 25.0	-0.00358	-0.01414	-0.03096	-0.05226	-0.07445	-0.09121	-0.09322	-0.07131	-0.02813
25.0 - 30.0	-0.00306	-0.01201	-0.02604	-0.04330	-0.06030	-0.07144	-0.06951	-0.04946	-0.01755
30.0 - 35.0	-0.00271	-0.01059	-0.02273	-0.03722	-0.05072	-0.05832	-0.05451	-0.03685	-0.01246
35.0 - 40.0	-0.00245	-0.00950	-0.02019	-0.03260	-0.04355	-0.04878	-0.04414	-0.02879	-0.00953
40.0 - 45.0	-0.00222	-0.00859	-0.01809	-0.02881	-0.03782	-0.04142	-0.03650	-0.02320	-0.00760
45.0 - 50.0	-0.00203	-0.00779	-0.01628	-0.02562	-0.03310	-0.03555	-0.03067	-0.01913	-0.00622
50.0 - 55.0	-0.00186	-0.00709	-0.01470	-0.02288	-0.02914	-0.03079	-0.02610	-0.01605	-0.00520
55.0 - 60.0	-0.00170	-0.00647	-0.01331	-0.02051	-0.02580	-0.02687	-0.02246	-0.01366	-0.00440
60.0 - 65.0	-0.00156	-0.00591	-0.01208	-0.01845	-0.02295	-0.02361	-0.01950	-0.01176	-0.00378
65.0 - 70.0	-0.00143	-0.00541	-0.01099	-0.01664	-0.02050	-0.02087	-0.01707	-0.01022	-0.00328
70.0 - 75.0	-0.00132	-0.00495	-0.01001	-0.01505	-0.01838	-0.01854	-0.01504	-0.00896	-0.00287
75.0 - 80.0	-0.00121	-0.00454	-0.00914	-0.01365	-0.01654	-0.01655	-0.01334	-0.00791	-0.00253
80.0 - 85.0	-0.00111	-0.00417	-0.00835	-0.01240	-0.01493	-0.01484	-0.01189	-0.00702	-0.00224
85.0 - 90.0	-0.00103	-0.00383	-0.00764	-0.01129	-0.01351	-0.01335	-0.01064	-0.00627	-0.00200
90.0 - 95.0	-0.00095	-0.00353	-0.00700	-0.01030	-0.01226	-0.01205	-0.00957	-0.00562	-0.00179
95.0 - 100.0	-0.00087	-0.00325	-0.00642	-0.00941	-0.01114	-0.01091	-0.00863	-0.00506	-0.00161
100.0 - 105.0	-0.00081	-0.00299	-0.00590	-0.00860	-0.01015	-0.00990	-0.00781	-0.00457	-0.00145
105.0 - 110.0	-0.00074	-0.00275	-0.00542	-0.00788	-0.00927	-0.00900	-0.00708	-0.00414	-0.00132
110.0 - 115.0	-0.00069	-0.00254	-0.00499	-0.00723	-0.00847	-0.00821	-0.00644	-0.00376	-0.00120
115.0 - 120.0	-0.00063	-0.00234	-0.00459	-0.00664	-0.00776	-0.00749	-0.00587	-0.00342	-0.00109
120.0 - 125.0	-0.00059	-0.00216	-0.00423	-0.00610	-0.00711	-0.00685	-0.00536	-0.00312	-0.00099
125.0 - 130.0	-0.00054	-0.00200	-0.00390	-0.00561	-0.00653	-0.00628	-0.00490	-0.00285	-0.00091

130.0 - 135.0	-0.00050	-0.00185	-0.00360	-0.00517	-0.00600	-0.00576	-0.00449	-0.00261	-0.00083
135.0 - 140.0	-0.00046	-0.00171	-0.00332	-0.00477	-0.00552	-0.00529	-0.00411	-0.00239	-0.00076
140.0 - 145.0	-0.00043	-0.00159	-0.00309	-0.00443	-0.00514	-0.00493	-0.00384	-0.00222	-0.00070
145.0 - 150.0	-0.00040	-0.00146	-0.00287	-0.00416	-0.00491	-0.00485	-0.00395	-0.00246	-0.00088

iterations = 14

input transient time completed

common dumped to tape 8

1***** computational time summary *****

subroutine energy.....	0.28 sec
subroutine moment.....	0.41 sec
subroutine reheat.....	0.00 sec
subroutine recirc (pressure loop)....	0.28 sec
subroutine result.....	0.17 sec
subroutine setup.....	0.06 sec
other subroutines.....	0.31 sec
total cpu time.....	1.52 sec

APPENDIX C

DEVELOPING FLOW IN A SQUARE DUCT OUTPUT

APPENDIX C

DEVELOPING FLOW IN A SQUARE DUCT OUTPUT

cobra dimension parameters:

id= 6	ie= 40	lif= 15
ih= 9	lip= 8	iq= 7
ir= 9	lit= 3	iu= 6
liw= 6	ix= 8	liz= 15
la= 15	lb= 1	llc= 1
ld= 1	le= 1	lf= 1
ma= 20	mc= 40	me= 31
mg= 50	mh= 6	mi= 12
mj= 1	mk= 3	ml= 9
lmn= 20	mn= 6	mp= 20
mq= 1	mr= 20	ms= 30
mt= 1	mw= 40	mx= 31
my= 4	nd= 9	no= 2
nv= 2	inz= 10	

1***** the following is an image listing of the cobra-sfs input cards *****

```

radx generated input is not included
0      0      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890

2      1      fluid shear sample problem no. 3
3      prop 2      1
4          0.0      50.      18.07      0.332      1.000      0.016      37.52
5          0.0      100.      67.97      0.364      0.998      0.016      37.52
6      1 none      1.0      1.0      1.0
7      chan 1      30      0      1
8          150.      90.
9          1      1      25      0      1
10         1      0      0      0      0
11         1      1.0      1.0      0.0      2      1.0      1.0      6      1.0      1.0
12         2      1.0      1.0      0.0      3      1.0      1.0      7      1.0      1.0
13         3      1.0      1.0      0.0      4      1.0      1.0      8      1.0      1.0
14         4      1.0      1.0      0.0      5      1.0      1.0      9      1.0      1.0
15         5      1.0      1.0      0.0      10     1.0      1.0
16         6      1.0      1.0      0.0      7      1.0      1.0      11     1.0      1.0
17         7      1.0      1.0      0.0      8      1.0      1.0      12     1.0      1.0
18         8      1.0      1.0      0.0      9      1.0      1.0      13     1.0      1.0
19         9      1.0      1.0      0.0      10     1.0      1.0      14     1.0      1.0
20         10     1.0      1.0      0.0      15     1.0      1.0
21         11     1.0      1.0      0.0      12     1.0      1.0      16     1.0      1.0
22         12     1.0      1.0      0.0      13     1.0      1.0      17     1.0      1.0
23         13     1.0      1.0      0.0      14     1.0      1.0      18     1.0      1.0

```

C.2

```

24      14 1.0 1.0 0.0 15 1.0 1.0 19 1.0 1.0
25      15 1.0 1.0 0.0 20 1.0 1.0
26      16 1.0 1.0 0.0 17 1.0 1.0 21 1.0 1.0
27      17 1.0 1.0 0.0 18 1.0 1.0 22 1.0 1.0
28      18 1.0 1.0 0.0 19 1.0 1.0 23 1.0 1.0
29      19 1.0 1.0 0.0 20 1.0 1.0 24 1.0 1.0
30      20 1.0 1.0 0.0 25 1.0 1.0
31      21 1.0 1.0 0.0 22 1.0 1.0
32      22 1.0 1.0 0.0 23 1.0 1.0
33      23 1.0 1.0 0.0 24 1.0 1.0
34      24 1.0 1.0 0.0 25 1.0 1.0
35      25 1.0 1.0 0.0
36      0.0
37      slab      0      1      10
38      1      1 1.0 0.0
39      2      1 1.0 0.0
40      3      1 1.0 0.0
41      4      1 1.0 0.0
42      5      1 1.0 0.0
43      6      1 1.0 0.0
44      7      1 1.0 0.0
45      8      1 1.0 0.0
46      9      1 1.0 0.0
47     10      1 1.0 0.0
48      1      0.0      1.0
49      1      1      1      1
50      2      1      1      2      1
51      3      1      1      3      1
0      0      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890

1
0      0      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890

52      4      1      1      4      1
53      5      1      1      5      1
54      6      1      1      1      1
55      7      1      1      6      1
56      8      1      1      11     1
57      9      1      1      16     1
58     10      1      1      21     1
59
60      oper      1      0
61      0.0      70.      .00900      0.0      50.
62      calc      0
63      .001      .50
64
65      outp      1
66      endd
0      0      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890

linput for case      1      fluid shear sample problem no. 1      date 01/05/89 time

summary of input options
group n1      n2      n3      n4      n5      n6      n7      n8      n9      n10     n11     n12     n13     n14     n15

```


prop	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
chan	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0
slab	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0
oper	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
calc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
outp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
endd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

fluid property table

pliq	temliq	hliq	conliq	cpliq	vliq	visliq
(psia)	(f)	(btu/lbm)	(btu/hr-ft-f)	(btu/lbm-f)	(ft ³ /lbm)	(lbm/hr-ft)
0.0000	50.0000	18.0700	0.3320	1.0000	0.0160	37.5200
0.0000	100.0000	67.9700	0.3640	0.9980	0.0160	37.5200

solid property table

type	material	cpso	rhoso	thermal conductivity
		(btu/hr-ft-f)	(lbm/ft ³)	(btu/hr-ft-f)
1	none	1.0000	1.0000	1.000E+00 + 1.000E+00*t + 0.000E+00*t**2 + 0.000E+00*t**3

assembly number 1 input description

axial heat flux profile number	1	heat transfer correlation number	0
heat flux vs. time profile number	0	inlet flow vs. time profile number	0

subchannel input data for assembly number 1

loc.	glb.	frictn	area	wetted	heated	hydraulic	(adjacent channel no., momentum control volume width and length)
ch.	ch.	factor	(sq-in)	perim.	perim.	diameter	
no.	no.	type		(in)	(in)	(in)	
1	1	0	1.0000	1.0000	0.0000	4.0000	(2, 1.000, 1.000) (6, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
2	2	0	1.0000	1.0000	0.0000	4.0000	(3, 1.000, 1.000) (7, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
3	3	0	1.0000	1.0000	0.0000	4.0000	(4, 1.000, 1.000) (8, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
4	4	0	1.0000	1.0000	0.0000	4.0000	(5, 1.000, 1.000) (9, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
5	5	0	1.0000	1.0000	0.0000	4.0000	(10, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
6	6	0	1.0000	1.0000	0.0000	4.0000	(7, 1.000, 1.000) (11, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
7	7	0	1.0000	1.0000	0.0000	4.0000	(8, 1.000, 1.000) (12, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
8	8	0	1.0000	1.0000	0.0000	4.0000	(9, 1.000, 1.000) (13, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
9	9	0	1.0000	1.0000	0.0000	4.0000	(10, 1.000, 1.000) (14, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
10	10	0	1.0000	1.0000	0.0000	4.0000	(15, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
11	11	0	1.0000	1.0000	0.0000	4.0000	(12, 1.000, 1.000) (16, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
12	12	0	1.0000	1.0000	0.0000	4.0000	(13, 1.000, 1.000) (17, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
13	13	0	1.0000	1.0000	0.0000	4.0000	(14, 1.000, 1.000) (18, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
14	14	0	1.0000	1.0000	0.0000	4.0000	(15, 1.000, 1.000) (19, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
15	15	0	1.0000	1.0000	0.0000	4.0000	(20, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
16	16	0	1.0000	1.0000	0.0000	4.0000	(17, 1.000, 1.000) (21, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
17	17	0	1.0000	1.0000	0.0000	4.0000	(18, 1.000, 1.000) (22, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
18	18	0	1.0000	1.0000	0.0000	4.0000	(19, 1.000, 1.000) (23, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
19	19	0	1.0000	1.0000	0.0000	4.0000	(20, 1.000, 1.000) (24, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
20	20	0	1.0000	1.0000	0.0000	4.0000	(25, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
21	21	0	1.0000	1.0000	0.0000	4.0000	(22, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
22	22	0	1.0000	1.0000	0.0000	4.0000	(23, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
23	23	0	1.0000	1.0000	0.0000	4.0000	(24, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
24	24	0	1.0000	1.0000	0.0000	4.0000	(25, 1.000, 1.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
25	25	0	1.0000	1.0000	0.0000	4.0000	(0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)

solid-to-fluid thermal connection type table

connection type	geometry factor	slab-fluid resistance (ft-f-s/btu)	slab wetted perimeter (in)
1	0.000	0.000	0.083

calculation parameters

lateral resistance factor	0.5000
s/l parameter	0.5000
turbulent momentum factor	0.0000
channel orientation (degrees)	90.0000
channel length (inches)	150.0000
number of axial nodes	30
total transient time (seconds)	0.0000
number of time steps	0
nominal time step (seconds)	*****
roll option (0 - no roll)	0

data for implicit solution

external iteration limit	20
convergence factors	
internal (dp/p)	0.00100
energy (dh/h)	0.00100
acceleration factors	
crossflow solution	1.60000
lateral delta-p	0.80000
flow	0.50000
density	1.00000
slab energy	1.20000

axial nodding

node no.	integral height (in.)	nodal length (in.)	node no.	integral height (in.)	nodal length (in.)	node no.	integral height (in.)	nodal length (in.)
1	0.0- 5.0	5.000	2	5.0- 10.0	5.000	3	10.0- 15.0	5.000
4	15.0- 20.0	5.000	5	20.0- 25.0	5.000	6	25.0- 30.0	5.000
7	30.0- 35.0	5.000	8	35.0- 40.0	5.000	9	40.0- 45.0	5.000
10	45.0- 50.0	5.000	11	50.0- 55.0	5.000	12	55.0- 60.0	5.000
13	60.0- 65.0	5.000	14	65.0- 70.0	5.000	15	70.0- 75.0	5.000
16	75.0- 80.0	5.000	17	80.0- 85.0	5.000	18	85.0- 90.0	5.000
19	90.0- 95.0	5.000	20	95.0- 100.0	5.000	21	100.0- 105.0	5.000
22	105.0- 110.0	5.000	23	110.0- 115.0	5.000	24	115.0- 120.0	5.000
25	120.0- 125.0	5.000	26	125.0- 130.0	5.000	27	130.0- 135.0	5.000
28	135.0- 140.0	5.000	29	140.0- 145.0	5.000	30	145.0- 150.0	5.000

operating conditions

system pressure	=	0.0 psia
inlet enthalpy	=	38.0 btu/lbm
inlet temperature	=	70.000 degrees f
nominal mass flux	=	0.009 million lbm/ft2-hr
nominal power density	=	0.0000 million btu/hr-ft3
exit enthalpy	=	50.0 btu/lbm

uniform inlet temperature

0 uniform inlet mass velocity

1

parameter summary

parameter	description	dimensioned for	amount used
id	max. no. of solid material property types	6	1
if	max. no. of boundary thermal connection types	15	0
lip	max. no. of radial boundary regions	8	1
iq	max. no. of circumferential boundary nodes	7	0
lit	max. no. of assembly types	3	1
iu	max. no. of assemblies	6	1
iw	max. no. of loss coeff. profiles, friction factor or heat transfer corr.	6	0
iz	max. no. of slab-slab and slab-fluid connection types	15	1
ma	max. no. of channels with area variations	20	0
mc	max. no. of channels	40	25
me	mx if not using roll option; 3 if roll is used	31	31
mg	max. no. of channel gap connections	50	40
mh	max. no. of slab-slab solid connections	6	0
mj	max. no. of assembly groupings in network model	1	0
mk	max. no. of loss coefficients	3	0
ml	max. no. of axial locations for gap and area variations	9	0
lmm	max. no. of points in selected profile tables	20	0
mn	max. no. of fuel nodes in a rod	6	1
mp	max. no. of entries in property, axial heat flux or transient tables	20	2
mq	max. no. of channel groups that have local axial losses	1	0
mr	max. no. of fuel rods	20	0
ms	max. no. of gaps that can have gap spacing variations	30	0
mt	max. no. of fuel types	1	0
mv	max. no. of axial heat flux profiles	1	1
mw	max. no. of slab nodes	40	10
mx	max. no. of axial nodes plus one	31	31
my	max. no. of axial fuel type divisions	4	0
nd	max. no. of fluid channels connected to a wall node	9	1
no	max. no. of boundary temperature types	2	0
nv	max. no. of user-defined radiation groups	2	0
lnz	max. no. of surfaces in a user-defined radiation group	10	0
la	no. of radiation surfaces in enclosure type 1	15	0
lb	no. of radiation surfaces in enclosure type 2	1	0
llc	no. of radiation surfaces in enclosure type 3	1	0
ld	no. of radiation surfaces in enclosure type 4	1	0
le	no. of radiation surfaces in enclosure type 5	1	0
lf	no. of radiation surfaces in enclosure type 6	1	0

total heat generation in the problem is 0.00000 btu/sec or 0.00000 kw

data from iterative solution using the recirculation module

time = 0.0000 dt = ***** implicit dt = 0.0000 explicit dt = 7.8950 mode = 0

iteration no.	sweep no.	peak clad -----	total flow (lbm/s)	pressure drop(psi)	error -----
------------------	--------------	--------------------	-----------------------	-----------------------	----------------

		temp(f)	level	rod	ass.			total energy	flow	fluid energy	rod energy
1	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.4952	0.0000	0.0000
2	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.2666	0.0000	0.0000
3	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.1346	0.0000	0.0000
4	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.0676	0.0000	0.0000
5	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.0333	0.0000	0.0000
6	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.0163	0.0000	0.0000
7	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.0080	0.0000	0.0000
8	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.0039	0.0000	0.0000
9	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.0019	0.0000	0.0000
10	1	0.0	0	0	0	0.434E+00	0.0000000	0.0000	0.0010	0.0000	0.0000

cobra-sfs code results

case 1 fluid shear sample problem no. 1

date 01/05/89 time

calculated fluid conditions at time = 0.0000 seconds

channel 1
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000599	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000543	38.03	70.00	62.5000	0.0073186	0.0037940	0.0168621	1.00000
10.0	0.0000506	38.03	70.00	62.5000	0.0037433	0.0019405	0.0086245	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0028313	0.0014677	0.0065232	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0024726	0.0012818	0.0056968	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0022479	0.0011653	0.0051792	1.00000
30.0	0.0000399	38.03	70.00	62.5000	0.0020898	0.0010834	0.0048150	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0019749	0.0010238	0.0045502	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0018891	0.0009793	0.0043525	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0018232	0.0009452	0.0042007	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0017713	0.0009182	0.0040811	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0017295	0.0008966	0.0039847	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0016951	0.0008787	0.0039055	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0016665	0.0008639	0.0038395	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0016423	0.0008514	0.0037838	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0016216	0.0008407	0.0037363	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0016039	0.0008315	0.0036953	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0015885	0.0008235	0.0036599	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0015751	0.0008165	0.0036290	1.00000

95.0	0.0000169	38.03	70.00	62.5000	0.0015634	0.0008105	0.0036020	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0015531	0.0008051	0.0035783	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0015440	0.0008004	0.0035574	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0015360	0.0007962	0.0035389	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0015288	0.0007926	0.0035225	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0015225	0.0007893	0.0035079	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0015169	0.0007864	0.0034949	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0015119	0.0007838	0.0034834	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0015074	0.0007814	0.0034731	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0015034	0.0007794	0.0034639	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0014999	0.0007776	0.0034559	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0014953	0.0007751	0.0034451	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 2

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000597	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000544	38.03	70.00	62.5000	0.0132895	0.0068893	0.0306191	1.00000
10.0	0.0000506	38.03	70.00	62.5000	0.0103714	0.0053765	0.0238957	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0087059	0.0045131	0.0200584	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0077288	0.0040066	0.0178072	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0070988	0.0036800	0.0163557	1.00000
30.0	0.0000399	38.03	70.00	62.5000	0.0066616	0.0034534	0.0153482	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0063434	0.0032884	0.0146151	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0061037	0.0031641	0.0140629	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0059179	0.0030679	0.0136349	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0057705	0.0029914	0.0132952	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0056510	0.0029295	0.0130200	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0055527	0.0028785	0.0127933	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0054705	0.0028359	0.0126040	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0054010	0.0027999	0.0124440	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0053418	0.0027692	0.0123075	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0052908	0.0027428	0.0121901	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0052467	0.0027199	0.0120885	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0052083	0.0027000	0.0120000	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0051748	0.0026826	0.0119226	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0051453	0.0026673	0.0118547	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0051193	0.0026538	0.0117948	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0050963	0.0026419	0.0117419	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0050760	0.0026314	0.0116951	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0050579	0.0026220	0.0116535	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0050419	0.0026137	0.0116165	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0050276	0.0026063	0.0115835	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0050148	0.0025997	0.0115541	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0050034	0.0025938	0.0115279	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0049933	0.0025885	0.0115047	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0049818	0.0025825	0.0114780	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 3

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000595	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0144793	0.0075060	0.0333602	1.00000
10.0	0.0000507	38.03	70.00	62.5000	0.0122103	0.0063298	0.0281325	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0106589	0.0055256	0.0245581	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0096497	0.0050024	0.0222329	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0089791	0.0046548	0.0206879	1.00000
30.0	0.0000399	38.03	70.00	62.5000	0.0085140	0.0044136	0.0196162	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0081773	0.0042391	0.0188405	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0079245	0.0041081	0.0182582	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0077287	0.0040065	0.0178069	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0075727	0.0039257	0.0174476	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0074459	0.0038599	0.0171553	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0073408	0.0038055	0.0169133	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0072526	0.0037598	0.0167101	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0071778	0.0037210	0.0165376	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0071136	0.0036877	0.0163898	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0070583	0.0036590	0.0162623	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0070102	0.0036341	0.0161516	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0069683	0.0036124	0.0160550	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0069315	0.0035933	0.0159703	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0068992	0.0035766	0.0158958	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0068707	0.0035618	0.0158301	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0068455	0.0035487	0.0157719	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0068231	0.0035371	0.0157204	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0068032	0.0035268	0.0156746	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0067855	0.0035176	0.0156338	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0067697	0.0035094	0.0155974	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0067556	0.0035021	0.0155650	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0067430	0.0034956	0.0155360	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0067319	0.0034898	0.0155103	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0067197	0.0034835	0.0154822	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 4
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000593	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0146596	0.0075995	0.0337757	1.00000
10.0	0.0000507	38.03	70.00	62.5000	0.0126703	0.0065683	0.0291925	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0112559	0.0058351	0.0259336	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0103038	0.0053415	0.0237399	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0096687	0.0050122	0.0222766	1.00000
30.0	0.0000399	38.03	70.00	62.5000	0.0092352	0.0047875	0.0212779	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0089284	0.0046285	0.0205710	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0087027	0.0045115	0.0200509	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0085304	0.0044221	0.0196539	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0083945	0.0043517	0.0193410	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0082846	0.0042947	0.0190877	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0081937	0.0042476	0.0188784	1.00000

65.0	0.0000267	38.03	70.00	62.5000	0.0081174	0.0042080	0.0187024	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0080524	0.0041744	0.0185527	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0079966	0.0041454	0.0184241	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0079483	0.0041204	0.0183128	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0079062	0.0040986	0.0182159	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0078694	0.0040795	0.0181310	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0078370	0.0040627	0.0180564	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0078085	0.0040479	0.0179907	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0077832	0.0040348	0.0179326	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0077609	0.0040232	0.0178810	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0077410	0.0040129	0.0178353	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0077233	0.0040038	0.0177946	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0077076	0.0039956	0.0177583	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0076935	0.0039883	0.0177259	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0076810	0.0039818	0.0176970	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0076697	0.0039760	0.0176711	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0076599	0.0039709	0.0176483	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0076489	0.0039652	0.0176231	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 5
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000593	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0146534	0.0075963	0.0337614	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0127544	0.0066119	0.0293861	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0114053	0.0059125	0.0262778	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0104899	0.0054380	0.0241687	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0098811	0.0051224	0.0227661	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0094713	0.0049099	0.0218219	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0091869	0.0047625	0.0211667	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0089819	0.0046562	0.0206942	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0088281	0.0045765	0.0203400	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0087087	0.0045146	0.0200648	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0086130	0.0044650	0.0198442	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0085343	0.0044242	0.0196631	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0084685	0.0043901	0.0195114	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0084126	0.0043611	0.0193826	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0083645	0.0043362	0.0192718	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0083228	0.0043146	0.0191758	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0082865	0.0042957	0.0190921	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0082546	0.0042792	0.0190187	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0082266	0.0042647	0.0189540	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0082018	0.0042518	0.0188969	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0081799	0.0042404	0.0188464	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0081604	0.0042303	0.0188015	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0081431	0.0042214	0.0187616	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0081276	0.0042134	0.0187260	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0081139	0.0042062	0.0186943	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0081016	0.0041999	0.0186660	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0080906	0.0041942	0.0186407	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0080807	0.0041891	0.0186180	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0080722	0.0041846	0.0185982	1.00000

150.0 0.0000000 38.03 70.00 62.5000 0.0080623 0.0041795 0.0185755 1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 6
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000597	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000544	38.03	70.00	62.5000	0.0132895	0.0068893	0.0306191	1.00000
10.0	0.0000506	38.03	70.00	62.5000	0.0103714	0.0053765	0.0238957	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0087059	0.0045131	0.0200584	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0077288	0.0040066	0.0178072	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0070988	0.0036800	0.0163557	1.00000
30.0	0.0000399	38.03	70.00	62.5000	0.0066616	0.0034534	0.0153482	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0063434	0.0032884	0.0146151	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0061037	0.0031641	0.0140629	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0059179	0.0030679	0.0136349	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0057705	0.0029914	0.0132952	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0056510	0.0029295	0.0130200	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0055527	0.0028785	0.0127933	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0054705	0.0028359	0.0126040	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0054010	0.0027999	0.0124440	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0053418	0.0027692	0.0123075	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0052908	0.0027428	0.0121901	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0052467	0.0027199	0.0120885	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0052083	0.0027000	0.0120000	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0051748	0.0026826	0.0119226	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0051453	0.0026673	0.0118547	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0051193	0.0026538	0.0117948	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0050963	0.0026419	0.0117419	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0050760	0.0026314	0.0116951	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0050579	0.0026220	0.0116535	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0050419	0.0026137	0.0116165	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0050276	0.0026063	0.0115835	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0050148	0.0025997	0.0115541	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0050034	0.0025938	0.0115279	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0049933	0.0025885	0.0115047	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0049818	0.0025825	0.0114780	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 7
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000595	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0178752	0.0092665	0.0411844	1.00000
10.0	0.0000507	38.03	70.00	62.5000	0.0172836	0.0089598	0.0398213	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0165312	0.0085698	0.0380879	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0158083	0.0081950	0.0364222	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0151653	0.0078617	0.0349409	1.00000
30.0	0.0000399	38.03	70.00	62.5000	0.0146191	0.0075786	0.0336825	1.00000

35.0	0.0000378	38.03	70.00	62.5000	0.0141652	0.0073432	0.0326366	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0137898	0.0071486	0.0317718	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0134790	0.0069875	0.0310555	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0132205	0.0068535	0.0304601	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0130045	0.0067415	0.0299624	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0128228	0.0066474	0.0295438	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0126690	0.0065676	0.0291893	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0125377	0.0064996	0.0288869	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0124251	0.0064411	0.0286273	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0123278	0.0063907	0.0284032	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0122433	0.0063469	0.0282086	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0121697	0.0063087	0.0280389	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0121051	0.0062753	0.0278903	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0120484	0.0062459	0.0277596	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0119985	0.0062200	0.0276444	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0119543	0.0061971	0.0275426	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0119151	0.0061768	0.0274524	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0118803	0.0061587	0.0273722	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0118494	0.0061427	0.0273009	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0118218	0.0061284	0.0272374	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0117972	0.0061156	0.0271806	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0117752	0.0061043	0.0271301	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0117554	0.0060940	0.0270845	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0117360	0.0060839	0.0270397	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 8
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft ²)	velocity (ft/sec)	area (sq-in)
0.0	0.0000593	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0188941	0.0097947	0.0435320	1.00000
10.0	0.0000507	38.03	70.00	62.5000	0.0192909	0.0100004	0.0444462	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0192268	0.0099672	0.0442985	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0189848	0.0098417	0.0437409	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0186782	0.0096828	0.0430346	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0183631	0.0095194	0.0423086	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0180662	0.0093655	0.0416245	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0177979	0.0092264	0.0410063	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0175606	0.0091034	0.0404597	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0173533	0.0089960	0.0399821	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0171732	0.0089026	0.0395670	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0170170	0.0088216	0.0392071	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0168814	0.0087513	0.0388949	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0167637	0.0086903	0.0386235	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0166610	0.0086371	0.0383870	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0165713	0.0085906	0.0381803	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0164927	0.0085498	0.0379992	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0164236	0.0085140	0.0378400	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0163627	0.0084824	0.0376997	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0163089	0.0084545	0.0375757	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0162612	0.0084298	0.0374659	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0162190	0.0084079	0.0373685	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0161814	0.0083884	0.0372819	1.00000

120.0	0.0000091	38.03	70.00	62.5000	0.0161479	0.0083711	0.0372047	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0161180	0.0083556	0.0371359	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0160914	0.0083418	0.0370745	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0160675	0.0083294	0.0370196	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0160462	0.0083184	0.0369705	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0160268	0.0083083	0.0369259	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0160095	0.0082993	0.0368858	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 9
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000591	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0190362	0.0098684	0.0438594	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0197503	0.0102385	0.0455046	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0199821	0.0103587	0.0460389	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0200075	0.0103719	0.0460973	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0199391	0.0103364	0.0459396	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0198282	0.0102789	0.0456841	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0197018	0.0102134	0.0453929	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0195744	0.0101474	0.0450994	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0194533	0.0100846	0.0448204	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0193417	0.0100267	0.0445633	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0192406	0.0099743	0.0443304	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0191500	0.0099273	0.0441215	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0190691	0.0098854	0.0439352	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0189972	0.0098481	0.0437695	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0189333	0.0098150	0.0436224	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0188766	0.0097856	0.0434916	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0188261	0.0097595	0.0433754	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0187813	0.0097362	0.0432721	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0187414	0.0097155	0.0431801	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0187058	0.0096971	0.0430981	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0186740	0.0096806	0.0430250	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0186457	0.0096659	0.0429597	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0186204	0.0096528	0.0429013	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0185977	0.0096410	0.0428491	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0185774	0.0096305	0.0428023	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0185592	0.0096211	0.0427604	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0185429	0.0096127	0.0427229	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0185283	0.0096051	0.0426892	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0185149	0.0095981	0.0426584	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0185037	0.0095923	0.0426326	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 10
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000590	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000

5.0	0.0000547	38.03	70.00	62.5000	0.0190149	0.0098573	0.0438103	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0198074	0.0102681	0.0456362	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0201363	0.0104387	0.0463940	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0202644	0.0105051	0.0466892	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0202996	0.0105233	0.0467704	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0202874	0.0105170	0.0467421	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0202509	0.0104981	0.0466581	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0202038	0.0104736	0.0465495	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0201534	0.0104475	0.0464334	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0201035	0.0104216	0.0463184	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0200559	0.0103970	0.0462087	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0200114	0.0103739	0.0461062	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0199703	0.0103526	0.0460116	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0199327	0.0103331	0.0459249	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0198984	0.0103153	0.0458459	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0198672	0.0102992	0.0457741	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0198390	0.0102846	0.0457091	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0198135	0.0102713	0.0456503	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0197905	0.0102594	0.0455972	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0197697	0.0102486	0.0455493	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0197509	0.0102389	0.0455062	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0197341	0.0102301	0.0454673	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0197189	0.0102223	0.0454323	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0197052	0.0102152	0.0454007	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0196929	0.0102088	0.0453724	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0196818	0.0102030	0.0453468	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0196718	0.0101979	0.0453239	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0196629	0.0101932	0.0453032	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0196546	0.0101889	0.0452841	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0196481	0.0101856	0.0452692	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 11

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000595	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0144793	0.0075060	0.0333602	1.00000
10.0	0.0000507	38.03	70.00	62.5000	0.0122103	0.0063298	0.0281325	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0106589	0.0055256	0.0245581	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0096497	0.0050024	0.0222329	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0089791	0.0046548	0.0206879	1.00000
30.0	0.0000399	38.03	70.00	62.5000	0.0085140	0.0044136	0.0196162	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0081773	0.0042391	0.0188405	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0079245	0.0041081	0.0182582	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0077287	0.0040065	0.0178069	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0075727	0.0039257	0.0174476	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0074459	0.0038599	0.0171553	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0073408	0.0038055	0.0169133	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0072526	0.0037598	0.0167101	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0071778	0.0037210	0.0165376	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0071136	0.0036877	0.0163898	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0070583	0.0036590	0.0162623	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0070102	0.0036341	0.0161516	1.00000

90.0	0.0000185	38.03	70.00	62.5000	0.0069683	0.0036124	0.0160550	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0069315	0.0035933	0.0159703	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0068992	0.0035766	0.0158958	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0068707	0.0035618	0.0158301	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0068455	0.0035487	0.0157719	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0068231	0.0035371	0.0157204	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0068032	0.0035268	0.0156746	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0067855	0.0035176	0.0156338	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0067697	0.0035094	0.0155974	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0067556	0.0035021	0.0155650	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0067430	0.0034956	0.0155360	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0067319	0.0034898	0.0155103	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0067197	0.0034835	0.0154822	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 12
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000593	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0188941	0.0097947	0.0435320	1.00000
10.0	0.0000507	38.03	70.00	62.5000	0.0192909	0.0100004	0.0444462	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0192268	0.0099672	0.0442985	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0189848	0.0098417	0.0437409	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0186782	0.0096828	0.0430346	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0183631	0.0095194	0.0423086	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0180662	0.0093655	0.0416245	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0177979	0.0092264	0.0410063	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0175606	0.0091034	0.0404597	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0173533	0.0089960	0.0399821	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0171732	0.0089026	0.0395670	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0170170	0.0088216	0.0392071	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0168814	0.0087513	0.0388949	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0167637	0.0086903	0.0386235	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0166610	0.0086371	0.0383870	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0165713	0.0085906	0.0381803	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0164927	0.0085498	0.0379992	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0164236	0.0085140	0.0378400	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0163627	0.0084824	0.0376997	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0163089	0.0084545	0.0375757	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0162612	0.0084298	0.0374659	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0162190	0.0084079	0.0373685	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0161814	0.0083884	0.0372819	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0161479	0.0083711	0.0372047	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0161180	0.0083556	0.0371359	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0160914	0.0083418	0.0370745	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0160675	0.0083294	0.0370196	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0160462	0.0083184	0.0369705	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0160268	0.0083083	0.0369259	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0160095	0.0082993	0.0368858	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 13
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000590	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0198812	0.0103064	0.0458064	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0213830	0.0110850	0.0492665	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0222045	0.0115108	0.0511592	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0226461	0.0117397	0.0521765	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0228656	0.0118535	0.0526823	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0229544	0.0118996	0.0528869	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0229674	0.0119063	0.0529170	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0229377	0.0118909	0.0528485	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0228852	0.0118637	0.0527275	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0228220	0.0118309	0.0525819	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0227554	0.0117964	0.0524283	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0226895	0.0117622	0.0522766	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0226267	0.0117297	0.0521319	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0225681	0.0116993	0.0519970	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0225142	0.0116714	0.0518728	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0224651	0.0116459	0.0517596	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0224206	0.0116228	0.0516570	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0223803	0.0116020	0.0515643	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0223441	0.0115832	0.0514807	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0223114	0.0115663	0.0514056	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0222821	0.0115510	0.0513380	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0222557	0.0115374	0.0512772	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0222320	0.0115251	0.0512226	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0222107	0.0115140	0.0511735	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0221915	0.0115041	0.0511293	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0221743	0.0114952	0.0510896	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0221588	0.0114871	0.0510539	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0221449	0.0114799	0.0510218	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0221321	0.0114733	0.0509923	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0221225	0.0114683	0.0509702	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 14
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000589	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0200330	0.0103851	0.0461561	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0218934	0.0113495	0.0504424	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0230785	0.0119639	0.0531729	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0238604	0.0123692	0.0549744	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0243923	0.0126450	0.0561999	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0247618	0.0128365	0.0570512	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0250229	0.0129719	0.0576527	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0252100	0.0130689	0.0580840	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0253461	0.0131394	0.0583973	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0254461	0.0131913	0.0586278	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0255205	0.0132298	0.0587992	1.00000

60.0	0.0000284	38.03	70.00	62.5000	0.0255764	0.0132588	0.0589281	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0256189	0.0132809	0.0590260	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0256515	0.0132978	0.0591011	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0256768	0.0133108	0.0591593	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0256965	0.0133211	0.0592047	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0257120	0.0133291	0.0592405	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0257244	0.0133355	0.0592690	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0257343	0.0133406	0.0592918	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0257423	0.0133448	0.0593102	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0257487	0.0133481	0.0593251	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0257541	0.0133509	0.0593373	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0257584	0.0133532	0.0593474	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0257621	0.0133550	0.0593558	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0257651	0.0133566	0.0593627	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0257676	0.0133579	0.0593685	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0257697	0.0133590	0.0593734	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0257715	0.0133599	0.0593775	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0257729	0.0133607	0.0593808	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0257767	0.0133626	0.0593894	1.00000

calculated fluid conditions at time = 0.0000 seconds

channel 15

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000588	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0200206	0.0103787	0.0461275	1.00000
10.0	0.0000509	38.03	70.00	62.5000	0.0219705	0.0113895	0.0506201	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0232701	0.0120632	0.0536143	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0241759	0.0125328	0.0557012	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0248357	0.0128748	0.0572214	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0253314	0.0131318	0.0583635	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0257129	0.0133296	0.0592426	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0260126	0.0134849	0.0599330	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0262520	0.0136090	0.0604846	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0264460	0.0137096	0.0609316	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0266051	0.0137921	0.0612981	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0267368	0.0138604	0.0616016	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0268469	0.0139174	0.0618552	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0269395	0.0139654	0.0620686	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0270180	0.0140061	0.0622495	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0270850	0.0140409	0.0624038	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0271424	0.0140706	0.0625362	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0271920	0.0140963	0.0626503	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0272349	0.0141186	0.0627491	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0272722	0.0141379	0.0628351	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0273048	0.0141548	0.0629102	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0273333	0.0141696	0.0629760	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0273585	0.0141826	0.0630339	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0273806	0.0141941	0.0630849	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0274002	0.0142043	0.0631300	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0274175	0.0142133	0.0631700	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0274329	0.0142212	0.0632055	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0274466	0.0142283	0.0632370	1.00000

145.0	0.0000015	38.03	70.00	62.5000	0.0274588	0.0142346	0.0632651	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0274720	0.0142415	0.0632954	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 16
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000593	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0146596	0.0075995	0.0337757	1.00000
10.0	0.0000507	38.03	70.00	62.5000	0.0126703	0.0065683	0.0291925	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0112559	0.0058351	0.0259336	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0103038	0.0053415	0.0237399	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0096687	0.0050122	0.0222766	1.00000
30.0	0.0000399	38.03	70.00	62.5000	0.0092352	0.0047875	0.0212779	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0089284	0.0046285	0.0205710	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0087027	0.0045115	0.0200509	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0085304	0.0044221	0.0196539	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0083945	0.0043517	0.0193410	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0082846	0.0042947	0.0190877	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0081937	0.0042476	0.0188784	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0081174	0.0042080	0.0187024	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0080524	0.0041744	0.0185527	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0079966	0.0041454	0.0184241	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0079483	0.0041204	0.0183128	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0079062	0.0040986	0.0182159	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0078694	0.0040795	0.0181310	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0078370	0.0040627	0.0180564	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0078085	0.0040479	0.0179907	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0077832	0.0040348	0.0179326	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0077609	0.0040232	0.0178810	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0077410	0.0040129	0.0178353	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0077233	0.0040038	0.0177946	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0077076	0.0039956	0.0177583	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0076935	0.0039883	0.0177259	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0076810	0.0039818	0.0176970	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0076697	0.0039760	0.0176711	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0076599	0.0039709	0.0176483	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0076489	0.0039652	0.0176231	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 17
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000591	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0190362	0.0098684	0.0438594	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0197503	0.0102385	0.0455046	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0199821	0.0103587	0.0460389	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0200075	0.0103719	0.0460973	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0199391	0.0103364	0.0459396	1.00000

30.0	0.0000400	38.03	70.00	62.5000	0.0198282	0.0102789	0.0456841	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0197018	0.0102134	0.0453929	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0195744	0.0101474	0.0450994	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0194533	0.0100846	0.0448204	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0193417	0.0100267	0.0445633	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0192406	0.0099743	0.0443304	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0191500	0.0099273	0.0441215	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0190691	0.0098854	0.0439352	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0189972	0.0098481	0.0437695	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0189333	0.0098150	0.0436224	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0188766	0.0097856	0.0434916	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0188261	0.0097595	0.0433754	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0187813	0.0097362	0.0432721	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0187414	0.0097155	0.0431801	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0187058	0.0096971	0.0430981	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0186740	0.0096806	0.0430250	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0186457	0.0096659	0.0429597	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0186204	0.0096528	0.0429013	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0185977	0.0096410	0.0428491	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0185774	0.0096305	0.0428023	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0185592	0.0096211	0.0427604	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0185429	0.0096127	0.0427229	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0185283	0.0096051	0.0426892	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0185149	0.0095981	0.0426584	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0185037	0.0095923	0.0426326	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 18
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000589	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0200330	0.0103851	0.0461561	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0218934	0.0113495	0.0504424	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0230785	0.0119639	0.0531729	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0238604	0.0123692	0.0549744	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0243923	0.0126450	0.0561999	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0247618	0.0128365	0.0570512	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0250229	0.0129719	0.0576527	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0252100	0.0130689	0.0580840	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0253461	0.0131394	0.0583973	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0254461	0.0131913	0.0586278	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0255205	0.0132298	0.0587992	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0255764	0.0132588	0.0589281	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0256189	0.0132809	0.0590260	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0256515	0.0132978	0.0591011	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0256768	0.0133108	0.0591593	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0256965	0.0133211	0.0592047	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0257120	0.0133291	0.0592405	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0257244	0.0133355	0.0592690	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0257343	0.0133406	0.0592918	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0257423	0.0133448	0.0593102	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0257487	0.0133481	0.0593251	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0257541	0.0133509	0.0593373	1.00000

115.0	0.0000106	38.03	70.00	62.5000	0.0257584	0.0133532	0.0593474	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0257621	0.0133550	0.0593558	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0257651	0.0133566	0.0593627	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0257676	0.0133579	0.0593685	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0257697	0.0133590	0.0593734	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0257715	0.0133599	0.0593775	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0257729	0.0133607	0.0593808	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0257767	0.0133626	0.0593894	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 19
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000587	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0202004	0.0104719	0.0465417	1.00000
10.0	0.0000509	38.03	70.00	62.5000	0.0224459	0.0116360	0.0517154	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0240280	0.0124561	0.0553604	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0251801	0.0130533	0.0580149	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0260513	0.0135050	0.0600221	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0267291	0.0138564	0.0615839	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0272687	0.0141361	0.0628270	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0277061	0.0143628	0.0638349	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0280662	0.0145495	0.0646645	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0283662	0.0147051	0.0653558	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0286189	0.0148360	0.0659380	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0288335	0.0149473	0.0664324	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0290171	0.0150425	0.0668554	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0291751	0.0151244	0.0672195	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0293119	0.0151953	0.0675347	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0294309	0.0152570	0.0678088	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0295348	0.0153108	0.0680482	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0296259	0.0153581	0.0682580	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0297060	0.0153996	0.0684425	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0297766	0.0154362	0.0686052	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0298390	0.0154685	0.0687490	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0298943	0.0154972	0.0688764	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0299434	0.0155226	0.0689895	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0299870	0.0155453	0.0690901	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0300259	0.0155654	0.0691796	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0300605	0.0155834	0.0692595	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0300915	0.0155994	0.0693308	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0301191	0.0156137	0.0693944	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0301439	0.0156266	0.0694516	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0301686	0.0156394	0.0695086	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 20
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
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0.0	0.0000586	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0201967	0.0104700	0.0465333	1.00000
10.0	0.0000509	38.03	70.00	62.5000	0.0225426	0.0116861	0.0519382	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0242515	0.0125720	0.0558754	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0255377	0.0132388	0.0588389	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0265453	0.0137611	0.0611603	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0273579	0.0141824	0.0630327	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0280279	0.0145296	0.0645762	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0285894	0.0148208	0.0658701	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0290663	0.0150680	0.0669687	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0294752	0.0152799	0.0679108	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0298285	0.0154631	0.0687248	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0301356	0.0156223	0.0694324	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0304038	0.0157613	0.0700504	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0306390	0.0158833	0.0705923	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0308460	0.0159906	0.0710691	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0310286	0.0160852	0.0714898	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0311900	0.0161689	0.0718619	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0313332	0.0162431	0.0721916	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0314603	0.0163090	0.0724844	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0315733	0.0163676	0.0727449	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0316740	0.0164198	0.0729769	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0317638	0.0164664	0.0731838	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0318440	0.0165079	0.0733686	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0319157	0.0165451	0.0735338	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0319798	0.0165783	0.0736815	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0320373	0.0166081	0.0738139	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0320888	0.0166348	0.0739325	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0321349	0.0166587	0.0740388	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0321765	0.0166803	0.0741347	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0322155	0.0167005	0.0742246	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 21
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft ²)	velocity (ft/sec)	area (sq-in)
0.0	0.0000593	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000546	38.03	70.00	62.5000	0.0146534	0.0075963	0.0337614	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0127544	0.0066119	0.0293861	1.00000
15.0	0.0000475	38.03	70.00	62.5000	0.0114053	0.0059125	0.0262778	1.00000
20.0	0.0000447	38.03	70.00	62.5000	0.0104899	0.0054380	0.0241687	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0098811	0.0051224	0.0227661	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0094713	0.0049099	0.0218219	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0091869	0.0047625	0.0211667	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0089819	0.0046562	0.0206942	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0088281	0.0045765	0.0203400	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0087087	0.0045146	0.0200648	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0086130	0.0044650	0.0198442	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0085343	0.0044242	0.0196631	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0084685	0.0043901	0.0195114	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0084126	0.0043611	0.0193826	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0083645	0.0043362	0.0192718	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0083228	0.0043146	0.0191758	1.00000

85.0	0.0000201	38.03	70.00	62.5000	0.0082865	0.0042957	0.0190921	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0082546	0.0042792	0.0190187	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0082266	0.0042647	0.0189540	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0082018	0.0042518	0.0188969	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0081799	0.0042404	0.0188464	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0081604	0.0042303	0.0188015	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0081431	0.0042214	0.0187616	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0081276	0.0042134	0.0187260	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0081139	0.0042062	0.0186943	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0081016	0.0041999	0.0186660	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0080906	0.0041942	0.0186407	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0080807	0.0041891	0.0186180	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0080722	0.0041846	0.0185982	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0080623	0.0041795	0.0185755	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 22
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000590	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0190149	0.0098573	0.0438103	1.00000
10.0	0.0000508	38.03	70.00	62.5000	0.0198074	0.0102681	0.0456362	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0201363	0.0104387	0.0463940	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0202644	0.0105051	0.0466892	1.00000
25.0	0.0000422	38.03	70.00	62.5000	0.0202996	0.0105233	0.0467704	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0202874	0.0105170	0.0467421	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0202509	0.0104981	0.0466581	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0202038	0.0104736	0.0465495	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0201534	0.0104475	0.0464334	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0201035	0.0104216	0.0463184	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0200559	0.0103970	0.0462087	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0200114	0.0103739	0.0461062	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0199703	0.0103526	0.0460116	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0199327	0.0103331	0.0459249	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0198984	0.0103153	0.0458459	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0198672	0.0102992	0.0457741	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0198390	0.0102846	0.0457091	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0198135	0.0102713	0.0456503	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0197905	0.0102594	0.0455972	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0197697	0.0102486	0.0455493	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0197509	0.0102389	0.0455062	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0197341	0.0102301	0.0454673	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0197189	0.0102223	0.0454323	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0197052	0.0102152	0.0454007	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0196929	0.0102088	0.0453724	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0196818	0.0102030	0.0453468	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0196718	0.0101979	0.0453239	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0196629	0.0101932	0.0453032	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0196546	0.0101889	0.0452841	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0196481	0.0101856	0.0452692	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 23
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000588	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0200206	0.0103787	0.0461275	1.00000
10.0	0.0000509	38.03	70.00	62.5000	0.0219705	0.0113895	0.0506201	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0232701	0.0120632	0.0536143	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0241759	0.0125328	0.0557012	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0248357	0.0128748	0.0572214	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0253314	0.0131318	0.0583635	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0257129	0.0133296	0.0592426	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0260126	0.0134849	0.0599330	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0262520	0.0136090	0.0604846	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0264460	0.0137096	0.0609316	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0266051	0.0137921	0.0612981	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0267368	0.0138604	0.0616016	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0268469	0.0139174	0.0618552	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0269395	0.0139654	0.0620686	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0270180	0.0140061	0.0622495	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0270850	0.0140409	0.0624038	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0271424	0.0140706	0.0625362	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0271920	0.0140963	0.0626503	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0272349	0.0141186	0.0627491	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0272722	0.0141379	0.0628351	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0273048	0.0141548	0.0629102	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0273333	0.0141696	0.0629760	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0273585	0.0141826	0.0630339	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0273806	0.0141941	0.0630849	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0274002	0.0142043	0.0631300	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0274175	0.0142133	0.0631700	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0274329	0.0142212	0.0632055	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0274466	0.0142283	0.0632370	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0274588	0.0142346	0.0632651	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0274720	0.0142415	0.0632954	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 24
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000586	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0201967	0.0104700	0.0465333	1.00000
10.0	0.0000509	38.03	70.00	62.5000	0.0225426	0.0116861	0.0519382	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0242515	0.0125720	0.0558754	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0255377	0.0132388	0.0588389	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0265453	0.0137611	0.0611603	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0273579	0.0141824	0.0630327	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0280279	0.0145296	0.0645762	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0285894	0.0148208	0.0658701	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0290663	0.0150680	0.0669687	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0294752	0.0152799	0.0679108	1.00000

55.0	0.0000302	38.03	70.00	62.5000	0.0298285	0.0154631	0.0687248	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0301356	0.0156223	0.0694324	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0304038	0.0157613	0.0700504	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0306390	0.0158833	0.0705923	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0308460	0.0159906	0.0710691	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0310286	0.0160852	0.0714898	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0311900	0.0161689	0.0718619	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0313332	0.0162431	0.0721916	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0314603	0.0163090	0.0724844	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0315733	0.0163676	0.0727449	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0316740	0.0164198	0.0729769	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0317638	0.0164664	0.0731838	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0318440	0.0165079	0.0733686	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0319157	0.0165451	0.0735338	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0319798	0.0165783	0.0736815	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0320373	0.0166081	0.0738139	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0320888	0.0166348	0.0739325	1.00000
140.0	0.0000030	38.03	70.00	62.5000	0.0321349	0.0166587	0.0740388	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0321765	0.0166803	0.0741347	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0322155	0.0167005	0.0742246	1.00000

calculated fluid conditions at time = 0.0000 seconds
channel 25
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0000585	38.03	70.00	62.5000	0.0173611	0.0090000	0.0400000	1.00000
5.0	0.0000547	38.03	70.00	62.5000	0.0201975	0.0104704	0.0465352	1.00000
10.0	0.0000509	38.03	70.00	62.5000	0.0226489	0.0117412	0.0521831	1.00000
15.0	0.0000476	38.03	70.00	62.5000	0.0244903	0.0126958	0.0564256	1.00000
20.0	0.0000448	38.03	70.00	62.5000	0.0259151	0.0134344	0.0597083	1.00000
25.0	0.0000423	38.03	70.00	62.5000	0.0270619	0.0140289	0.0623506	1.00000
30.0	0.0000400	38.03	70.00	62.5000	0.0280117	0.0145212	0.0645389	1.00000
35.0	0.0000378	38.03	70.00	62.5000	0.0288144	0.0149374	0.0663885	1.00000
40.0	0.0000358	38.03	70.00	62.5000	0.0295032	0.0152945	0.0679755	1.00000
45.0	0.0000339	38.03	70.00	62.5000	0.0301008	0.0156042	0.0693522	1.00000
50.0	0.0000320	38.03	70.00	62.5000	0.0306234	0.0158752	0.0705563	1.00000
55.0	0.0000302	38.03	70.00	62.5000	0.0310832	0.0161135	0.0716156	1.00000
60.0	0.0000284	38.03	70.00	62.5000	0.0314894	0.0163241	0.0725516	1.00000
65.0	0.0000267	38.03	70.00	62.5000	0.0318496	0.0165108	0.0733815	1.00000
70.0	0.0000250	38.03	70.00	62.5000	0.0321698	0.0166768	0.0741191	1.00000
75.0	0.0000233	38.03	70.00	62.5000	0.0324549	0.0168246	0.0747761	1.00000
80.0	0.0000217	38.03	70.00	62.5000	0.0327093	0.0169565	0.0753622	1.00000
85.0	0.0000201	38.03	70.00	62.5000	0.0329365	0.0170743	0.0758857	1.00000
90.0	0.0000185	38.03	70.00	62.5000	0.0331397	0.0171796	0.0763539	1.00000
95.0	0.0000169	38.03	70.00	62.5000	0.0333216	0.0172739	0.0767729	1.00000
100.0	0.0000153	38.03	70.00	62.5000	0.0334845	0.0173584	0.0771484	1.00000
105.0	0.0000137	38.03	70.00	62.5000	0.0336306	0.0174341	0.0774849	1.00000
110.0	0.0000122	38.03	70.00	62.5000	0.0337616	0.0175020	0.0777868	1.00000
115.0	0.0000106	38.03	70.00	62.5000	0.0338792	0.0175630	0.0780578	1.00000
120.0	0.0000091	38.03	70.00	62.5000	0.0339848	0.0176177	0.0783011	1.00000
125.0	0.0000076	38.03	70.00	62.5000	0.0340797	0.0176669	0.0785196	1.00000
130.0	0.0000060	38.03	70.00	62.5000	0.0341649	0.0177111	0.0787160	1.00000
135.0	0.0000045	38.03	70.00	62.5000	0.0342416	0.0177508	0.0788926	1.00000

140.0	0.0000030	38.03	70.00	62.5000	0.0343105	0.0177865	0.0790513	1.00000
145.0	0.0000015	38.03	70.00	62.5000	0.0343728	0.0178188	0.0791949	1.00000
150.0	0.0000000	38.03	70.00	62.5000	0.0344292	0.0178481	0.0793249	1.00000

slab temperature summary time = 0.0000 seconds
(assembly no. - channel no.)

axial zone (inches)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0.0 - 5.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
5.0 - 10.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
10.0 - 15.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
15.0 - 20.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
20.0 - 25.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
25.0 - 30.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
30.0 - 35.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
35.0 - 40.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
40.0 - 45.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
45.0 - 50.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
50.0 - 55.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
55.0 - 60.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
60.0 - 65.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
65.0 - 70.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
70.0 - 75.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
75.0 - 80.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
80.0 - 85.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
85.0 - 90.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
90.0 - 95.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
95.0 - 100.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
100.0 - 105.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
105.0 - 110.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
110.0 - 115.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
115.0 - 120.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
120.0 - 125.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
125.0 - 130.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
130.0 - 135.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
135.0 - 140.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
140.0 - 145.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
145.0 - 150.0	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00

crossflow between adjacent channels at time = 0.0000 seconds

assembly number	1	1	1	1	1	1	1	1	1	1
axial zone	1 2	1 6	2 3	2 7	3 4	3 8	4 5	4 9	5 10	6 7
0.0 - 5.0	0.01205	0.01205	0.01154	0.01028	0.00813	0.01032	0.00411	0.01050	0.01061	0.01028
5.0 - 10.0	0.00429	0.00429	0.00614	0.00516	0.00523	0.00636	0.00289	0.00711	0.00745	0.00516
10.0 - 15.0	0.00109	0.00109	0.00263	0.00246	0.00268	0.00367	0.00159	0.00448	0.00483	0.00246
15.0 - 20.0	0.00043	0.00043	0.00134	0.00144	0.00151	0.00225	0.00093	0.00286	0.00313	0.00144
20.0 - 25.0	0.00027	0.00027	0.00080	0.00099	0.00094	0.00147	0.00058	0.00188	0.00205	0.00099

axial zone	6 11	7 8	7 12	8 9	8 13	9 10	9 14	10 15	11 12	11 16
25.0 - 30.0	0.00019	0.00019	0.00052	0.00072	0.00062	0.00101	0.00039	0.00127	0.00137	0.00072
30.0 - 35.0	0.00014	0.00014	0.00038	0.00053	0.00045	0.00073	0.00029	0.00090	0.00097	0.00053
35.0 - 40.0	0.00010	0.00010	0.00030	0.00038	0.00036	0.00054	0.00023	0.00067	0.00072	0.00038
40.0 - 45.0	0.00008	0.00008	0.00024	0.00028	0.00024	0.00042	0.00019	0.00052	0.00056	0.00028
45.0 - 50.0	0.00006	0.00006	0.00020	0.00022	0.00024	0.00033	0.00016	0.00041	0.00045	0.00022
50.0 - 55.0	0.00005	0.00005	0.00017	0.00017	0.00020	0.00027	0.00013	0.00034	0.00036	0.00017
55.0 - 60.0	0.00004	0.00004	0.00014	0.00014	0.00017	0.00022	0.00011	0.00028	0.00030	0.00014
60.0 - 65.0	0.00003	0.00003	0.00012	0.00011	0.00015	0.00018	0.00010	0.00024	0.00025	0.00011
65.0 - 70.0	0.00003	0.00003	0.00011	0.00009	0.00013	0.00016	0.00008	0.00020	0.00022	0.00009
70.0 - 75.0	0.00002	0.00002	0.00008	0.00007	0.00010	0.00013	0.00006	0.00015	0.00019	0.00006
75.0 - 80.0	0.00002	0.00002	0.00006	0.00006	0.00006	0.00011	0.00006	0.00015	0.00016	0.00006
80.0 - 85.0	0.00002	0.00002	0.00007	0.00005	0.00009	0.00010	0.00006	0.00013	0.00014	0.00005
85.0 - 90.0	0.00002	0.00002	0.00006	0.00005	0.00008	0.00009	0.00005	0.00012	0.00013	0.00005
90.0 - 95.0	0.00001	0.00001	0.00006	0.00004	0.00007	0.00007	0.00005	0.00010	0.00011	0.00004
95.0 - 100.0	0.00001	0.00001	0.00005	0.00003	0.00006	0.00006	0.00004	0.00009	0.00010	0.00003
100.0 - 105.0	0.00001	0.00001	0.00004	0.00003	0.00006	0.00006	0.00003	0.00008	0.00009	0.00003
105.0 - 110.0	0.00001	0.00001	0.00004	0.00002	0.00005	0.00005	0.00003	0.00007	0.00008	0.00002
110.0 - 115.0	0.00001	0.00001	0.00004	0.00002	0.00005	0.00004	0.00003	0.00006	0.00007	0.00002
115.0 - 120.0	0.00001	0.00001	0.00003	0.00002	0.00004	0.00003	0.00002	0.00006	0.00006	0.00002
120.0 - 125.0	0.00001	0.00001	0.00003	0.00002	0.00004	0.00003	0.00002	0.00005	0.00006	0.00002
125.0 - 130.0	0.00001	0.00001	0.00003	0.00001	0.00003	0.00003	0.00002	0.00004	0.00005	0.00001
130.0 - 135.0	0.00001	0.00001	0.00002	0.00001	0.00003	0.00003	0.00002	0.00003	0.00004	0.00001
135.0 - 140.0	0.00000	0.00000	0.00002	0.00001	0.00003	0.00002	0.00002	0.00004	0.00004	0.00001
140.0 - 145.0	0.00000	0.00000	0.00002	0.00001	0.00003	0.00002	0.00002	0.00003	0.00004	0.00001
145.0 - 150.0	0.00001	0.00001	0.00002	0.00001	0.00003	0.00002	0.00002	0.00004	0.00004	0.00001

crossflow between adjacent channels at time = 0.0000 seconds

assembly number	1	1	1	1	1	1	1	1	1	1
axial zone	6 11	7 8	7 12	8 9	8 13	9 10	9 14	10 15	11 12	11 16
0.0 - 5.0	0.01154	0.00967	0.00967	0.00667	0.00964	0.00331	0.00983	0.00996	0.01032	0.00813
5.0 - 10.0	0.00614	0.00587	0.00587	0.00448	0.00679	0.00235	0.00753	0.00789	0.00636	0.00523
10.0 - 15.0	0.00263	0.00337	0.00337	0.00278	0.00442	0.00151	0.00519	0.00555	0.00367	0.00268
15.0 - 20.0	0.00134	0.00230	0.00230	0.00203	0.00311	0.00113	0.00370	0.00395	0.00225	0.00151
20.0 - 25.0	0.00080	0.00176	0.00176	0.00163	0.00233	0.00094	0.00274	0.00290	0.00147	0.00094
25.0 - 30.0	0.00052	0.00138	0.00138	0.00134	0.00180	0.00078	0.00209	0.00219	0.00101	0.00062
30.0 - 35.0	0.00038	0.00107	0.00107	0.00109	0.00142	0.00065	0.00165	0.00171	0.00073	0.00045
35.0 - 40.0	0.00030	0.00083	0.00083	0.00089	0.00113	0.00054	0.00132	0.00137	0.00054	0.00036
40.0 - 45.0	0.00024	0.00066	0.00066	0.00072	0.00092	0.00045	0.00109	0.00113	0.00042	0.00029
45.0 - 50.0	0.00020	0.00053	0.00053	0.00060	0.00076	0.00037	0.00090	0.00094	0.00033	0.00024
50.0 - 55.0	0.00017	0.00043	0.00043	0.00050	0.00063	0.00032	0.00076	0.00079	0.00027	0.00020
55.0 - 60.0	0.00014	0.00035	0.00035	0.00042	0.00053	0.00027	0.00065	0.00068	0.00022	0.00017
60.0 - 65.0	0.00012	0.00029	0.00029	0.00035	0.00045	0.00023	0.00055	0.00058	0.00018	0.00015
65.0 - 70.0	0.00011	0.00025	0.00025	0.00030	0.00039	0.00020	0.00048	0.00050	0.00016	0.00013
70.0 - 75.0	0.00009	0.00021	0.00021	0.00026	0.00033	0.00017	0.00042	0.00044	0.00013	0.00011
75.0 - 80.0	0.00008	0.00018	0.00018	0.00022	0.00029	0.00015	0.00036	0.00039	0.00011	0.00010
80.0 - 85.0	0.00007	0.00015	0.00015	0.00019	0.00025	0.00013	0.00032	0.00034	0.00010	0.00009
85.0 - 90.0	0.00006	0.00013	0.00013	0.00017	0.00022	0.00011	0.00028	0.00030	0.00009	0.00008
90.0 - 95.0	0.00006	0.00012	0.00012	0.00015	0.00019	0.00009	0.00025	0.00027	0.00007	0.00007
95.0 - 100.0	0.00005	0.00010	0.00010	0.00013	0.00017	0.00009	0.00022	0.00024	0.00006	0.00006
100.0 - 105.0	0.00004	0.00009	0.00009	0.00011	0.00015	0.00008	0.00019	0.00021	0.00006	0.00006
105.0 - 110.0	0.00004	0.00008	0.00008	0.00010	0.00013	0.00007	0.00017	0.00019	0.00005	0.00005
110.0 - 115.0	0.00004	0.00007	0.00007	0.00009	0.00011	0.00006	0.00015	0.00017	0.00004	0.00004
115.0 - 120.0	0.00003	0.00006	0.00006	0.00008	0.00010	0.00005	0.00014	0.00015	0.00004	0.00004

120.0 - 125.0	0.00003	0.00005	0.00005	0.00007	0.00009	0.00005	0.00012	0.00013	0.00003	0.00004
125.0 - 130.0	0.00003	0.00005	0.00005	0.00006	0.00008	0.00004	0.00011	0.00012	0.00003	0.00003
130.0 - 135.0	0.00002	0.00004	0.00004	0.00006	0.00007	0.00004	0.00010	0.00011	0.00003	0.00003
135.0 - 140.0	0.00002	0.00004	0.00004	0.00005	0.00006	0.00003	0.00009	0.00010	0.00002	0.00003
140.0 - 145.0	0.00002	0.00003	0.00003	0.00004	0.00006	0.00003	0.00008	0.00009	0.00002	0.00003
145.0 - 150.0	0.00002	0.00003	0.00003	0.00004	0.00006	0.00003	0.00008	0.00009	0.00002	0.00003

crossflow between adjacent channels at time = 0.0000 seconds

assembly number	1	1	1	1	1	1	1	1	1	1
axial zone	12 13	12 17	13 14	13 18	14 15	14 19	15 20	16 17	16 21	17 18
0.0 - 5.0	0.00964	0.00667	0.00662	0.00662	0.00328	0.00676	0.00686	0.01050	0.00411	0.00983
5.0 - 10.0	0.00679	0.00448	0.00499	0.00499	0.00256	0.00550	0.00577	0.00711	0.00289	0.00753
10.0 - 15.0	0.00442	0.00278	0.00343	0.00343	0.00181	0.00397	0.00424	0.00448	0.00159	0.00519
15.0 - 20.0	0.00311	0.00203	0.00258	0.00258	0.00140	0.00299	0.00318	0.00286	0.00093	0.00370
20.0 - 25.0	0.00233	0.00163	0.00207	0.00207	0.00116	0.00236	0.00248	0.00188	0.00058	0.00274
25.0 - 30.0	0.00180	0.00134	0.00170	0.00170	0.00099	0.00192	0.00199	0.00127	0.00039	0.00209
30.0 - 35.0	0.00142	0.00109	0.00141	0.00141	0.00084	0.00159	0.00163	0.00090	0.00029	0.00165
35.0 - 40.0	0.00113	0.00089	0.00117	0.00117	0.00071	0.00133	0.00137	0.00067	0.00023	0.00132
40.0 - 45.0	0.00092	0.00072	0.00098	0.00098	0.00061	0.00113	0.00116	0.00052	0.00019	0.00109
45.0 - 50.0	0.00076	0.00060	0.00083	0.00083	0.00052	0.00097	0.00100	0.00041	0.00016	0.00090
50.0 - 55.0	0.00063	0.00050	0.00071	0.00071	0.00045	0.00084	0.00086	0.00034	0.00013	0.00076
55.0 - 60.0	0.00053	0.00042	0.00061	0.00061	0.00039	0.00073	0.00075	0.00028	0.00011	0.00065
60.0 - 65.0	0.00045	0.00035	0.00053	0.00053	0.00034	0.00064	0.00066	0.00024	0.00010	0.00055
65.0 - 70.0	0.00039	0.00030	0.00046	0.00046	0.00030	0.00056	0.00058	0.00020	0.00008	0.00048
70.0 - 75.0	0.00033	0.00026	0.00040	0.00040	0.00026	0.00049	0.00051	0.00017	0.00007	0.00042
75.0 - 80.0	0.00029	0.00022	0.00035	0.00035	0.00023	0.00043	0.00045	0.00015	0.00006	0.00036
80.0 - 85.0	0.00025	0.00019	0.00030	0.00030	0.00020	0.00038	0.00040	0.00013	0.00006	0.00032
85.0 - 90.0	0.00022	0.00017	0.00027	0.00027	0.00018	0.00034	0.00036	0.00012	0.00005	0.00028
90.0 - 95.0	0.00019	0.00015	0.00023	0.00023	0.00016	0.00030	0.00032	0.00010	0.00005	0.00025
95.0 - 100.0	0.00017	0.00013	0.00021	0.00021	0.00014	0.00027	0.00029	0.00009	0.00004	0.00022
100.0 - 105.0	0.00015	0.00011	0.00018	0.00018	0.00012	0.00024	0.00026	0.00008	0.00004	0.00019
105.0 - 110.0	0.00013	0.00010	0.00016	0.00016	0.00011	0.00021	0.00023	0.00007	0.00003	0.00017
110.0 - 115.0	0.00011	0.00009	0.00014	0.00014	0.00010	0.00019	0.00020	0.00006	0.00003	0.00015
115.0 - 120.0	0.00010	0.00008	0.00013	0.00013	0.00009	0.00017	0.00018	0.00006	0.00003	0.00014
120.0 - 125.0	0.00009	0.00007	0.00011	0.00011	0.00008	0.00015	0.00016	0.00005	0.00002	0.00012
125.0 - 130.0	0.00008	0.00006	0.00010	0.00010	0.00007	0.00013	0.00015	0.00004	0.00002	0.00011
130.0 - 135.0	0.00007	0.00006	0.00009	0.00009	0.00006	0.00012	0.00013	0.00004	0.00002	0.00010
135.0 - 140.0	0.00006	0.00005	0.00008	0.00008	0.00005	0.00011	0.00012	0.00004	0.00002	0.00009
140.0 - 145.0	0.00006	0.00004	0.00007	0.00007	0.00005	0.00010	0.00011	0.00003	0.00002	0.00008
145.0 - 150.0	0.00006	0.00004	0.00007	0.00007	0.00005	0.00009	0.00010	0.00004	0.00002	0.00008

crossflow between adjacent channels at time = 0.0000 seconds

assembly number	1	1	1	1	1	1	1	1	1	1
axial zone	17 22	18 19	18 23	19 20	19 24	20 25	21 22	22 23	23 24	24 25
0.0 - 5.0	0.00331	0.00676	0.00328	0.00335	0.00335	0.00340	0.01061	0.00996	0.00686	0.00340
5.0 - 10.0	0.00235	0.00550	0.00256	0.00280	0.00280	0.00294	0.00745	0.00789	0.00577	0.00294
10.0 - 15.0	0.00151	0.00397	0.00181	0.00207	0.00207	0.00221	0.00483	0.00555	0.00424	0.00221
15.0 - 20.0	0.00113	0.00299	0.00140	0.00161	0.00161	0.00171	0.00313	0.00395	0.00318	0.00171
20.0 - 25.0	0.00094	0.00236	0.00116	0.00132	0.00132	0.00138	0.00205	0.00290	0.00248	0.00138

25.0 - 30.0	0.00078	0.00192	0.00099	0.00110	0.00110	0.00114	0.00137	0.00219	0.00199	0.00114
30.0 - 35.0	0.00065	0.00159	0.00084	0.00094	0.00094	0.00096	0.00097	0.00171	0.00163	0.00096
35.0 - 40.0	0.00054	0.00133	0.00071	0.00081	0.00081	0.00083	0.00072	0.00137	0.00137	0.00083
40.0 - 45.0	0.00045	0.00113	0.00061	0.00070	0.00070	0.00072	0.00056	0.00113	0.00116	0.00072
45.0 - 50.0	0.00037	0.00097	0.00052	0.00061	0.00061	0.00063	0.00045	0.00094	0.00100	0.00063
50.0 - 55.0	0.00032	0.00084	0.00045	0.00054	0.00054	0.00055	0.00036	0.00079	0.00086	0.00055
55.0 - 60.0	0.00027	0.00073	0.00039	0.00047	0.00047	0.00049	0.00030	0.00068	0.00075	0.00049
60.0 - 65.0	0.00023	0.00064	0.00034	0.00042	0.00042	0.00043	0.00025	0.00058	0.00066	0.00043
65.0 - 70.0	0.00020	0.00056	0.00030	0.00037	0.00037	0.00038	0.00022	0.00050	0.00058	0.00038
70.0 - 75.0	0.00017	0.00049	0.00026	0.00033	0.00033	0.00034	0.00019	0.00044	0.00051	0.00034
75.0 - 80.0	0.00015	0.00043	0.00023	0.00029	0.00029	0.00031	0.00016	0.00039	0.00045	0.00031
80.0 - 85.0	0.00013	0.00038	0.00020	0.00026	0.00026	0.00027	0.00014	0.00034	0.00040	0.00027
85.0 - 90.0	0.00011	0.00034	0.00018	0.00023	0.00023	0.00024	0.00013	0.00030	0.00036	0.00024
90.0 - 95.0	0.00010	0.00030	0.00016	0.00020	0.00020	0.00022	0.00011	0.00027	0.00032	0.00022
95.0 - 100.0	0.00009	0.00027	0.00014	0.00018	0.00018	0.00020	0.00010	0.00024	0.00029	0.00020
100.0 - 105.0	0.00008	0.00024	0.00012	0.00016	0.00016	0.00018	0.00009	0.00021	0.00026	0.00018
105.0 - 110.0	0.00007	0.00021	0.00011	0.00014	0.00014	0.00016	0.00008	0.00019	0.00023	0.00016
110.0 - 115.0	0.00006	0.00019	0.00010	0.00013	0.00013	0.00014	0.00007	0.00017	0.00020	0.00014
115.0 - 120.0	0.00005	0.00017	0.00009	0.00012	0.00012	0.00013	0.00006	0.00015	0.00018	0.00013
120.0 - 125.0	0.00005	0.00015	0.00008	0.00010	0.00010	0.00011	0.00006	0.00013	0.00016	0.00011
125.0 - 130.0	0.00004	0.00013	0.00007	0.00009	0.00009	0.00010	0.00005	0.00012	0.00015	0.00010
130.0 - 135.0	0.00004	0.00012	0.00006	0.00008	0.00008	0.00009	0.00005	0.00011	0.00013	0.00009
135.0 - 140.0	0.00003	0.00011	0.00005	0.00007	0.00007	0.00008	0.00004	0.00010	0.00012	0.00008
140.0 - 145.0	0.00003	0.00010	0.00005	0.00007	0.00007	0.00007	0.00004	0.00009	0.00011	0.00007
145.0 - 150.0	0.00003	0.00009	0.00005	0.00006	0.00006	0.00007	0.00004	0.00009	0.00010	0.00007

iterations = 10

input transient time completed

common dumped to tape 8

1***** computational time summary *****

subroutine energy.....	0.68 sec
subroutine moment.....	1.49 sec
subroutine reheat.....	0.00 sec
subroutine recirc (pressure loop)....	1.03 sec
subroutine result.....	0.45 sec
subroutine setup.....	0.10 sec
other subroutines.....	0.49 sec
total cpu time.....	4.25 sec

APPENDIX D

NATURAL CIRCULATION IN A SQUARE CAVITY OUTPUT

APPENDIX D

DEVELOPING FLOW IN A CYLINDRICAL PIPE OUTPUT

cobra dimension parameters:

id= 6	ie= 40	lif= 15
ih= 9	lip= 8	iq= 7
ir= 9	lit= 3	iu= 6
liw= 6	ix= 8	liz= 15
la= 15	lb= 1	llc= 1
ld= 1	le= 1	lf= 1
ma= 20	mc= 40	me= 31
mg= 50	mh= 6	mi= 12
mj= 1	mk= 3	ml= 9
lmm= 20	mn= 6	mp= 20
mq= 1	mr= 20	ms= 30
mc= 1	mw= 40	mx= 31
my= 4	nd= 9	no= 2
nv= 2	inz= 10	

1***** the following is an image listing of the cobra-sfs input cards *****

radx generated input is not included

0 0 1 2 3 4 5 6 7 8
 1234567890123456789012345678901234567890123456789012345678901234567890

2 1 fluid shear sample problem no. 4

3 prop 3 1
 4 0. 32. 117.6 .0140 .240 12.35 .0419
 5 0. 100. 133.9 .0154 .240 14.08 .0463
 6 0. 200. 157.9 .0174 .241 16.67 .0518
 7 1 alum 0. 0. 119.

8 chan 1 28 1
 9 14.0 0.
 10 1 1 10 0 1
 11 1 0 0 0 0
 12 1 0.14 1.0 0.0 2 1.0 0.14
 13 2 0.14 1.0 0.0 3 1.0 0.14
 14 3 0.14 1.0 0.0 4 1.0 0.14
 15 4 0.14 1.0 0.0 5 1.0 0.14
 16 5 0.14 1.0 0.0 6 1.0 0.14
 17 6 0.14 1.0 0.0 7 1.0 0.14
 18 7 0.14 1.0 0.0 8 1.0 0.14
 19 8 0.14 1.0 0.0 9 1.0 0.14
 20 9 0.14 1.0 0.0 10 1.0 0.14
 21 10 0.14 1.0 0.0
 22

23 slab 0 1 2


```

24      1      1      1.0      0.0      1      0
25      2      1      1.0      0.0      1      0
26      1      1.e-6      1.0
27      1      1      1      1
28      2      1      1      10      1
29
30      heat      1      1
31      1.0      1.0      1.0
32
33      bdry      1      2      2      0
34      1      1.e+3      1.0      1.0
35      1      2      0.0      155.      1.0      155.
36      2      2      0.0      70.      1.0      70.
37      1      1      1.0      1
38      1      1.0      1      1.0      1
39      2      1      1.0      2
40      1      1.0      1      1.0      1
41      oper      1      0      4
42      0.0      100.      0.0      0.0      120.      0.0
43      calc      0
44      0.4      0.8
45      50
46      outp      1
47      endd
0      0      1      2      3      4      5      6      7      8
123456789012345678901234567890123456789012345678901234567890

```

input for case 1 fluid shear sample problem no. 1 date 01/05/89 time

```

summary of input options
group n1 n2 n3 n4 n5 n6 n7 n8 n9 n10 n11 n12 n13 n14 n15
prop 3 1 0 0 0 0 0 0 0 0 0 0 0 0 0
chan 1 28 0 1 0 0 0 0 0 0 0 0 0 0 0
slab 0 1 2 0 0 0 0 0 0 0 0 0 0 0 0
heat 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0
bdry 1 2 2 0 0 0 0 0 0 0 0 0 0 0 0
oper 1 0 4 0 0 0 0 0 0 0 0 0 0 0 0
calc 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
outp 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
endd 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

```

fluid property table

pliq (psia)	temliq (f)	hliq (btu/lbm)	conliq (btu/hr-ft-f)	cp liq (btu/lbm-f)	vliq (ft ³ /lbm)	visliq (lbm/hr-ft)
0.0000	32.0000	117.6000	0.0140	0.2400	12.3500	0.0419
0.0000	100.0000	133.9000	0.0154	0.2400	14.0800	0.0463
0.0000	200.0000	157.9000	0.0174	0.2410	16.6700	0.0518

solid property table

type	material	cp sol (btu/hr-ft-f)	rho sol (lbm/ft ³)	thermal conductivity (btu/hr-ft-f)
1	alum	0.0000	0.0000	1.190E+02 + 0.000E+00*t + 0.000E+00*t**2 + 0.000E+00*t**3

assembly number 1 input description

axial heat flux profile number 1 heat transfer correlation number 0
 heat flux vs. time profile number 0 inlet flow vs. time profile number 0

subchannel input data for assembly number 1
 loc. glb. frictn area wetted heated hydraulic (adjacent channel no., momentum control volume width and length)
 ch. ch. factor (sq-in) perim. perim. diameter
 no. no. type (in) (in) (in)
 1 1 0 0.1400 1.0000 0.0000 0.5600 (2, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 2 2 0 0.1400 1.0000 0.0000 0.5600 (3, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 3 3 0 0.1400 1.0000 0.0000 0.5600 (4, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 4 4 0 0.1400 1.0000 0.0000 0.5600 (5, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 5 5 0 0.1400 1.0000 0.0000 0.5600 (6, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 6 6 0 0.1400 1.0000 0.0000 0.5600 (7, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 7 7 0 0.1400 1.0000 0.0000 0.5600 (8, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 8 8 0 0.1400 1.0000 0.0000 0.5600 (9, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 9 9 0 0.1400 1.0000 0.0000 0.5600 (10, 1.000, 0.140) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)
 10 10 0 0.1400 1.0000 0.0000 0.5600 (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000) (0, 0.000, 0.000)

solid-to-fluid thermal connection type table

connection type	geometry factor	slab-fluid resistance (ft-f-s/btu)	slab wetted perimeter (in)
1	0.000	0.000	0.083

calculation parameters

lateral resistance factor	0.5000
s/l parameter	0.5000
turbulent momentum factor	0.0000
channel orientation (degrees)	0.0000
channel length (inches)	14.0000
number of axial nodes	28
total transient time (seconds)	0.0000
number of time steps	0
nominal time step (seconds)	*****
roll option (0 - no roll)	0

data for implicit solution

external iteration limit	50
convergence factors	
internal (dp/p)	0.00100
energy (dh/h)	0.00100
acceleration factors	
crossflow solution	1.60000
lateral delta-p	0.80000
flow	0.40000
density	1.00000
slab energy	0.80000

axial noding

node no.	integral height (in.)	nodal length (in.)	node no.	integral height (in.)	nodal length (in.)	node no.	integral height (in.)	nodal length (in.)
1	0.0- 0.5	0.500	2	0.5- 1.0	0.500	3	1.0- 1.5	0.500
4	1.5- 2.0	0.500	5	2.0- 2.5	0.500	6	2.5- 3.0	0.500

7	3.0-	3.5	0.500	8	3.5-	4.0	0.500	9	4.0-	4.5	0.500
10	4.5-	5.0	0.500	11	5.0-	5.5	0.500	12	5.5-	6.0	0.500
13	6.0-	6.5	0.500	14	6.5-	7.0	0.500	15	7.0-	7.5	0.500
16	7.5-	8.0	0.500	17	8.0-	8.5	0.500	18	8.5-	9.0	0.500
19	9.0-	9.5	0.500	20	9.5-	10.0	0.500	21	10.0-	10.5	0.500
22	10.5-	11.0	0.500	23	11.0-	11.5	0.500	24	11.5-	12.0	0.500
25	12.0-	12.5	0.500	26	12.5-	13.0	0.500	27	13.0-	13.5	0.500
28	13.5-	14.0	0.500								

0mixing parameters

assembly	mixing	mixing coefficients		conduction mixing
type no.	correlation	abeta	bbeta	geometry factor
1	0	0.000	0.000	1.000

operating conditions

system pressure = 0.0 psia
 inlet enthalpy = 133.9 btu/lbm
 inlet temperature = 100.000 degrees f
 nominal mass flux = 0.000 million lbm/ft2-hr
 nominal power density = 0.0000 million btu/hr-ft3
 exit enthalpy = 120.0 btu/lbm

uniform inlet temperature

0 uniform inlet mass velocity

1

parameter summary

parameter	description	dimensioned for	amount used
id	max. no. of solid material property types	6	1
if	max. no. of boundary thermal connection types	15	1
lip	max. no. of radial boundary regions	8	2
iq	max. no. of circumferential boundary nodes	7	2
lit	max. no. of assembly types	3	1
lu	max. no. of assemblies	6	1
iw	max. no. of loss coeff. profiles, friction factor or heat transfer corr.	6	1
iz	max. no. of slab-slab and slab-fluid connection types	15	1
na	max. no. of channels with area variations	20	0
nc	max. no. of channels	40	10
ne	mx if not using roll option; 3 if roll is used	31	29
ng	max. no. of channel gap connections	50	9
nh	max. no. of slab-slab solid connections	6	0
mj	max. no. of assembly groupings in network model	1	0
nk	max. no. of loss coefficients	3	0
ml	max. no. of axial locations for gap and area variations	9	0
lnm	max. no. of points in selected profile tables	20	0
nn	max. no. of fuel nodes in a rod	6	1
mp	max. no. of entries in property, axial heat flux or transient tables	20	3
nq	max. no. of channel groups that have local axial losses	1	0
nr	max. no. of fuel rods	20	0
ns	max. no. of gaps that can have gap spacing variations	30	0
nt	max. no. of fuel types	1	0
nv	max. no. of axial heat flux profiles	1	1
nw	max. no. of slab nodes	40	2
nx	max. no. of axial nodes plus one	31	29
ny	max. no. of axial fuel type divisions	4	0

nd	max. no. of fluid channels connected to a wall node	9	1
no	max. no. of boundary temperature types	2	2
nv	max. no. of user-defined radiation groups	2	0
lnz	max. no. of surfaces in a user-defined radiation group	10	0
la	no. of radiation surfaces in enclosure type 1	15	0
lb	no. of radiation surfaces in enclosure type 2	1	0
llc	no. of radiation surfaces in enclosure type 3	1	0
ld	no. of radiation surfaces in enclosure type 4	1	0
le	no. of radiation surfaces in enclosure type 5	1	0
lf	no. of radiation surfaces in enclosure type 6	1	0

total heat generation in the problem is 0.00000 btu/sec or 0.00000 kw

data from iterative solution using the recirculation module

time = 0.0000 dt = ***** implicit dt = 0.0000 explicit dt = 0.0586 mode = 0

iteration no.	sweep no.	peak clad				total flow (lbm/s)	pressure drop(psi)	error			
		temp(f)	level	rod	ass.			total energy	flow	fluid energy	rod energy
1	1	0.0	0	0	0	0.121E-09	0.0000000	0.0000	1.0000	0.0643	0.0000
	2	0.0	0	0	0			0.0000	1.0000	0.1063	0.0000
2	1	0.0	0	0	0	0.377E-09	0.0000000	0.0000	3.8083	0.0484	0.0000
	2	0.0	0	0	0			0.0000	3.8083	0.0149	0.0000
3	1	0.0	0	0	0	0.435E-09	0.0000000	0.0000	1.4334	0.0110	0.0000
	2	0.0	0	0	0			0.0000	1.4334	0.0048	0.0000
4	1	0.0	0	0	0	0.242E-09	0.0000000	0.0000	0.9217	0.0046	0.0000
	2	0.0	0	0	0			0.0000	0.9217	0.0025	0.0000
5	1	0.0	0	0	0	0.525E-09	0.0000000	0.0000	0.7818	0.0017	0.0000
	2	0.0	0	0	0			0.0000	0.7818	0.0017	0.0000
6	1	0.0	0	0	0	0.505E-09	0.0000000	0.0000	0.5354	0.0010	0.0000
	2	0.0	0	0	0			0.0000	0.5354	0.0011	0.0000
7	1	0.0	0	0	0	0.497E-09	0.0000000	0.0000	0.3841	0.0007	0.0000
	2	0.0	0	0	0			0.0000	0.3841	0.0007	0.0000
8	1	0.0	0	0	0	0.442E-09	0.0000000	0.0000	0.2573	0.0006	0.0000
	2	0.0	0	0	0			0.0000	0.2573	0.0009	0.0000
9	1	0.0	0	0	0	0.228E-09	0.0000000	0.0000	0.2283	0.0007	0.0000
	2	0.0	0	0	0			0.0000	0.2283	0.0005	0.0000
10	1	0.0	0	0	0	0.210E-09	0.0000000	0.0000	0.1868	0.0004	0.0000
	2	0.0	0	0	0			0.0000	0.1868	0.0004	0.0000
11	1	0.0	0	0	0	0.792E-09	0.0000000	0.0000	0.1524	0.0003	0.0000

	2	0.0	0	0	0			0.0000	0.1524	0.0005	0.0000
12	1	0.0	0	0	0	0.581E-09	0.0000000	0.0000	0.1423	0.0004	0.0000
	2	0.0	0	0	0			0.0000	0.1423	0.0006	0.0000
13	1	0.0	0	0	0	-0.227E-09	0.0000000	0.0000	0.1342	0.0004	0.0000
	2	0.0	0	0	0			0.0000	0.1342	0.0004	0.0000
14	1	0.0	0	0	0	-0.387E-09	0.0000000	0.0000	0.1523	0.0003	0.0000
	2	0.0	0	0	0			0.0000	0.1523	0.0003	0.0000
15	1	0.0	0	0	0	-0.105E-09	0.0000000	0.0000	0.1524	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1524	0.0003	0.0000
16	1	0.0	0	0	0	-0.320E-09	0.0000000	0.0000	0.1521	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1521	0.0003	0.0000
17	1	0.0	0	0	0	-0.399E-09	0.0000000	0.0000	0.1507	0.0003	0.0000
	2	0.0	0	0	0			0.0000	0.1507	0.0003	0.0000
18	1	0.0	0	0	0	-0.441E-09	0.0000000	0.0000	0.1569	0.0003	0.0000
	2	0.0	0	0	0			0.0000	0.1569	0.0002	0.0000
19	1	0.0	0	0	0	-0.466E-09	0.0000000	0.0000	0.1677	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1677	0.0002	0.0000
20	1	0.0	0	0	0	-0.616E-09	0.0000000	0.0000	0.1705	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1705	0.0002	0.0000
21	1	0.0	0	0	0	-0.543E-09	0.0000000	0.0000	0.1685	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1685	0.0002	0.0000
22	1	0.0	0	0	0	-0.473E-09	0.0000000	0.0000	0.1631	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1631	0.0002	0.0000
23	1	0.0	0	0	0	-0.405E-09	0.0000000	0.0000	0.1552	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1552	0.0002	0.0000
24	1	0.0	0	0	0	-0.331E-09	0.0000000	0.0000	0.1490	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1490	0.0002	0.0000
25	1	0.0	0	0	0	-0.255E-09	0.0000000	0.0000	0.1174	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1174	0.0002	0.0000
26	1	0.0	0	0	0	-0.177E-09	0.0000000	0.0000	0.1079	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1079	0.0002	0.0000
27	1	0.0	0	0	0	-0.103E-09	0.0000000	0.0000	0.1014	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1014	0.0002	0.0000
28	1	0.0	0	0	0	-0.332E-10	0.0000000	0.0000	0.0985	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.0985	0.0002	0.0000
29	1	0.0	0	0	0	-0.910E-09	0.0000000	0.0000	0.1013	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1013	0.0002	0.0000
30	1	0.0	0	0	0	0.938E-10	0.0000000	0.0000	0.1039	0.0002	0.0000

	2	0.0	0	0	0			0.0000	0.1039	0.0002	0.0000
31	1	0.0	0	0	0	0.138E-09	0.0000000	0.0000	0.1052	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1052	0.0002	0.0000
32	1	0.0	0	0	0	0.181E-09	0.0000000	0.0000	0.1048	0.0002	0.0000
	2	0.0	0	0	0			0.0000	0.1048	0.0001	0.0000
33	1	0.0	0	0	0	0.220E-09	0.0000000	0.0000	0.1020	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.1020	0.0002	0.0000
34	1	0.0	0	0	0	0.249E-09	0.0000000	0.0000	0.0971	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0971	0.0002	0.0000
35	1	0.0	0	0	0	0.269E-09	0.0000000	0.0000	0.0904	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0904	0.0001	0.0000
36	1	0.0	0	0	0	0.280E-09	0.0000000	0.0000	0.0822	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0822	0.0001	0.0000
37	1	0.0	0	0	0	0.285E-09	0.0000000	0.0000	0.0779	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0779	0.0001	0.0000
38	1	0.0	0	0	0	0.285E-09	0.0000000	0.0000	0.0758	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0758	0.0001	0.0000
39	1	0.0	0	0	0	0.282E-09	0.0000000	0.0000	0.0722	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0722	0.0001	0.0000
40	1	0.0	0	0	0	0.280E-09	0.0000000	0.0000	0.0673	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0673	0.0001	0.0000
41	1	0.0	0	0	0	0.277E-09	0.0000000	0.0000	0.0613	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0613	0.0001	0.0000
42	1	0.0	0	0	0	0.889E-09	0.0000000	0.0000	0.0543	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0543	0.0001	0.0000
43	1	0.0	0	0	0	0.129E-08	0.0000000	0.0000	0.0463	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0463	0.0001	0.0000
44	1	0.0	0	0	0	0.140E-08	0.0000000	0.0000	0.0386	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0386	0.0001	0.0000
45	1	0.0	0	0	0	0.148E-08	0.0000000	0.0000	0.0317	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0317	0.0001	0.0000
46	1	0.0	0	0	0	0.161E-08	0.0000000	0.0000	0.0286	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0286	0.0001	0.0000
47	1	0.0	0	0	0	0.176E-08	0.0000000	0.0000	0.0255	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0255	0.0001	0.0000
48	1	0.0	0	0	0	0.188E-08	0.0000000	0.0000	0.0234	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0234	0.0001	0.0000
49	1	0.0	0	0	0	0.195E-08	0.0000000	0.0000	0.0252	0.0001	0.0000

	2	0.0	0	0	0			0.0000	0.0252	0.0001	0.0000
50	1	0.0	0	0	0	0.207E-08	0.0000000	0.0000	0.0257	0.0001	0.0000
	2	0.0	0	0	0			0.0000	0.0257	0.0001	0.0000

cobra-sfs code results

case 1 fluid shear sample problem no. 1

date 01/05/89 time

calculated fluid conditions at time = 0.0000 seconds

channel 1

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0005548	136.79	112.03	0.0708	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005334	136.79	112.03	0.0708	0.0000124	0.0000458	0.1797007	0.14000
1.0	0.0005117	137.64	115.59	0.0703	0.0000214	0.0000793	0.3132384	0.14000
1.5	0.0004899	138.46	118.98	0.0699	0.0000278	0.0001030	0.4096722	0.14000
2.0	0.0004684	139.25	122.29	0.0695	0.0000321	0.0001188	0.4751191	0.14000
2.5	0.0004470	139.99	125.39	0.0691	0.0000348	0.0001288	0.5181412	0.14000
3.0	0.0004258	140.64	128.09	0.0687	0.0000367	0.0001357	0.5485491	0.14000
3.5	0.0004046	141.19	130.36	0.0685	0.0000381	0.0001411	0.5725267	0.14000
4.0	0.0003836	141.65	132.29	0.0682	0.0000392	0.0001453	0.5916416	0.14000
4.5	0.0003626	142.06	134.00	0.0680	0.0000401	0.0001483	0.6056256	0.14000
5.0	0.0003417	142.44	135.56	0.0678	0.0000405	0.0001501	0.6146330	0.14000
5.5	0.0003209	142.78	137.00	0.0677	0.0000407	0.0001508	0.6192279	0.14000
6.0	0.0003002	143.09	138.30	0.0675	0.0000407	0.0001506	0.6198560	0.14000
6.5	0.0002796	143.36	139.44	0.0674	0.0000404	0.0001497	0.6170190	0.14000
7.0	0.0002591	143.61	140.45	0.0673	0.0000400	0.0001479	0.6110285	0.14000
7.5	0.0002387	143.83	141.38	0.0671	0.0000393	0.0001454	0.6015234	0.14000
8.0	0.0002183	144.04	142.25	0.0670	0.0000383	0.0001420	0.5881194	0.14000
8.5	0.0001981	144.24	143.07	0.0670	0.0000372	0.0001378	0.5717005	0.14000
9.0	0.0001779	144.42	143.85	0.0669	0.0000360	0.0001333	0.5537994	0.14000
9.5	0.0001579	144.60	144.58	0.0668	0.0000347	0.0001286	0.5349396	0.14000
10.0	0.0001379	144.77	145.28	0.0667	0.0000333	0.0001233	0.5133899	0.14000
10.5	0.0001180	144.93	145.96	0.0666	0.0000314	0.0001164	0.4852839	0.14000
11.0	0.0000983	145.10	146.65	0.0665	0.0000289	0.0001068	0.4460709	0.14000
11.5	0.0000788	145.27	147.38	0.0665	0.0000254	0.0000939	0.3924172	0.14000
12.0	0.0000594	145.46	148.19	0.0664	0.0000209	0.0000773	0.3233679	0.14000
12.5	0.0000402	145.68	149.10	0.0663	0.0000155	0.0000574	0.2405067	0.14000
13.0	0.0000212	145.94	150.17	0.0661	0.0000095	0.0000353	0.1484124	0.14000
13.5	0.0000021	146.25	151.46	0.0660	0.0000037	0.0000139	0.0583099	0.14000
14.0	0.0000000	146.63	153.02	0.0658	0.0000000	0.0000000	0.0000000	0.14000

calculated fluid conditions at time = 0.0000 seconds

channel 2

assembly 1

distance	delta-p	enthalpy	temperature	density	flow	mass flux	velocity	area
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(in.)	(psi)	(btu/lb)	(deg-f)	(lb/cu-ft)	(lb/sec)	(mlb/hr-ft2)	(ft/sec)	(sq-in)
0.0	0.0005550	130.52	85.92	0.0743	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005334	130.52	85.90	0.0743	0.0000045	0.0000168	0.0628749	0.14000
1.0	0.0005117	131.30	89.16	0.0738	0.0000127	0.0000471	0.1773528	0.14000
1.5	0.0004899	132.03	92.19	0.0734	0.0000194	0.0000717	0.2713948	0.14000
2.0	0.0004684	132.73	95.13	0.0730	0.0000238	0.0000883	0.3359655	0.14000
2.5	0.0004470	133.42	98.00	0.0726	0.0000267	0.0000989	0.3783943	0.14000
3.0	0.0004258	134.07	100.71	0.0722	0.0000288	0.0001066	0.4098243	0.14000
3.5	0.0004046	134.67	103.21	0.0719	0.0000306	0.0001132	0.4373345	0.14000
4.0	0.0003836	135.23	105.53	0.0716	0.0000322	0.0001192	0.4625700	0.14000
4.5	0.0003626	135.77	107.77	0.0713	0.0000336	0.0001245	0.4850403	0.14000
5.0	0.0003417	136.29	109.97	0.0710	0.0000348	0.0001290	0.5047048	0.14000
5.5	0.0003209	136.81	112.13	0.0707	0.0000359	0.0001329	0.5217490	0.14000
6.0	0.0003002	137.32	114.25	0.0705	0.0000368	0.0001361	0.5364891	0.14000
6.5	0.0002796	137.84	116.40	0.0702	0.0000375	0.0001388	0.5492049	0.14000
7.0	0.0002591	138.35	118.53	0.0699	0.0000381	0.0001411	0.5605377	0.14000
7.5	0.0002387	138.85	120.63	0.0697	0.0000385	0.0001426	0.5688069	0.14000
8.0	0.0002183	139.35	122.69	0.0694	0.0000387	0.0001433	0.5736953	0.14000
8.5	0.0001981	139.83	124.69	0.0692	0.0000387	0.0001432	0.5754015	0.14000
9.0	0.0001779	140.28	126.59	0.0689	0.0000385	0.0001426	0.5747402	0.14000
9.5	0.0001579	140.71	128.37	0.0687	0.0000382	0.0001414	0.5718494	0.14000
10.0	0.0001379	141.13	130.10	0.0685	0.0000376	0.0001393	0.5648515	0.14000
10.5	0.0001180	141.55	131.87	0.0683	0.0000365	0.0001351	0.5495788	0.14000
11.0	0.0000983	142.01	133.77	0.0680	0.0000344	0.0001276	0.5206869	0.14000
11.5	0.0000788	142.51	135.86	0.0678	0.0000312	0.0001156	0.4734933	0.14000
12.0	0.0000594	143.06	138.15	0.0675	0.0000266	0.0000985	0.4051411	0.14000
12.5	0.0000402	143.66	140.68	0.0672	0.0000206	0.0000762	0.3146756	0.14000
13.0	0.0000211	144.33	143.46	0.0669	0.0000132	0.0000491	0.2036843	0.14000
13.5	0.0000021	145.08	146.58	0.0665	0.0000054	0.0000199	0.0829848	0.14000
14.0	0.0000000	145.93	150.11	0.0661	0.0000000	0.0000000	0.0000000	0.14000

calculated fluid conditions at time = 0.0000 seconds

channel 3

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0005552	129.04	79.72	0.0751	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005335	129.03	79.70	0.0751	0.0000018	0.0000066	0.0245797	0.14000
1.0	0.0005117	129.97	83.61	0.0746	0.0000081	0.0000299	0.1113447	0.14000
1.5	0.0004899	130.68	86.56	0.0742	0.0000133	0.0000494	0.1849905	0.14000
2.0	0.0004683	131.24	88.89	0.0738	0.0000163	0.0000602	0.2266495	0.14000
2.5	0.0004470	131.71	90.86	0.0736	0.0000173	0.0000639	0.2411863	0.14000
3.0	0.0004258	132.15	92.71	0.0733	0.0000173	0.0000642	0.2432473	0.14000
3.5	0.0004046	132.59	94.55	0.0731	0.0000173	0.0000641	0.2438017	0.14000
4.0	0.0003836	133.06	96.49	0.0728	0.0000174	0.0000644	0.2457225	0.14000
4.5	0.0003626	133.57	98.60	0.0725	0.0000175	0.0000649	0.2487678	0.14000
5.0	0.0003417	134.09	100.81	0.0722	0.0000178	0.0000658	0.2530861	0.14000
5.5	0.0003209	134.63	103.02	0.0719	0.0000181	0.0000669	0.2584351	0.14000
6.0	0.0003002	135.15	105.21	0.0716	0.0000184	0.0000681	0.2640992	0.14000
6.5	0.0002796	135.67	107.38	0.0714	0.0000187	0.0000692	0.2694250	0.14000
7.0	0.0002591	136.20	109.57	0.0711	0.0000190	0.0000703	0.2748576	0.14000
7.5	0.0002387	136.74	111.84	0.0708	0.0000196	0.0000726	0.2848678	0.14000
8.0	0.0002183	137.31	114.20	0.0705	0.0000205	0.0000758	0.2986466	0.14000
8.5	0.0001981	137.87	116.54	0.0702	0.0000213	0.0000788	0.3118440	0.14000

9.0	0.0001779	138.41	118.77	0.0699	0.0000220	0.0000815	0.3238708	0.14000
9.5	0.0001579	138.91	120.89	0.0696	0.0000227	0.0000841	0.3356255	0.14000
10.0	0.0001379	139.41	122.95	0.0694	0.0000234	0.0000867	0.3472686	0.14000
10.5	0.0001180	139.92	125.07	0.0691	0.0000239	0.0000885	0.3558935	0.14000
11.0	0.0000983	140.47	127.37	0.0688	0.0000238	0.0000881	0.3555128	0.14000
11.5	0.0000788	141.09	129.96	0.0685	0.0000226	0.0000837	0.3395524	0.14000
12.0	0.0000594	141.79	132.88	0.0682	0.0000201	0.0000743	0.3029715	0.14000
12.5	0.0000402	142.58	136.17	0.0678	0.0000160	0.0000592	0.2425690	0.14000
13.0	0.0000211	143.47	139.86	0.0673	0.0000103	0.0000383	0.1579730	0.14000
13.5	0.0000020	144.47	144.02	0.0668	0.0000040	0.0000146	0.0607905	0.14000
14.0	0.0000000	145.57	148.64	0.0663	0.0000000	0.0000000	0.0000000	0.14000

calculated fluid conditions at time = 0.0000 seconds
channel 4
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0005555	128.72	78.39	0.0753	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005336	128.71	78.36	0.0753	0.0000013	0.0000048	0.0176118	0.14000
1.0	0.0005117	129.79	82.86	0.0747	0.0000057	0.0000211	0.0784441	0.14000
1.5	0.0004899	130.62	86.34	0.0742	0.0000097	0.0000360	0.1348059	0.14000
2.0	0.0004683	131.22	88.80	0.0739	0.0000119	0.0000439	0.1651292	0.14000
2.5	0.0004470	131.61	90.44	0.0736	0.0000118	0.0000438	0.1652302	0.14000
3.0	0.0004258	131.90	91.66	0.0735	0.0000105	0.0000389	0.1471077	0.14000
3.5	0.0004046	132.22	92.99	0.0733	0.0000090	0.0000333	0.1260693	0.14000
4.0	0.0003836	132.65	94.80	0.0730	0.0000078	0.0000288	0.1097333	0.14000
4.5	0.0003626	133.21	97.10	0.0727	0.0000071	0.0000264	0.1007841	0.14000
5.0	0.0003417	133.78	99.48	0.0724	0.0000069	0.0000254	0.0973262	0.14000
5.5	0.0003209	134.31	101.72	0.0721	0.0000067	0.0000248	0.0954133	0.14000
6.0	0.0003002	134.83	103.87	0.0718	0.0000065	0.0000241	0.0932683	0.14000
6.5	0.0002796	135.36	106.08	0.0715	0.0000063	0.0000234	0.0910319	0.14000
7.0	0.0002591	135.91	108.37	0.0712	0.0000062	0.0000230	0.0898753	0.14000
7.5	0.0002387	136.48	110.75	0.0709	0.0000062	0.0000231	0.0905782	0.14000
8.0	0.0002183	137.06	113.17	0.0706	0.0000065	0.0000241	0.0948775	0.14000
8.5	0.0001981	137.63	115.55	0.0703	0.0000071	0.0000264	0.1044978	0.14000
9.0	0.0001779	138.16	117.77	0.0700	0.0000079	0.0000292	0.1158399	0.14000
9.5	0.0001579	138.66	119.83	0.0698	0.0000087	0.0000323	0.1284206	0.14000
10.0	0.0001379	139.13	121.78	0.0695	0.0000097	0.0000360	0.1436653	0.14000
10.5	0.0001180	139.58	123.67	0.0693	0.0000108	0.0000400	0.1603348	0.14000
11.0	0.0000983	140.06	125.68	0.0690	0.0000117	0.0000431	0.1736186	0.14000
11.5	0.0000788	140.63	128.04	0.0687	0.0000119	0.0000439	0.1775316	0.14000
12.0	0.0000594	141.32	130.90	0.0684	0.0000111	0.0000411	0.1669097	0.14000
12.5	0.0000402	142.13	134.31	0.0680	0.0000091	0.0000337	0.1377497	0.14000
13.0	0.0000211	143.09	138.30	0.0675	0.0000058	0.0000216	0.0888294	0.14000
13.5	0.0000019	144.20	142.92	0.0670	0.0000020	0.0000074	0.0307944	0.14000
14.0	0.0000000	145.43	148.04	0.0664	0.0000000	0.0000000	0.0000000	0.14000

calculated fluid conditions at time = 0.0000 seconds
channel 5
assembly 1

distance	delta-p	enthalpy	temperature	density	flow	mass flux	velocity	area
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calculated fluid conditions at time = 0.000 seconds
 channel 6
 assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0005557	128.65	78.12	0.0754	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005338	128.65	78.09	0.0754	0.0000007	0.0000024	-0.0090239	0.14000
1.0	0.0005118	129.81	82.92	0.0747	0.0000028	0.0000104	-0.0086753	0.14000
1.5	0.0004899	130.79	87.01	0.0741	0.0000052	0.0000193	-0.0722050	0.14000
2.0	0.0004683	131.51	90.03	0.0737	0.0000069	0.0000255	-0.0962872	0.14000
2.5	0.0004469	131.96	91.90	0.0734	0.0000070	0.0000261	-0.0986646	0.14000
3.0	0.0004258	132.18	92.81	0.0733	0.0000056	0.0000208	-0.0789810	0.14000
3.5	0.0004046	132.43	93.86	0.0732	0.0000038	0.0000141	-0.0537087	0.14000
4.0	0.0003836	132.92	95.90	0.0729	0.0000028	0.0000103	-0.0393574	0.14000
4.5	0.0003626	133.56	98.58	0.0725	0.0000027	0.0000101	-0.0385820	0.14000
5.0	0.0003417	134.12	100.93	0.0722	0.0000027	0.0000102	-0.0390497	0.14000
5.5	0.0003209	134.62	102.99	0.0719	0.0000024	0.0000091	-0.0349517	0.14000
6.0	0.0003002	135.11	105.03	0.0717	0.0000020	0.0000072	-0.0280118	0.14000
6.5	0.0002796	135.66	107.33	0.0714	0.0000015	0.0000056	-0.0219516	0.14000
7.0	0.0002591	136.25	109.80	0.0710	0.0000013	0.0000048	-0.0187258	0.14000
7.5	0.0002387	136.86	112.33	0.0707	0.0000012	0.0000043	-0.0168585	0.14000
8.0	0.0002183	137.47	114.86	0.0704	0.0000011	0.0000040	-0.0158933	0.14000
8.5	0.0001981	138.05	117.31	0.0701	0.0000010	0.0000038	-0.0149656	0.14000
9.0	0.0001779	138.60	119.58	0.0698	0.0000010	0.0000037	-0.0147947	0.14000
9.5	0.0001579	139.10	121.65	0.0695	0.0000011	0.0000040	-0.0158933	0.14000
10.0	0.0001379	139.54	123.49	0.0693	0.0000012	0.0000043	-0.0172464	0.14000
10.5	0.0001180	139.91	125.04	0.0691	0.0000014	0.0000051	-0.0205735	0.14000
11.0	0.0000983	140.27	126.53	0.0689	0.0000018	0.0000068	-0.02722564	0.14000
11.5	0.0000787	140.72	128.40	0.0687	0.0000024	0.0000088	-0.0354991	0.14000
12.0	0.0000594	141.31	130.89	0.0684	0.0000027	0.0000100	-0.0406651	0.14000
12.5	0.0000402	142.08	134.09	0.0680	0.0000025	0.0000093	-0.0380368	0.14000
13.0	0.0000210	143.02	138.00	0.0670	0.0000017	0.0000062	-0.0254205	0.14000
13.5	0.0000017	144.14	142.65	0.0670	0.0000005	0.0000019	-0.0079519	0.14000
14.0	0.0000000	145.39	147.87	0.0664	0.0000000	0.0000000	0.0000000	0.14000
8.5	0.0001981	138.05	117.31	0.0701	0.0000010	0.0000037	-0.0147947	0.14000
8.0	0.0002183	137.47	114.86	0.0704	0.0000011	0.0000040	-0.0158933	0.14000
7.5	0.0002387	136.86	112.33	0.0707	0.0000012	0.0000043	-0.0168585	0.14000
7.0	0.0002591	136.25	109.80	0.0710	0.0000013	0.0000048	-0.0187258	0.14000
6.5	0.0002796	135.66	107.33	0.0714	0.0000015	0.0000056	-0.0219516	0.14000
6.0	0.0003002	135.11	105.03	0.0717	0.0000020	0.0000072	-0.0280118	0.14000
5.5	0.0003209	134.62	102.99	0.0719	0.0000024	0.0000091	-0.0349517	0.14000
5.0	0.0003417	134.12	100.93	0.0722	0.0000027	0.0000102	-0.0390497	0.14000
4.5	0.0003626	133.56	98.58	0.0725	0.0000027	0.0000101	-0.0385820	0.14000
4.0	0.0003836	132.92	95.90	0.0729	0.0000028	0.0000103	-0.0393574	0.14000
3.5	0.0004046	132.43	93.86	0.0732	0.0000038	0.0000141	-0.0537087	0.14000
3.0	0.0004258	132.18	92.81	0.0733	0.0000056	0.0000208	-0.0789810	0.14000
2.5	0.0004469	131.96	91.90	0.0734	0.0000070	0.0000261	-0.0986646	0.14000
2.0	0.0004683	131.51	90.03	0.0737	0.0000069	0.0000255	-0.0962872	0.14000
1.5	0.0004899	130.79	87.01	0.0741	0.0000052	0.0000193	-0.0722050	0.14000
1.0	0.0005118	129.81	82.92	0.0747	0.0000028	0.0000104	-0.0086753	0.14000
0.5	0.0005338	128.65	78.09	0.0754	0.0000007	0.0000024	-0.0090239	0.14000
0.0	0.0005557	128.65	78.12	0.0754	0.0000000	0.0000000	0.0000000	0.14000
8.5	0.0001981	138.05	117.31	0.0701	0.0000010	0.0000037	-0.0147947	0.14000
8.0	0.0002183	137.47	114.86	0.0704	0.0000011	0.0000040	-0.0158933	0.14000
7.5	0.0002387	136.86	112.33	0.0707	0.0000012	0.0000043	-0.0168585	0.14000
7.0	0.0002591	136.25	109.80	0.0710	0.0000013	0.0000048	-0.0187258	0.14000
6.5	0.0002796	135.66	107.33	0.0714	0.0000015	0.0000056	-0.0219516	0.14000
6.0	0.0003002	135.11	105.03	0.0717	0.0000020	0.0000072	-0.0280118	0.14000
5.5	0.0003209	134.62	102.99	0.0719	0.0000024	0.0000091	-0.0349517	0.14000
5.0	0.0003417	134.12	100.93	0.0722	0.0000027	0.0000102	-0.0390497	0.14000
4.5	0.0003626	133.56	98.58	0.0725	0.0000027	0.0000101	-0.0385820	0.14000
4.0	0.0003836	132.92	95.90	0.0729	0.0000028	0.0000103	-0.0393574	0.14000
3.5	0.0004046	132.43	93.86	0.0732	0.0000038	0.0000141	-0.0537087	0.14000
3.0	0.0004258	132.18	92.81	0.0733	0.0000056	0.0000208	-0.0789810	0.14000
2.5	0.0004469	131.96	91.90	0.0734	0.0000070	0.0000261	-0.0986646	0.14000
2.0	0.0004683	131.51	90.03	0.0737	0.0000069	0.0000255	-0.0962872	0.14000
1.5	0.0004899	130.79	87.01	0.0741	0.0000052	0.0000193	-0.0722050	0.14000
1.0	0.0005119	129.83	83.02	0.0747	-0.0000013	-0.0000047	-0.0175202	0.14000
0.5	0.0005339	128.64	78.04	0.0754	-0.0000006	-0.0000021	-0.0078023	0.14000
0.0	0.0005559	128.64	78.06	0.0754	0.0000000	0.0000000	0.0000000	0.14000
8.5	0.0001981	138.05	117.31	0.0701	0.0000010	0.0000037	-0.0147947	0.14000
8.0	0.0002183	137.47	114.86	0.0704	0.0000011	0.0000040	-0.0158933	0.14000
7.5	0.0002387	136.86	112.33	0.0707	0.0000012	0.0000043	-0.0168585	0.14000
7.0	0.0002591	136.25	109.80	0.0710	0.0000013	0.0000048	-0.0187258	0.14000
6.5	0.0002796	135.66	107.33	0.0714	0.0000015	0.0000056	-0.0219516	0.14000
6.0	0.0003002	135.11	105.03	0.0717	0.0000020	0.0000072	-0.0280118	0.14000
5.5	0.0003209	134.62	102.99	0.0719	0.0000024	0.0000091	-0.0349517	0.14000
5.0	0.0003417	134.12	100.93	0.0722	0.0000027	0.0000102	-0.0390497	0.14000
4.5	0.0003626	133.56	98.58	0.0725	0.0000027	0.0000101	-0.0385820	0.14000
4.0	0.0003836	132.92	95.90	0.0729	0.0000028	0.0000103	-0.0393574	0.14000
3.5	0.0004046	132.43	93.86	0.0732	0.0000038	0.0000141	-0.0537087	0.14000
3.0	0.0004257	132.63	94.72	0.0730	0.0000006	0.0000024	-0.0089253	0.14000
2.5	0.0004469	132.37	93.60	0.0732	0.0000006	0.0000024	-0.0089253	0.14000
2.0	0.0004683	131.77	91.10	0.0735	-0.0000003	-0.0000013	-0.0048293	0.14000
1.5	0.0004899	130.90	87.50	0.0740	-0.0000012	-0.0000044	-0.0165638	0.14000
1.0	0.0005119	129.83	83.02	0.0747	-0.0000013	-0.0000047	-0.0175202	0.14000
0.5	0.0005339	128.64	78.04	0.0754	-0.0000006	-0.0000021	-0.0078023	0.14000
0.0	0.0005559	128.64	78.06	0.0754	0.0000000	0.0000000	0.0000000	0.14000
8.5	0.0001981	138.05	117.31	0.0701	0.0000010	0.0000037	-0.0147947	0.14000
8.0	0.0002183	137.47	114.86	0.0704	0.0000011	0.0000040	-0.0158933	0.14000
7.5	0.0002387	136.86	112.33	0.0707	0.0000012	0.0000043	-0.0168585	0.14000
7.0	0.0002591	136.25	109.80	0.0710	0.0000013	0.0000048	-0.0187258	0.14000
6.5	0.0002796	135.66	107.33	0.0714	0.0000015	0.0000056	-0.0219516	0.14000
6.0	0.0003002	135.11	105.03	0.0717	0.0000020	0.0000072	-0.0280118	0.14000
5.5	0.0003209	134.62	102.99	0.0719	0.0000024	0.0000091	-0.0349517	0.14000
5.0	0.0003417	134.12	100.93	0.0722	0.0000027	0.0000102	-0.0390497	0.14000
4.5	0.0003626	133.56	98.58	0.0725	0.0000027	0.0000101	-0.0385820	0.14000
4.0	0.0003836	132.92	95.90	0.0729	0.0000028	0.0000103	-0.0393574	0.14000
3.5	0.0004046	132.43	93.86	0.0732	0.0000038	0.0000141	-0.0537087	0.14000
3.0	0.0004257	132.63	94.72	0.0730	0.0000006	0.0000024	-0.0089253	0.14000
2.5	0.0004469	132.37	93.60	0.0732	0.0000006	0.0000024	-0.0089253	0.14000
2.0	0.0004683	131.77	91.10	0.0735	-0.0000003	-0.0000013	-0.0048293	0.14000
1.5	0.0004899	130.90	87.50	0.0740	-0.0000012	-0.0000044	-0.0165638	0.14000
1.0	0.0005119	129.83	83.02	0.0747	-0.0000013	-0.0000047	-0.0175202	0.14000
0.5	0.0005339	128.64	78.04	0.0754	-0.0000006	-0.0000021	-0.0078023	0.14000
0.0	0.0005559	128.64	78.06	0.0754	0.0000000	0.0000000	0.0000000	0.14000
8.5	0.0001981	138.05	117.31	0.0701	0.0000010	0.0000037	-0.0147947	0.14000
8.0	0.0002183	137.47	114.86	0.0704	0.0000011	0.0000040	-0.0158933	0.14000
7.5	0.0002387	136.86	112.33	0.0707	0.0000012	0.0000043	-0.0168585	0.14000
7.0	0.0002591	136.25	109.80	0.0710	0.0000013	0.0000048	-0.0187258	0.14000
6.5	0.0002796	135.66	107.33	0.0714	0.0000015	0.0000056	-0.0219516	0.14000
6.0	0.0003002	135.11	105.03	0.0717	0.0000020	0.0000072	-0.028011	

9.0	0.0001779	139.12	121.77	0.0695	-0.0000023	-0.0000086	-0.0343622	0.14000
9.5	0.0001579	139.63	123.87	0.0693	-0.0000031	-0.0000116	-0.0468266	0.14000
10.0	0.0001379	140.06	125.66	0.0690	-0.0000041	-0.0000153	-0.0618063	0.14000
10.5	0.0001180	140.40	127.08	0.0689	-0.0000050	-0.0000186	-0.0753596	0.14000
11.0	0.0000983	140.71	128.37	0.0687	-0.0000054	-0.0000201	-0.0816061	0.14000
11.5	0.0000787	141.07	129.89	0.0685	-0.0000051	-0.0000190	-0.0773020	0.14000
12.0	0.0000594	141.57	131.96	0.0683	-0.0000042	-0.0000156	-0.0636203	0.14000
12.5	0.0000401	142.24	134.74	0.0679	-0.0000029	-0.0000107	-0.0440633	0.14000
13.0	0.0000208	143.09	138.30	0.0675	-0.0000014	-0.0000054	-0.0222003	0.14000
13.5	0.0000015	144.14	142.67	0.0670	-0.0000003	-0.0000010	-0.0041305	0.14000
14.0	0.0000000	145.36	147.73	0.0664	0.0000000	0.0000000	0.0000000	0.14000

calculated fluid conditions at time = 0.0000 seconds
channel 7
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft ²)	velocity (ft/sec)	area (sq-in)
0.0	0.0005561	128.61	77.94	0.0754	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005340	128.61	77.91	0.0754	-0.0000026	-0.0000096	-0.0356818	0.14000
1.0	0.0005119	129.79	82.87	0.0747	-0.0000065	-0.0000240	-0.0901197	0.14000
1.5	0.0004899	130.89	87.45	0.0740	-0.0000091	-0.0000336	-0.1269612	0.14000
2.0	0.0004683	131.82	91.31	0.0735	-0.0000098	-0.0000363	-0.1378120	0.14000
2.5	0.0004469	132.53	94.29	0.0731	-0.0000089	-0.0000331	-0.1263481	0.14000
3.0	0.0004257	133.03	96.36	0.0728	-0.0000073	-0.0000271	-0.1035733	0.14000
3.5	0.0004046	133.44	98.09	0.0726	-0.0000061	-0.0000226	-0.0868828	0.14000
4.0	0.0003836	133.97	100.28	0.0723	-0.0000059	-0.0000217	-0.0835723	0.14000
4.5	0.0003626	134.48	102.43	0.0720	-0.0000060	-0.0000220	-0.0853735	0.14000
5.0	0.0003417	134.99	104.52	0.0717	-0.0000059	-0.0000218	-0.0847222	0.14000
5.5	0.0003209	135.50	106.65	0.0715	-0.0000056	-0.0000206	-0.0805422	0.14000
6.0	0.0003002	136.03	108.88	0.0712	-0.0000052	-0.0000193	-0.0756692	0.14000
6.5	0.0002796	136.60	111.26	0.0709	-0.0000051	-0.0000188	-0.0740033	0.14000
7.0	0.0002591	137.19	113.72	0.0705	-0.0000053	-0.0000195	-0.0772421	0.14000
7.5	0.0002387	137.78	116.15	0.0702	-0.0000057	-0.0000210	-0.0832772	0.14000
8.0	0.0002183	138.35	118.55	0.0699	-0.0000062	-0.0000230	-0.0916334	0.14000
8.5	0.0001981	138.91	120.87	0.0696	-0.0000069	-0.0000255	-0.1020945	0.14000
9.0	0.0001779	139.43	123.05	0.0694	-0.0000077	-0.0000285	-0.1146675	0.14000
9.5	0.0001579	139.91	125.05	0.0691	-0.0000087	-0.0000321	-0.1295211	0.14000
10.0	0.0001379	140.34	126.82	0.0689	-0.0000097	-0.0000360	-0.1457303	0.14000
10.5	0.0001180	140.71	128.38	0.0687	-0.0000107	-0.0000395	-0.1602343	0.14000
11.0	0.0000983	141.06	129.84	0.0685	-0.0000112	-0.0000413	-0.1679451	0.14000
11.5	0.0000787	141.43	131.39	0.0683	-0.0000108	-0.0000400	-0.1633380	0.14000
12.0	0.0000593	141.88	133.26	0.0681	-0.0000094	-0.0000349	-0.1428409	0.14000
12.5	0.0000400	142.45	135.64	0.0678	-0.0000069	-0.0000257	-0.1057781	0.14000
13.0	0.0000207	143.18	138.69	0.0675	-0.0000036	-0.0000133	-0.0552737	0.14000
13.5	0.0000013	144.11	142.52	0.0670	-0.0000005	-0.0000019	-0.0079100	0.14000
14.0	0.0000000	145.23	147.20	0.0665	0.0000000	0.0000000	0.0000000	0.14000

calculated fluid conditions at time = 0.0000 seconds
channel 8
assembly 1

distance	delta-p	enthalpy	temperature	density	flow	mass flux	velocity	area
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(in.)	(psi)	(btu/lb)	(deg-f)	(lb/cu-ft)	(lb/sec)	(mlb/hr-ft2)	(ft/sec)	(sq-in)
0.0	0.0005562	128.47	77.34	0.0755	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005341	128.46	77.32	0.0755	-0.0000051	-0.0000191	-0.0707466	0.14000
1.0	0.0005120	129.55	81.87	0.0748	-0.0000123	-0.0000455	-0.1703825	0.14000
1.5	0.0004900	130.58	86.16	0.0742	-0.0000178	-0.0000659	-0.2485099	0.14000
2.0	0.0004683	131.49	89.96	0.0737	-0.0000208	-0.0000770	-0.2920932	0.14000
2.5	0.0004469	132.27	93.20	0.0732	-0.0000214	-0.0000792	-0.3019002	0.14000
3.0	0.0004257	132.91	95.86	0.0729	-0.0000204	-0.0000755	-0.2889512	0.14000
3.5	0.0004046	133.43	98.04	0.0726	-0.0000193	-0.0000713	-0.2739639	0.14000
4.0	0.0003836	133.89	99.97	0.0723	-0.0000190	-0.0000702	-0.2705093	0.14000
4.5	0.0003626	134.35	101.87	0.0721	-0.0000191	-0.0000709	-0.2740913	0.14000
5.0	0.0003417	134.84	103.93	0.0718	-0.0000192	-0.0000710	-0.2759388	0.14000
5.5	0.0003209	135.38	106.16	0.0715	-0.0000189	-0.0000700	-0.2729703	0.14000
6.0	0.0003002	135.94	108.49	0.0712	-0.0000184	-0.0000681	-0.2669418	0.14000
6.5	0.0002796	136.50	110.85	0.0709	-0.0000179	-0.0000664	-0.2610571	0.14000
7.0	0.0002591	137.06	113.17	0.0706	-0.0000177	-0.0000655	-0.2585235	0.14000
7.5	0.0002387	137.58	115.34	0.0703	-0.0000177	-0.0000656	-0.2600010	0.14000
8.0	0.0002183	138.10	117.48	0.0701	-0.0000178	-0.0000659	-0.2623266	0.14000
8.5	0.0001981	138.60	119.57	0.0698	-0.0000179	-0.0000663	-0.2648277	0.14000
9.0	0.0001779	139.08	121.60	0.0695	-0.0000180	-0.0000667	-0.2673036	0.14000
9.5	0.0001579	139.55	123.56	0.0693	-0.0000181	-0.0000670	-0.2696423	0.14000
10.0	0.0001379	140.01	125.45	0.0691	-0.0000182	-0.0000672	-0.2713873	0.14000
10.5	0.0001180	140.45	127.31	0.0688	-0.0000181	-0.0000669	-0.2709742	0.14000
11.0	0.0000983	140.90	129.16	0.0686	-0.0000176	-0.0000652	-0.2649732	0.14000
11.5	0.0000787	141.35	131.06	0.0684	-0.0000164	-0.0000608	-0.2480914	0.14000
12.0	0.0000593	141.84	133.10	0.0681	-0.0000142	-0.0000524	-0.2145715	0.14000
12.5	0.0000400	142.39	135.39	0.0679	-0.0000105	-0.0000389	-0.1601763	0.14000
13.0	0.0000206	143.04	138.07	0.0675	-0.0000056	-0.0000207	-0.0855805	0.14000
13.5	0.0000011	143.81	141.31	0.0672	-0.0000007	-0.0000025	-0.0103854	0.14000
14.0	0.0000000	144.75	145.22	0.0667	0.0000000	0.0000000	0.0000000	0.14000

calculated fluid conditions at time = 0.0000 seconds

channel 9

assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0005563	128.10	75.81	0.0757	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005341	128.10	75.80	0.0757	-0.0000071	-0.0000262	-0.0968864	0.14000
1.0	0.0005120	128.96	79.41	0.0752	-0.0000167	-0.0000619	-0.2300956	0.14000
1.5	0.0004900	129.77	82.75	0.0747	-0.0000251	-0.0000928	-0.3471223	0.14000
2.0	0.0004683	130.49	85.77	0.0743	-0.0000310	-0.0001150	-0.4320837	0.14000
2.5	0.0004469	131.13	88.43	0.0739	-0.0000345	-0.0001277	-0.4819504	0.14000
3.0	0.0004257	131.67	90.68	0.0736	-0.0000358	-0.0001327	-0.5026812	0.14000
3.5	0.0004046	132.11	92.53	0.0733	-0.0000361	-0.0001338	-0.5083755	0.14000
4.0	0.0003836	132.49	94.12	0.0731	-0.0000364	-0.0001346	-0.5128781	0.14000
4.5	0.0003626	132.87	95.70	0.0729	-0.0000368	-0.0001363	-0.5208706	0.14000
5.0	0.0003417	133.28	97.43	0.0727	-0.0000373	-0.0001381	-0.5298338	0.14000
5.5	0.0003209	133.74	99.31	0.0724	-0.0000376	-0.0001393	-0.5362739	0.14000
6.0	0.0003002	134.21	101.28	0.0722	-0.0000377	-0.0001394	-0.5387246	0.14000
6.5	0.0002796	134.69	103.29	0.0719	-0.0000374	-0.0001385	-0.5372235	0.14000
7.0	0.0002591	135.17	105.31	0.0716	-0.0000369	-0.0001367	-0.5319280	0.14000
7.5	0.0002387	135.66	107.34	0.0714	-0.0000363	-0.0001343	-0.5245643	0.14000
8.0	0.0002183	136.13	109.31	0.0711	-0.0000356	-0.0001318	-0.5167355	0.14000
8.5	0.0001981	136.59	111.22	0.0709	-0.0000348	-0.0001290	-0.5073836	0.14000

9.0	0.0001779	137.06	113.18	0.0706	-0.0000339	-0.0001255	-0.4957063	0.14000
9.5	0.0001579	137.54	115.18	0.0704	-0.0000328	-0.0001215	-0.4815531	0.14000
10.0	0.0001379	138.04	117.25	0.0701	-0.0000315	-0.0001168	-0.4646355	0.14000
10.5	0.0001181	138.56	119.43	0.0698	-0.0000300	-0.0001111	-0.4438790	0.14000
11.0	0.0000983	139.11	121.73	0.0695	-0.0000280	-0.0001038	-0.4167442	0.14000
11.5	0.0000788	139.70	124.16	0.0692	-0.0000254	-0.0000940	-0.3789363	0.14000
12.0	0.0000593	140.31	126.70	0.0689	-0.0000217	-0.0000803	-0.3250592	0.14000
12.5	0.0000400	140.94	129.34	0.0686	-0.0000166	-0.0000615	-0.2501925	0.14000
13.0	0.0000205	141.60	132.09	0.0682	-0.0000101	-0.0000374	-0.1529868	0.14000
13.5	0.0000009	142.30	135.01	0.0679	-0.0000030	-0.0000110	-0.0452266	0.14000
14.0	0.0000000	143.00	137.92	0.0676	0.0000000	0.0000000	0.0000000	0.14000

calculated fluid conditions at time = 0.0000 seconds
channel 10
assembly 1

distance (in.)	delta-p (psi)	enthalpy (btu/lb)	temperature (deg-f)	density (lb/cu-ft)	flow (lb/sec)	mass flux (mlb/hr-ft2)	velocity (ft/sec)	area (sq-in)
0.0	0.0005563	127.33	72.58	0.0762	0.0000000	0.0000000	0.0000000	0.14000
0.5	0.0005341	127.33	72.57	0.0762	-0.0000053	-0.0000195	-0.0712890	0.14000
1.0	0.0005120	127.77	74.43	0.0759	-0.0000140	-0.0000517	-0.1896100	0.14000
1.5	0.0004900	128.11	75.83	0.0757	-0.0000223	-0.0000827	-0.3039623	0.14000
2.0	0.0004683	128.37	76.91	0.0755	-0.0000290	-0.0001072	-0.3949577	0.14000
2.5	0.0004469	128.57	77.77	0.0754	-0.0000334	-0.0001238	-0.4566359	0.14000
3.0	0.0004257	128.75	78.50	0.0753	-0.0000359	-0.0001331	-0.4916016	0.14000
3.5	0.0004046	128.91	79.17	0.0752	-0.0000373	-0.0001380	-0.5102461	0.14000
4.0	0.0003836	129.07	79.84	0.0751	-0.0000383	-0.0001417	-0.5248439	0.14000
4.5	0.0003626	129.24	80.55	0.0750	-0.0000395	-0.0001461	-0.5417794	0.14000
5.0	0.0003417	129.42	81.30	0.0749	-0.0000408	-0.0001509	-0.5605911	0.14000
5.5	0.0003209	129.61	82.09	0.0748	-0.0000420	-0.0001555	-0.5783446	0.14000
6.0	0.0003002	129.80	82.91	0.0747	-0.0000430	-0.0001592	-0.5930987	0.14000
6.5	0.0002796	130.01	83.77	0.0746	-0.0000437	-0.0001619	-0.6043314	0.14000
7.0	0.0002591	130.23	84.69	0.0744	-0.0000442	-0.0001637	-0.6119860	0.14000
7.5	0.0002387	130.47	85.67	0.0743	-0.0000444	-0.0001644	-0.6160202	0.14000
8.0	0.0002183	130.73	86.76	0.0741	-0.0000443	-0.0001642	-0.6165313	0.14000
8.5	0.0001981	131.02	87.97	0.0740	-0.0000440	-0.0001630	-0.6137712	0.14000
9.0	0.0001780	131.32	89.26	0.0738	-0.0000435	-0.0001610	-0.6077854	0.14000
9.5	0.0001579	131.66	90.65	0.0736	-0.0000427	-0.0001581	-0.5983897	0.14000
10.0	0.0001379	132.03	92.19	0.0734	-0.0000416	-0.0001541	-0.5853037	0.14000
10.5	0.0001181	132.44	93.91	0.0731	-0.0000402	-0.0001489	-0.5675817	0.14000
11.0	0.0000983	132.91	95.86	0.0729	-0.0000383	-0.0001419	-0.5429186	0.14000
11.5	0.0000788	133.43	98.05	0.0726	-0.0000357	-0.0001320	-0.5073838	0.14000
12.0	0.0000593	134.01	100.44	0.0723	-0.0000319	-0.0001181	-0.4559714	0.14000
12.5	0.0000400	134.62	102.99	0.0719	-0.0000267	-0.0000989	-0.3838127	0.14000
13.0	0.0000205	135.26	105.65	0.0716	-0.0000199	-0.0000737	-0.2873481	0.14000
13.5	0.0000007	135.92	108.42	0.0712	-0.0000112	-0.0000413	-0.1620542	0.14000
14.0	0.0000000	136.63	111.38	0.0708	0.0000000	0.0000000	0.0000000	0.14000

slab temperature summary time = 0.0000 seconds
{assembly no. - channel no.}

axial zone (inches)	(1)	(2)
0.0 - 0.5	155.00	70.00
0.5 - 1.0	155.00	70.00
1.0 - 1.5	155.00	70.00
1.5 - 2.0	155.00	70.00
2.0 - 2.5	155.00	70.00
2.5 - 3.0	155.00	70.00
3.0 - 3.5	155.00	70.00
3.5 - 4.0	155.00	70.00
4.0 - 4.5	155.00	70.00
4.5 - 5.0	155.00	70.00
5.0 - 5.5	155.00	70.00
5.5 - 6.0	155.00	70.00
6.0 - 6.5	155.00	70.00
6.5 - 7.0	155.00	70.00
7.0 - 7.5	155.00	70.00
7.5 - 8.0	155.00	70.00
8.0 - 8.5	155.00	70.00
8.5 - 9.0	155.00	70.00
9.0 - 9.5	155.00	70.00
9.5 - 10.0	155.00	70.00
10.0 - 10.5	155.00	70.00
10.5 - 11.0	155.00	70.00
11.0 - 11.5	155.00	70.00
11.5 - 12.0	155.00	70.00
12.0 - 12.5	155.00	70.00
12.5 - 13.0	155.00	70.00
13.0 - 13.5	155.00	70.00
13.5 - 14.0	155.00	70.00

crossflow between adjacent channels at time = 0.0000 seconds

assembly number	1	1	1	1	1	1	1	1	1
axial zone	1 2	2 3	3 4	4 5	5 6	6 7	7 8	8 9	9 10
0.0 - 0.5	-0.00030	-0.00041	-0.00045	-0.00048	-0.00050	-0.00048	-0.00042	-0.00030	-0.00013
0.5 - 1.0	-0.00022	-0.00041	-0.00056	-0.00067	-0.00072	-0.00070	-0.00061	-0.00044	-0.00021
1.0 - 1.5	-0.00015	-0.00031	-0.00044	-0.00054	-0.00059	-0.00060	-0.00053	-0.00040	-0.00020
1.5 - 2.0	-0.00010	-0.00021	-0.00028	-0.00033	-0.00037	-0.00039	-0.00037	-0.00030	-0.00016
2.0 - 2.5	-0.00007	-0.00013	-0.00016	-0.00016	-0.00016	-0.00018	-0.00020	-0.00019	-0.00011
2.5 - 3.0	-0.00004	-0.00009	-0.00010	-0.00006	-0.00003	-0.00003	-0.00007	-0.00009	-0.00006
3.0 - 3.5	-0.00003	-0.00008	-0.00008	-0.00004	0.00000	0.00002	-0.00001	-0.00004	-0.00003
3.5 - 4.0	-0.00003	-0.00007	-0.00007	-0.00004	-0.00001	-0.00002	-0.00002	-0.00003	-0.00002
4.0 - 4.5	-0.00002	-0.00005	-0.00006	-0.00004	-0.00004	-0.00005	-0.00004	-0.00004	-0.00003
4.5 - 5.0	-0.00001	-0.00004	-0.00005	-0.00004	-0.00004	-0.00004	-0.00004	-0.00004	-0.00003
5.0 - 5.5	0.00000	-0.00003	-0.00004	-0.00003	-0.00003	-0.00002	-0.00003	-0.00004	-0.00003
5.5 - 6.0	0.00000	-0.00002	-0.00003	-0.00002	-0.00001	0.00000	-0.00001	-0.00002	-0.00002
6.0 - 6.5	0.00001	-0.00001	-0.00002	-0.00001	0.00000	0.00000	0.00000	-0.00001	-0.00002
6.5 - 7.0	0.00001	0.00000	-0.00001	-0.00001	0.00000	0.00000	0.00001	0.00000	-0.00001
7.0 - 7.5	0.00002	0.00001	-0.00001	-0.00001	-0.00001	0.00000	0.00001	0.00001	0.00000
7.5 - 8.0	0.00002	0.00002	0.00000	-0.00001	-0.00001	0.00000	0.00002	0.00002	0.00000
8.0 - 8.5	0.00003	0.00003	0.00001	-0.00001	-0.00001	0.00001	0.00002	0.00003	0.00001
8.5 - 9.0	0.00003	0.00003	0.00002	0.00000	0.00000	0.00001	0.00003	0.00004	0.00001
9.0 - 9.5	0.00003	0.00004	0.00002	0.00000	0.00000	0.00002	0.00004	0.00005	0.00002

9.5 - 10.0	0.00003	0.00005	0.00003	0.00001	0.00001	0.00003	0.00005	0.00006	0.00003
10.0 - 10.5	0.00004	0.00007	0.00006	0.00003	0.00003	0.00005	0.00007	0.00007	0.00003
10.5 - 11.0	0.00006	0.00011	0.00011	0.00009	0.00008	0.00009	0.00010	0.00009	0.00005
11.0 - 11.5	0.00008	0.00016	0.00019	0.00018	0.00017	0.00016	0.00016	0.00013	0.00006
11.5 - 12.0	0.00011	0.00022	0.00028	0.00030	0.00029	0.00027	0.00023	0.00018	0.00009
12.0 - 12.5	0.00013	0.00027	0.00037	0.00042	0.00042	0.00039	0.00033	0.00025	0.00012
12.5 - 13.0	0.00014	0.00032	0.00045	0.00053	0.00055	0.00052	0.00044	0.00032	0.00016
13.0 - 13.5	0.00014	0.00033	0.00048	0.00057	0.00060	0.00057	0.00050	0.00038	0.00021
13.5 - 14.0	0.00009	0.00022	0.00031	0.00036	0.00037	0.00037	0.00036	0.00034	0.00027

side boundary temperature summary time = 0.0000 seconds
boundary slab node no. 1

axial zone (inches)	(1)	(2)	(
0.0 - 0.5	155.00	155.00	
0.5 - 1.0	155.00	155.00	
1.0 - 1.5	155.00	155.00	
1.5 - 2.0	155.00	155.00	
2.0 - 2.5	155.00	155.00	
2.5 - 3.0	155.00	155.00	
3.0 - 3.5	155.00	155.00	
3.5 - 4.0	155.00	155.00	
4.0 - 4.5	155.00	155.00	
4.5 - 5.0	155.00	155.00	
5.0 - 5.5	155.00	155.00	
5.5 - 6.0	155.00	155.00	
6.0 - 6.5	155.00	155.00	
6.5 - 7.0	155.00	155.00	
7.0 - 7.5	155.00	155.00	
7.5 - 8.0	155.00	155.00	
8.0 - 8.5	155.00	155.00	
8.5 - 9.0	155.00	155.00	
9.0 - 9.5	155.00	155.00	
9.5 - 10.0	155.00	155.00	
10.0 - 10.5	155.00	155.00	
10.5 - 11.0	155.00	155.00	
11.0 - 11.5	155.00	155.00	
11.5 - 12.0	155.00	155.00	
12.0 - 12.5	155.00	155.00	
12.5 - 13.0	155.00	155.00	
13.0 - 13.5	155.00	155.00	
13.5 - 14.0	155.00	155.00	

side boundary temperature summary time = 0.0000 seconds
boundary slab node no. 2

axial zone	(1)	(2)	(
------------	------	------	---

(inches)

0.0 - 0.5	70.00	70.00
0.5 - 1.0	70.00	70.00
1.0 - 1.5	70.00	70.00
1.5 - 2.0	70.00	70.00
2.0 - 2.5	70.00	70.00
2.5 - 3.0	70.00	70.00
3.0 - 3.5	70.00	70.00
3.5 - 4.0	70.00	70.00
4.0 - 4.5	70.00	70.00
4.5 - 5.0	70.00	70.00
5.0 - 5.5	70.00	70.00
5.5 - 6.0	70.00	70.00
6.0 - 6.5	70.00	70.00
6.5 - 7.0	70.00	70.00
7.0 - 7.5	70.00	70.00
7.5 - 8.0	70.00	70.00
8.0 - 8.5	70.00	70.00
8.5 - 9.0	70.00	70.00
9.0 - 9.5	70.00	70.00
9.5 - 10.0	70.00	70.00
10.0 - 10.5	70.00	70.00
10.5 - 11.0	70.00	70.00
11.0 - 11.5	70.00	70.00
11.5 - 12.0	70.00	70.00
12.0 - 12.5	70.00	70.00
12.5 - 13.0	70.00	70.00
13.0 - 13.5	70.00	70.00
13.5 - 14.0	70.00	70.00

iterations = 50

input transient time completed

common dumped to tape 8

1***** computational time summary *****

subroutine energy.....	4.72	sec
subroutine moment.....	1.13	sec
subroutine reheat.....	0.00	sec
subroutine recirc (pressure loop)....	3.16	sec
subroutine result.....	0.18	sec
subroutine setup.....	0.07	sec
other subroutines.....	1.57	sec
total cpu time.....	10.84	sec

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