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COBRA-IV-I: An Interim Version of COBRA for Thermal-Hydraulic Analysis of Rod Bundle Nuclear Fuel Elements and Cores

March 1976

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COBRA-IV-I: AN INTERIM VERSION OF COBRA FOR THERMAL-HYDRAULIC ANALYSIS OF ROD BUNDLE NUCLEAR FUEL ELEMENTS AND CORES

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ABSTRACT

The COBRA-IV-I computer code uses the subchannel analysis approach to determine the enthalpy and flow distribution in rod bundles for both steady-state and transient conditions. The steady-state and transient solution schemes used in COBRA-IIIC are still available in COBRA-IV-I as the implicit solution scheme option. In addition to these techniques, a new explicit solution scheme is now available which allows the calculation of severe transients involving flow reversals, recirculations, expulsion and reentry flows, with a pressure or flow boundary condition specified. Significant storage compaction and reduced running times have been achieved to allow the calculation of problems involving hundreds of subchannels.

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1.0 INTRODUCTION

The objective of this report is to present an interim version of the COBRA-IV computer program being developed at the Pacific Northwest Laboratory by Battelle-Northwest. The COBRA-IV-I code is an extended version of the COBRA-IIIC subchannel analysis code which computes the flow and enthalpy distributions in nuclear fuel rod bundles or cores for both steady state and transient conditions.[1]

Development of the COBRA computer code through the COBRA-IIIC version was sponsored by the Atomic Energy Commission (AEC). Since the reorganization of the AEC, COBRA-IV has been under the sponsorship of both the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC). The ERDA sponsorship has been directed toward expanded code capability for the liquid metal fast breeder reactor, while the NRC sponsorship has been directed toward improved computational and two-phase modeling for application to water reactor safety.

The approach used in COBRA-IV-I is similar to that used in COBRA-IIIC. The basic idea is to divide the bundle or core of a reactor into computational cells. The balance laws of mass, energy and momentum for the fluid are written for each cell where the independent variables of enthalpy, pressure and velocity are appropriate averages. The cells may have fuel rods or other solid materials which in the present treatment act as sources or sinks of heat and momentum to the fluid. The transient thermal response of the fuel or solids is included and is interfaced with the hydraulics through heat transfer coefficients. The use of the computational cell concept allows subchannel analysis, core analysis and general flow field analysis to be considered in a unified approach. The primary differences between the two programs are the level of detail included through averaging and the constitutive relationships used to close the set of equations.

COBRA-IIIC is currently in rather wide use for the thermal-hydraulic analysis of rod bundle fuel elements and cores for water, liquid metal and gas cooled reactors. COBRA users continually challenge its capability by attempting problems of increasing complexity. For example, design analysis for the LMFBR requires calculation of subchannel flow and temperature in a full 217-pin wire-wrapped bundle with provision for heat transfer to adjacent bundles or core structures. This must be accommodated by existing computers and be performed with reasonable computational time. Analysis for both liquid-metal and water cooled reactors requires the transient response of coolant flow and enthalpy to changes of inlet and exit pressure as the driving boundary condition. This can lead to flow reversals, coolant expulsion and reentry. Capability is also required for severe blockages where flow recirculation is possible. The application of COBRA-IV to water reactor safety currently requires more sophisticated two-phase flow modeling to account for relative motion of the liquid and vapor phases and the effects of thermal nonequilibrium. This is further complicated by the need to consider a wide range of pressure and velocity conditions. This poses a significant challenge to both the modeling of two-phase flow physical processes and the numerical procedure to solve the system of equations.

Significant progress has been made in the above areas; therefore, COBRA-IV-I is being published to provide interim capabilities to the user community. The report is structured primarily as a user manual with much of the fundamental equation and solution techniques deferred to the formal COBRA-IV documentation. It is hoped that this information will aid the COBRA-IV-I user in taking advantage of the new features now available in the code.

2.0 SUMMARY

Significant new capability has been added to COBRA since the publication of COBRA-IIIC. These can be grouped into two primary areas.

2.1 EXPANDED COBRA CAPABILITY

COBRA-IV-I includes all the previous capability of COBRA-IIIC plus significantly expanded computational capability described below.

- Very large bundles such as a full 217-pin wire-wrapped bundle can now be considered with typical running times of 5 minutes per wire wrap pitch on a CDC-7600. This has been made possible by using storage compaction techniques, auxiliary storage devices and an iterative solution procedure.
- The subchannel layout and card input for wire-wrapped bundles can be generated automatically by using an auxiliary program supplied with the code.
- The program size capability is easily changed by using an auxiliary program to generate a complete, consistent set of dimensions and common blocks according to user selected options. These can then be inserted in place of existing dimensions in COBRA to accommodate a wide range of problem sizes.
- Core analysis problems can now consider a thermally conducting wall which can conduct heat between two channels on opposite sides of the wall.
- The fuel rod heat conduction model now includes axial conduction and variable thermal conductivity. Also, each rod may now consist of several materials if desired. The storage requirement for the fuel model has been reduced by a factor of two with no loss in accuracy or increase in running time by using an orthogonal collocation numerical procedure.

- Correlations are now included to calculate the physical properties of superheated steam for water reactor applications. Heat transfer correlations are also included for subcooled, boiling and superheated conditions.
- "Dump and Restart" capabilities are now included. This allows problem solutions to be saved for subsequent use either to continue calculations or to provide an initial guess to a different problem. This feature can save significant computer time for similar problems.
- Line printer plotting capability is included to plot pressure drop, mass flux, enthalpy and/or crossflow versus axial position for all or a specified number of gaps and channels. While not suitable for hard copy, these plots can be of considerable aid in interpretating complex problems.

The two-phase flow model and implicit computational approach used previously for COBRA-IIIC are retained.

2.2 ADVANCED NUMERICAL CAPABILITY

A significantly improved numerical solution procedure has been developed for COBRA-IV to enhance its range of application. While still under development, it allows analysis of problems previously not possible with COBRA-IIIC. The basic approach uses a pressure-velocity method, which is an adaptation of the MAC methodology(2) and the Chorin-Hirt iteration procedure.(3) It differs from these approaches by an implicit coupling of the energy and momentum equation to account for convective influence on the time rate of change of density. The method is explicit relative to momentum convection; therefore, it requires a time step limitation to maintain computational stability. The algorithm under development is called the Advanced Continuous-Fluid Eulerian (ACE) method.

This advanced numerical capability is presently limited to incompressible, but thermally-expandable flows. Two-phase flows are limited to homogeneous, thermal-equilibrium conditions. Applications involving compressibility, relative phase motion and thermal nonequilibrium are being pursued under contract with the Nuclear Regulatory Commission.

The advanced numerical procedures allow new capability as follows:

- Arbitrary plenum pressure and/or flow boundary conditions can now be used to drive transients.
- The numerical solution has successfully considered bouyancy-dominated flow redistribution, flow reversals, coolant expulsion, reentry and recirculation.
- Severe flow blockages can be considered.
- All of the expanded COBRA capability mentioned previously can be used for the advanced numerical procedures under the restriction of homogeneous two-phase flow in thermal-equilibrium.
- The advanced procedure can be started from an arbitrary initial condition, one of which is the implicit COBRA-IIIC type of solution.

The sections which follow describe the basic features of COBRA-IV-I with major emphasis on the program description. Full documentation of details on the mathematical models, numerical procedures, additional experimental comparison and verification are to be presented in future reports.

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3.0 CONSERVATION EQUATIONS AND NUMERICAL SOLUTION ALGORITHMS FOR FLUID AND ENERGY TRANSPORT

The foundations of the COBRA computer programs are the conservation equations used to describe fluid and energy transport and the numerical methods employed to solve them. The conservation of mass, linear momentum, and energy are described by balance laws written for an Eulerian control volume. These governing equations, with appropriate boundary conditions and constitutive relationships, are then put into a framework for numerical solution. To provide the greatest possible computational capability and maintain the efficient use of computing facilities, the COBRA-IV code contains two numerical methods. One is an implicit technique similar to that used in COBRA-IIIC; the other, an explicit method, is new. Both algorithms have an important function and, in general, the implicit scheme is used for steady-state and slow transient simulation. The explicit method is used for transients where flows are expected to reverse direction.

The following descriptions of the applied conservation equations and numerical solution algorithms center on the description of additions and changes that have been made to COBRA-IIIC. Therefore, many details of the derivations have been omitted; however, pertinent results are summarized in all instances.

3.1 BASIC EQUATIONS

The basic equations of the mathematical model are derived by applying the general equations of continuity, energy, and momentum to a subchannel control volume. These equations were derived by Rowe[1] for subchannels in COBRA-IIIC and are also applied in the present treatment. The equations are:

Continuity

$$A \frac{\partial \rho}{\partial t} + \frac{\partial m}{\partial x} + [DC]^T w = 0 \qquad (1)$$

Energy

$$A \frac{\partial \rho h}{\partial t} + \frac{\partial mh}{\partial x} + [DC]^T h^* w = q' \qquad (2)$$

Axial Momentum

$$\frac{\partial m}{\partial t} + \frac{\partial mu}{\partial x} + [DC]^T u^* w + A \frac{\partial P}{\partial x} = F \qquad (3)$$

Transverse Momentum

$$\frac{\partial w}{\partial t} + \frac{\partial u^* w}{\partial x} + \frac{\partial v_y w}{\partial y} - [DC] P = c \qquad (4)$$

In the above equations [DC] is a matrix operator which performs the lateral finite difference operation, $[DC]^T$ is the transpose of [DC] and performs a summing operation instead of differencing,† F is the axial friction and gravity force, c is the lateral friction force, and q' is the heat transfer from all sources.

The balance equations are not complete without enumerating the restrictions and approximations that were made in their derivation. It is impractical to list all approximations that have been made to "the most general" balance laws; however, it is desirable to provide relevant limitations for those who use the COBRA code. Table 1 provides a description of the more important assumptions and restrictions that have been introduced and cites 1) the corresponding equations where they were made and 2) the terms and/or restrictions in simulation capability that are involved.

In addition to the conservation equations, it is necessary to specify fluid properties and constitutive equations to form a closed set of equations for solution. In COBRA, specifications are required for axial and lateral friction or form losses, heat transfer coefficients, coefficients for turbulent exchange, slip ratio, and an equation of state for an incompressible, but thermally expanding fluid. This is written as:

$$\rho = \rho(h, P^*) \qquad (5)$$

where P* = reference pressure.

†[DC] and $[DC]^T$ replace the notation [S] and $[S]^T$ in Reference 1.

TABLE 1. Major Assumptions and Restrictions

Assumption or Restriction	Equations Involved	Effects
Common to both numerical algorithms:		
Thermal equilibrium	All	Requires equal phase temperatures
Geometry constant in time	All	Restricts problems that can be addressed
Lateral turbulence model based on equal mass exchange	All	$w'_{ij} = w'_{ji}$
No turbulent mixing between axial nodes	All	$u' = 0$
Fluid properties are a function of h and the reference pressure	All	Thermal expansion is included but compressibility (due to local pressure changes) is not
$\delta p/\delta t$ neglected in the energy equation	Energy	No sonic propogation
Negligible heat generation within the fluid	Energy	Only mechanisms for internal energy change are heat transfer, convection, and turbulent mixing
Changes in kinetic energy assumed small	Energy	
Neglect viscous dissipation	Energy	
Neglect work against the gravity field	Energy	
Gravitational acceleration is the only body force	Momentum	Electromagnetic forces not considered
Transverse body force neglected	Transverse momentum	No lateral buoyancy effects (restricts only when flow channel not vertical)
Neglect surface tension contributions	Momentum	Requires equal phase pressures
Fluid drag forces represented by wall friction and form drag	Momentum	Fluid-fluid shear neglected (turbulent momentum exchange is modeled, however)
Neglect two of the six terms in the transverse momentum equation (see Appendix C for clarification)	Transverse momentum	Allows arbitrary lateral coupling of channels
Flow area varies linearly between axial locations	All	No step area changes
For the explicit method:		
Homogeneous fluid	Momentum and energy	Equal phase velocities, i.e., $u_g = u_l$, $V_g = V_l$
Courant restriction	All	Maximum time step limited to $\Delta t \leq \Delta x/u$
For the implicit method:		
Specified axial slip is an option; however, transverse slip is neglected	Momentum and energy	$u_g \neq u_l$, $V_g = V_l$
No reverse flow	All	Stability

(The brace groups the five "Energy" rows; the effect "Only mechanisms for internal energy change…" applies to the group of energy assumptions.)

3.2 IMPLICIT NUMERICAL SOLUTION

The implicit solution scheme is very similar to that used in COBRA-IIIC. The equations of change are solved using lumped parameter finite difference techniques. In the present treatment two new operators have been added, [S] and $[DW]^T$. The [S] operator is similar to [DC] except that [S] is the sum of two variables instead of the difference. The $[DW]^T$ operator performs the same function as $[DC]^T$ except that, where $[DC]^T$ orders subchannels by their connections, $[DW]^T$ orders subchannels and thermally conducting walls by their connections. This operator is necessary since COBRA-IV-I is capable of transferring energy between subchannels on opposite sides of a thermally-conducting wall.

Since the finite difference formulations of COBRA-IV-I differ but slightly from those given in Reference 1, the new formulations are only summarized here.

Continuity

$$\frac{A_j\ (\rho_j - \bar{\rho}_j)}{\Delta t} + \frac{m_j - m_{j-1}}{\Delta x} = -[DC]^T w_j \tag{6}$$

Energy

Coolant Energy Equation

$$\frac{A'\bar{\rho}\ (h_j - \bar{h}_j)}{\Delta t} + \frac{m_{j-1}\ (h_j - h_{j-1})}{\Delta x} + [DC]^T h_j^* w_j - h_j [DC]^T w_j$$

$$+ [DC]^T w' [DC] h_j + [DC]^T c [DC] T_j + \underline{\underline{[DW]^T U_w\ (T_{wj} - T_j)}}$$

$$= \underline{\underline{Q_A}} + q' \tag{7}$$

The underlined terms in equation (7) represent additional modes of heat transfer which were not available in COBRA-IIIC. The first underlined term accounts for energy transport between the coolant and a thermally-conducting wall. The second represents axial conduction in the fluid which is discussed in Section 4.3.

Axial Momentum

Differences in the derived axial momentum equation are the result of different algebraic manipulations of the basic equation.

The new form is:

$$\frac{m_j - \bar{m}_j}{\Delta t} + \frac{A' g_c (P_j - P_{j-1})}{\Delta x} = -K_L m_j^2 - \left(\frac{m_j u_j - m_{j-1} u_{j-1}}{\Delta x}\right)$$

$$- [DC]^T u_j {}^* w_j - [DC]^T w' [DC] u_j - gA' \rho\cos\theta \qquad (8)$$

where $$K_L = \frac{v_\ell f_\phi}{A_j^2 2D} + \frac{Kv'}{A_j^2 2\Delta x}$$

Using equation (6) and the following definitions and identities,

$$u_j = \frac{m_j v_j'}{A_j}$$

$$m^+ = \frac{(m_j + m_{j-1})}{2}$$

$$A' = \frac{(A_j + A_{j-1})}{2}$$

$$m_j^2 - m_{j-1}^2 = (m_j - m_{j-1})\, 2m^+$$

equation (8) becomes:

$$P_j = P_{j-1} + \Delta x \left\{ - \left(K_L + \frac{(v_j'/A_j - v_{j-1}'/A_{j-1})}{A' \Delta x}\right) \frac{m_{j-1}^2}{g_c} - \rho\cos\theta \right.$$

$$\left. - [DC]^T w' [DC] u_j + \frac{\rho_j - \bar{\rho}_j}{g_c \Delta t} \left(\frac{\Delta x}{\Delta t} + 2m^+ (v_j'/A_j) + K_L 2m^+ A' \Delta x\right)\right.$$

$$+ \frac{1}{A' g_c} \frac{(\overline{m}_j - m_{j-1})}{\Delta t} \Bigg\} + \Delta x \left[\left(\frac{\Delta x}{\Delta t} [DC]^T - [DC]^T u_j^* \right) \frac{1}{A'} \right.$$

$$\left. + \left(K_L \Delta x + \frac{v_j'/A_j}{A'} \right) 2m^+ \, [DC]^T \right] w_j \tag{9}$$

Transverse Momentum

The transverse momentum equation is the same as that in COBRA-IIIC; however, the $\frac{\partial v_y w}{\partial y}$ term in equation (4) has been approximated and the approximation may be used as an option. The transverse momentum equation is

$$\frac{w_j - \overline{w}_j}{\Delta t} + \frac{u_j^* w_j - u_{j-1}^* w_{j-1}}{\Delta x} + \frac{s}{\ell} c_j w_j = - \frac{s}{\ell} [S][DC]^T w_j^2 \frac{\cos\theta}{\rho^* s^2}$$

$$+ \frac{s}{\ell} [DC] P_{j-1} \tag{10}$$

As was done in COBRA-IIIC, equations (9) and (10) are combined as the resulting set of equations is solved for the crossflow w. Using the matrix notation of Reference 1, equation (9) is written as

$$\{P_{j-1}\} = \{P_j\} - \{F\}\Delta x - [R_j] \{w_j\} \Delta x \tag{11}$$

where F_j consists of the terms contained inside the {}, and R_j contains the terms inside the [] in equation (9).

Equation (10) is rearranged and written as

$$[DC] \{P_{j-1}\} = [RP] \{w\} + \{FP\} \tag{12}$$

where

$$[RP] = \left[\frac{1}{s_\ell} \left(\frac{1}{\Delta t} + \frac{u_j^*}{\Delta x} \right) + C_j \right] \tag{13}$$

and

$$\{FP\} = \left\{ [S][DC] \left\{ \frac{w_j^2 \cos\theta}{\rho^* S^2} \right\} - \frac{s}{\ell} \left\{ \frac{\overline{w}_j}{\Delta t} + \frac{u_{j-1}^* w_{j-1}}{\Delta x} \right\} \right\} \quad (14)$$

Using equation (11), the pressure difference between subchannels at elevation j-1 can be written as

$$[DC]\{P_{j-1}\} = [DC]\{P_j\} - [DC]\{F\}\Delta x - [DC][R_j]\{w_j\}\Delta x \quad (15)$$

Combining equation (15) with (12) results in the set of simultaneous equations of the form

$$[m_j]\{w_j\} = \{b_j\} \quad (16)$$

where

$$[m_j] = [DC][R_j]\Delta xt\,[RP] \quad (17)$$

and

$$\{b_j\} = [DC]\{P_j - F\,\Delta x\} - \{FP\} \quad (18)$$

To save storage, the coefficient matrix [m] of equation (16) is stored in a compressed form and the set of equations is solved by a Gauss-Seidel iteration scheme. The Gauss-Seidel method is an added internal iteration at each axial level and should not be confused with the external iteration scheme used in solving the implicit boundary value problem.

3.3 EXPLICIT NUMERICAL SOLUTION

As an alternate to the implicit solution scheme for calculating transients, a new explicit solution scheme has been developed. The explicit scheme allows the calculation of transients such as flow reversals, recirculations, and expulsion and reentry flows, with either an inlet flow or pressure drop boundary condition specified.

The method is an extension of earlier pressure-velocity solution methods, such as MAC;[2] the main departure is the incorporation of an implicit energy equation rather than the explicit equation. This was necessary to properly account for mass/energy transport across computational cells when large density gradients exist.

In the explicit solution scheme, the basic conservation equations are written for the computational cells illustrated in Figure 1. These equations are:

Continuity (Implicit)

$$A\Delta x \frac{\partial \rho}{\partial t} + [DC]^T w_j^{n+1} \Delta x + m_j^{n+1} - m_{j-1}^{n+1} = E_j^{n+1} \tag{19}$$

Energy (Implicit)

$$A\Delta x \frac{\partial \rho h}{\partial t} + [DC]^T h_k^* w_j^{n+1} \Delta x + m_j^{n+1} h_j^* - m_{j-1}^{n+1} h_{j-1}^* = Q_j \tag{20}$$

Axial Momentum (Implicit in pressure)

$$m_j^{n+1} = m_j^n - \Delta t M_j - A \frac{\Delta t}{\Delta x} g_c (P_{j+1}^{n+1} - P_j^{n+1}) \tag{21}$$

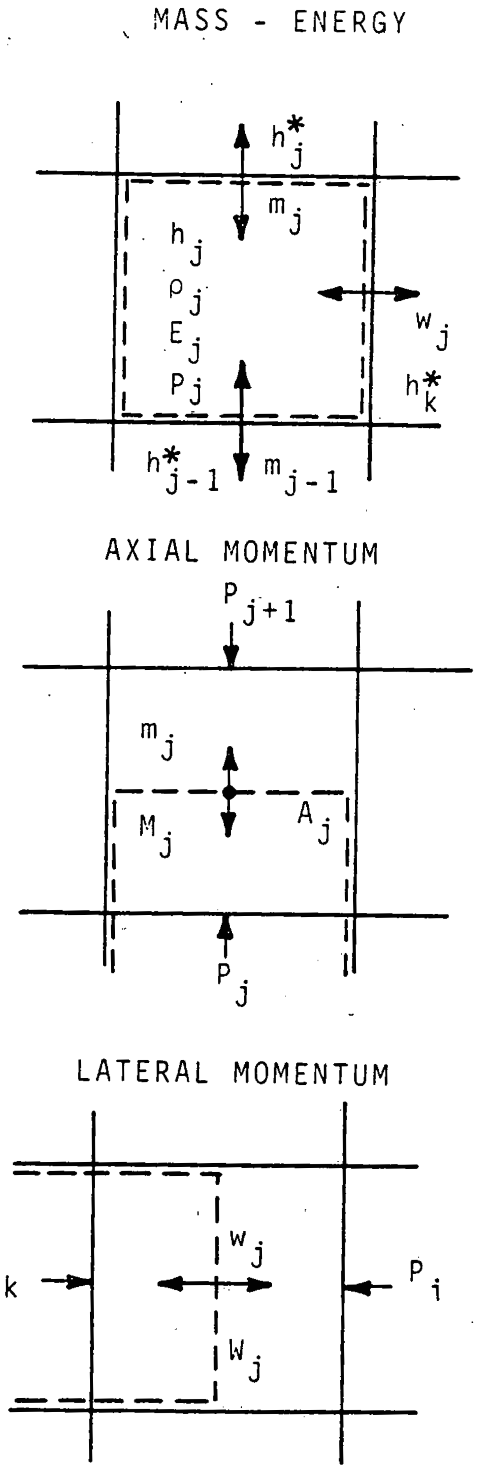
Lateral Momentum (Implicit in pressure)

$$w_j^{n+1} = w_j^n - \Delta t W_j + \frac{s}{\ell} g_c \Delta t [DC] P_j^{n+1} \tag{22}$$

The term, E_j, in equation (19) represents the error in continuity caused by incorrect flows. The miscellaneous explicit terms in equations (20) through (22) are not important in the derivation and have thus been lumped into the variables Q, M and W, respectively. The star superscript in the enthalpy in equation (20) indicates the quantity is convected by the associated flow.

In addition, an equation of state relating density to enthalpy (or internal energy) and the reference pressure is defined.

$$\rho = \rho(h, P^*) \tag{23}$$



(DASH LINES INDICATE POSITION OF MASS ENERGY CELL)

FIGURE 1. Conservation Cells for Mass, Energy, and Momentum

The following equation is derived from the energy equation (20) using equations (19) and (23).

$$E_j' = m_j^{n+1} \; v_j^* - \; m_{j-1}^{n+1} \; v_{j-1}^* + \Delta x[DC]^T \; w_j^{n+1} \; v_k^* - \Delta x \frac{\partial v}{\partial h} Q$$

$$- \Delta x A' \; \frac{\partial v}{\partial h} \; \rho_j^n \frac{\partial P}{\partial t} \tag{24}$$

In this case, E_j' represents the volume dilation or volumetric error which is to be corrected by pressure adjustment. The time derivative is absent because an Eulerian cell does not change its volume.

To form the pressure correction equation, the momentum equations (21) and (22) can be substituted for the flows in equation (24). The derivative of the result with respect to cell pressure is

$$\frac{\partial E_j'}{\partial P_j} = g \frac{\Delta t}{\Delta x} \; A\left[v_j^* + v_{j-1}^* + \frac{\Delta x^2}{A} \; \frac{s}{\ell} [DC]^T \; v_k^*[DC]\right] - A' \; \Delta x \rho_j^n \left.\frac{\partial v}{\partial P}\right|_h \tag{25}$$

The solution is accomplished by the point relaxation method where the pressure is adjusted by means of equation (25) in each computational cell to bring the volumetric dilation, E_j', to zero.

A computational cycle begins with the explicit calculation of tentative flows with the momentum equations (21) and (22) using either an initial guess for pressure or values from the previous cycle. Initial guesses for flows and pressures to be adjusted to their final values in the iterations to follow are now available.

The first step in the iteration is the calculation of the cell volume error, the dilation derivative, and any other required quantities from the initial guesses or last iterate values of the main variables. The amount of pressure change is calculated from equations (24) and (25) by

$$\delta P_j = \frac{-E_j'}{\frac{\partial E}{\partial P}} \tag{26}$$

This pressure change is employed to calculate incremental changes in flows and crossflows by use of derivatives of equations (21) and (24), respectively. The last step is the calculation of a new specific volume with equation (19) and a new enthalpy with equation (23). The iteration is terminated when the dilation, E_j', is sufficiently small.

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4.0 THERMAL TRANSPORT

In addition to the thermal transport mechanisms available in COBRA-IIIC, three new models have been added to COBRA-IV-I. These consist of:

1. a new fuel rod model in which the effects of axial conduction and variable thermal conductivity are included;
2. an axial thermal conduction model in the coolant; and
3. a wall heat conduction model which allows for energy transport between channels on opposite sides of a thermally-conducting wall.

4.1 FUEL ROD HEAT TRANSFER

The fuel rod heat transfer model in COBRA allows the computation of the rod surface heat fluxes and internal temperature distributions based on the heat generation in the fuel and the surface heat transfer coefficient.

The heat transfer model and solution method in COBRA-IV-I have changed significantly from those used in COBRA-IIIC. The primary improvement to the model is the inclusion of axial conduction and the temperature dependence of fuel thermal conductivity; this inclusion provides greater detail and allows consideration of a wider class of problems. Circumferential heat conduction is ignored to maintain a reasonable number of fuel nodes. This assumption can be justified if the heat transfer coefficients and fluid temperature distribution around a fuel rod are rather uniform.

The method of solution has also been changed to the Method of Weighted Residuals (MWR) as a replacement to the finite difference scheme in the radial direction.[4,5] Finite difference is still used for time derivatives and axial space derivatives. In MWR, orthogonal collocation is employed to determine the form of the approximate polynomial solution. MWR affords a higher order of accuracy by using the roots of orthogonal polynomials as the nodal positions where the solution is evaluated. Computer storage is reduced by a factor of two with this method while the accuracy of conventional finite difference schemes and similar computing times is maintained.

The heat conduction model in COBRA-IV is derived from the two-dimensional heat conduction equation with temperature dependent thermal conductivity. This equation is written below for both planar and cylindrical geometry with the radial coordinate nondimensionalized using the relationship r = r'/R (r' = radial coordinate and R = fuel radius):

$$\rho c \frac{\partial T}{\partial t} = \frac{1}{R^2} \frac{1}{r^{a-1}} \frac{\partial}{\partial r} r^{a-1} K(T) \frac{\partial T}{\partial r} + \frac{\partial}{\partial x} K(T) \frac{\partial T}{\partial x} + q \qquad (27)$$

a = 1 Planar

a = 2 Cylindrical

Equation (27) is reduced to a linear partial differential equation by introducing a new temperature related to T by Kirchoff's transformation:

$$\theta = \frac{1}{K_o} \int_{T_o}^{T} K(T) dT = G(T) \qquad (28)$$

(K_o = conductivity at reference temperature T_o)

The temperature dependence of the fuel thermal conductivity is supplied by a user-specified polynomial approximation. Making this substitution for the radial and time coordinates produces the transformed equation:

$$\rho c \frac{K_o}{K(T)} \frac{\partial \theta}{\partial t} = \frac{K_o}{R^2} \frac{1}{r^{a-1}} \frac{\partial}{\partial r} r^{a-1} \frac{\partial \theta}{\partial r} + \frac{\partial}{\partial x} K(T) \frac{\partial T}{\partial x} + q \qquad (29)$$

which is solved numerically in COBRA-IV by a combination of techniques.

First, the radial coordinate is approximated by the orthogonal collocation method of weighted residuals. In this method a polynomial expansion of the dependent variable is substituted into the differential equation and solved at N collocation points. In the present application, a symmetric polynomial is used:

$$\theta(r) = \sum_{i=1}^{N} (r^{2i-2}) \, d_i \qquad (30)$$

where d_i are the unknown coefficients of the expansion.

Evaluating this polynomial at the N collocation points defined by Finlayson[4] gives

$$\theta(r_j) = \sum_{i=1}^{N} (r^{2i-2})\Big|_{r_j} d_i \tag{31}$$

or, in matrix notation,

$$\{\theta\} = [Q]\{d\}$$

where

$$Q_{ji} = r^{2i-2}\Big|_{r_j}$$

From equation (31), the first derivative and Laplacian are evaluated giving:

$$\frac{d\theta}{dr}\Big|_{r_j} = \sum_{i=1}^{N} \frac{dr^{2i-2}}{dr}\Big|_{r_j} d_i \tag{32}$$

and

$$\nabla^2\theta\Big|_{r_j} = \sum_{i=1}^{N} \nabla^2(r^{2i-2})\Big|_{r_j} d_i \tag{33}$$

which, written in matrix notation with $\{d\}$ replaced by $[Q]^{-1}\{\theta\}$, gives

$$\frac{d\{\theta\}}{dr} = [C][Q]^{-1}\{\theta\} = [A]\{\theta\} \tag{34}$$

and

$$\nabla^2\{\theta\} = [D][Q]^{-1}\{\theta\} = [B]\{\theta\} \tag{35}$$

where

$$C_{ji} = \frac{dr^{2i-2}}{dr}\Big|_{r_j} \quad \text{and} \quad D_{ji} = \nabla^2(r^{2i-2})\Big|_{r_j}$$

Thus, the radial coordinate is represented by the orthogonal collocation approximation to the Laplacian (35). Additional terms in equation (29) are approximated by conventional finite difference techniques with a fully implicit time derivative and a fully explicit axial derivative.

The final equation, which is applied at the N-1 interior collocation points within the fuel, is given below. The implicit terms have been grouped on the left and the explicit terms are on the right:

Fuel Interior (i = 1 to N-1)

$$\frac{\rho c}{\Delta t} \frac{K_o}{K_i} \theta_i^{n+1} - \frac{K_o}{R^2} \sum_{L=1}^{N} B_{iL} \theta_L^{n+1} = \frac{\rho c}{\Delta t} \frac{K_o}{K_i} \theta_i^{n} + q \tag{36}$$

$$+ \frac{2}{\Delta x^2 \left(\frac{1}{K_{\ell-1}} + \frac{1}{K_i}\right)} (T_{\ell-1} - T_i) + \frac{2}{\Delta x^2 \left(\frac{1}{K_{\ell+1}} + \frac{1}{K_i}\right)} (T_{\ell+1} - T_i)$$

where n denotes previous time, $\ell+1$ and $\ell-1$ denote adjacent axial levels, and K_i is K(T) at radial position i.

The boundary conditions at the fuel and clad surfaces, N and N+1, respectively, are handled by a lumped parameter technique similar to that used in COBRA-IIIC. The time and axial derivatives are approximated by conventional finite differencing, whereas the radial derivative is approximated using the orthogonal collocation equation (34).

Fuel Surface (i = N)

$$\frac{-K_o}{R^2} \sum_{L=1}^{N} A_{N,L} \theta_L = H_{gap} (T_N^{n+1} - T_{N+1}^{n+1}) \tag{37}$$

where

$$\frac{1}{H_{gap}} = \frac{1}{h_{gap}} + \frac{t_{clad}}{K_{clad}}$$

Clad Surface (i = N+1)

$$\frac{(\rho c)_{clad}}{\Delta t}\frac{K_o}{K_i}\theta_i^{n+1} = \frac{(\rho c)_{clad}}{\Delta t}\frac{K_o}{K_i}\theta_i^{n} + \frac{K_{clad}}{\Delta x^2}(T_{\ell+1}^n - 2T_i^n + T_{\ell-1}^n) \tag{38}$$

$$+ \frac{H_{gap}CR^*}{t_{clad}}(T_N^{n+1} - T_{N+1}^{n+1}) - \frac{H_{surf}}{t_{clad}}(T_{N+1}^{n+1} - T_{fluid})$$

The set of equations (36, 37, and 38) defining the differential equation and boundary conditions is solved by an iterative procedure. The temperatures T_N^{n+1} and T_{N+1}^{n+1} appearing in the equations are evaluated via an iterative Newton-Raphson technique:

$$T_j = \hat{T}_j - \frac{G(\hat{T}_j)}{G'(\hat{T}_j)} + \frac{\theta_j}{G'(\hat{T}_j)} \tag{39}$$

where ^ denotes the previous iteration value, G is defined by equation (28), and G' is the derivative of G with respect to T. The term containing θ_j is substituted on the implicit side of the boundary equations with the other two terms evaluated explicitly from the previous iteration solution. Once the θ solution is determined, an inverse transformation is performed to obtain the true temperature solution.

Figure 2 shows the nodal positions for a 2nd order approximation in a cylindrical rod. Nodes i = 1 to i = 3 are positioned at roots of the specified polynomial expansion with node i = 4 at the clad surface.

*CR is the fuel-clad diameter ratio in cylindrical geometry and equals 1.0 for planar geometry.

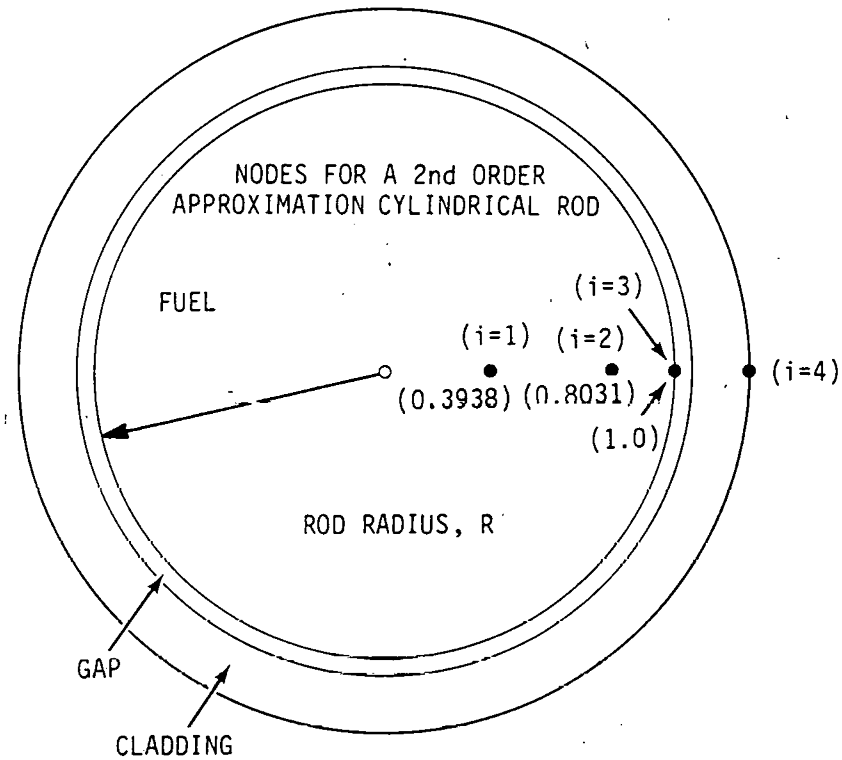

FIGURE 2. Fuel Rod Noding Using Orthogonal Collocation

4.2 HEAT TRANSFER THROUGH CONDUCTING WALLS

The model uses a single node lumped parameter representation of the wall region as shown in Figure 3. The finite difference form of energy balance on the wall is

$$(\rho C_p \Delta Y)_w \frac{(T_w - \overline{T}_w)}{\Delta t} = -U_i \ (T_w - T_i) + U_j \ (T_w - T_j) \tag{40}$$

where the temperature and thermal properties of the wall are denoted by a w subscript.

The effective heat transfer coefficients U_i and U_j for subchannels i and j, respectively, are defined by the expression

$$\frac{1}{U_k} = \frac{1}{h_k} + \frac{\Delta y_k}{k_w} \tag{41}$$

where

h_k = the subchannel surface heat transfer coefficient as calculated by subroutines PROP or HTCOR.

$\frac{\Delta y_k}{k_w}$ = an input heat conduction parameter

$(\rho C_p \Delta Y)_w$ = an input wall heat capacity parameter

In the implicit scheme, equation (40) is rewritten in the following form

$$\frac{(\rho C_p \Delta Y)_w}{\Delta t} + U_i - U_j \quad T_w - \frac{U_i h_i}{C_{pi}} + \frac{U_j h_j}{C_{pj}} = (U_j - U_i)\left(\frac{h_o}{C_{pi}} - T_o\right) \qquad (42)$$

$$+ \frac{(\rho C_p \Delta Y)_w}{\Delta t} \quad \bar{T}_w$$

where h_o and T_o are reference values.

Considering each wall to be a non-flowing subchannel, equation (42) can be combined with equation (7). The resulting set of equations can be represented by

$$[A]\{x\} = \{b\} \qquad (43)$$

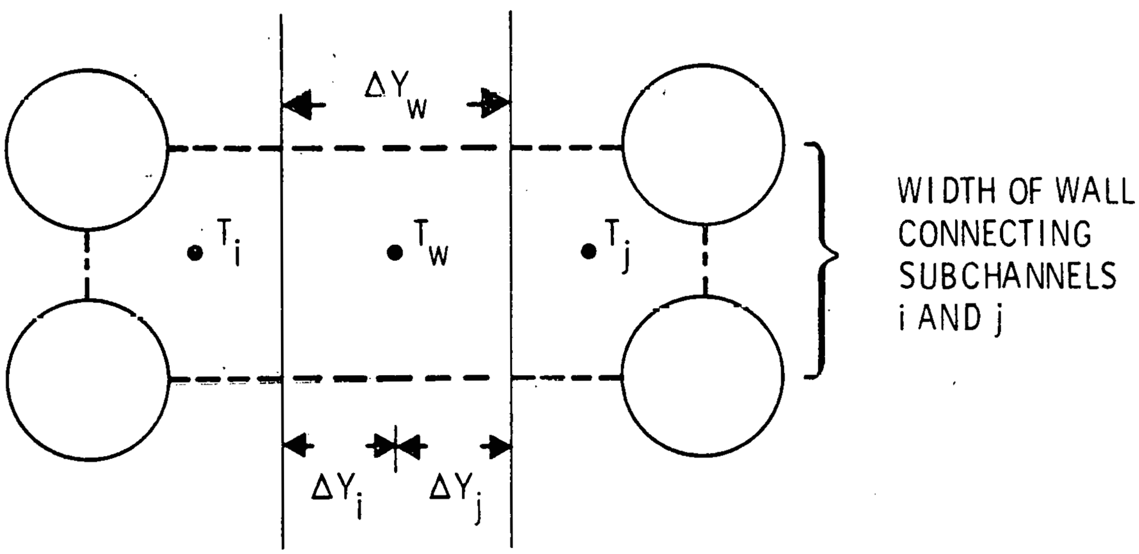

FIGURE 3. Single Node Model of Conducting Wall

where

[A] = an LxL coefficient matrix composed of all of the terms on the left side of the equal sign in equations (42) and (7).

[x] = vector of unknown wall temperatures and subchannel enthalpies.

{b} = vector of forcing functions composed of the terms on the right side of equations (42) and (7).

L = number of subchannels plus number of wall connections.

In the COBRA-IV-I code, equation (43) is solved using a Gauss-Seidel iteration procedure because, in order to reduce storage requirements, [A] is stored in a packed form similar to that used in the crossflow solution.

In the explicit scheme equation (43) is written in the form

$$T_w^{N+1} = (-U_i \; (T_w^{\,N} - T_i^{\,N}) + U_j \; (T_w^{\,N} - T_j^{\,N})) \frac{\Delta T}{(\rho C_p \Delta Y)_w} + \bar{T}_w$$

The heat transfer between the wall and the subchannel is included in the lumped explicit terms of equation (20).

4.3 COOLANT AXIAL CONDUCTION MODEL

The finite difference form of the coolant axial conduction model is

$$Q_A = \frac{-A_{j-1} \; C(T_j - T_{j-1})}{\Delta x^2} + \frac{A_j \; C(T_{j+1} - T_j)}{\Delta x^2}$$

This term is carried explicitly in both the implicit and explicit formulations. In the implicit scheme, Q_A is evaluated using values of T_j and T_{j-1} from the previous external iteration. In the explicit scheme the values of T_j and $\bar{T}_{j-1}$ are from the previous time step.

5.0 CONSTITUTIVE RELATIONSHIPS

In addition to the conservation laws several constitutive relationships must be specified to close the set of equations to be solved. These empirical and semiempirical correlations defining such phenomena as turbulent mixing, frictional losses, and two-phase flow have been retained as in the COBRA-IIIC code.

New correlations have been added to accommodate a broader range of application for the code. For example, the calculation of fuel rod temperatures in COBRA requires the specification of heat transfer coefficients at the clad surface. To meet this requirement for water cooled reactors, the correlations and basic selection logic contained in the RELAP4 computer program[6] have been incorporated into the COBRA-IV-I code.

Selection of the appropriate heat transfer correlation is based on several criteria. The first is an evaluation of the physical state of the fluid to determine which regime of heat transfer is occurring (e.g., forced convection, film boiling, etc.). The second is the evaluation of the critical heat flux (CHF) and the clad temperature that would exist at this heat flux to determine whether the pre-CHF or post-CHF correlations are appropriate. The third criterion is the comparison of two or more calculated heat transfer coefficients to select the proper coefficient in regions where correlations overlap.

Another addition to COBRA is the inclusion of a routine to calculate the properties of superheated steam to allow computations over a wider range of conditions.

The constitutive relationships used in the program are described in more detail in Appendix B.

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6.0 PROGRAM DESCRIPTION

The organization of COBRA-IV-I has changed significantly from that of its predecessor, COBRA-IIIC, with the addition of many new subroutines and calculational procedures. The most striking difference is the addition of an explicit solution scheme as an alternate to the implicit solution scheme retained from COBRA-IIIC. Also, much storage compaction has been achieved through overlapping variable storage techniques and use of peripheral storage devices. Improved running time has also been achieved through code optimization and changes in the basic solution algorithm. These improved capabilities are discussed in this section.

6.1 ORGANIZATION

The overall organization of the code can best be described by the flow chart in Figure 4. Following initializing calculations in the main program, subroutine SETUP is called. SETUP reads the input, calculates subchannel variables and sets up connection logic defining the geometry of the subchannel array. The input is then printed in a format similar to that of COBRA-IIIC.

After returning to the main program the code begins calculations according to the user-selected implicit or explicit solution schemes. For most cases except a zero initial flow transient, the implicit solution scheme is called first to calculate the initial or steady-state conditions. As in COBRA-IIIC, subroutine SCHEME is called to carry out the implicit calculations. The overall calculational procedures used for the implicit calculations have been maintained as in COBRA-IIIC; however, the solution algorithm has changed from a matrix inversion technique to an iterative procedure which greatly reduced the computer core storage requirements of COBRA-IV-I.

The results of the steady-state calculations are printed by subroutine RESULT with a format similar to COBRA-IIIC, after which the transient calculations begin according to the user-selected implicit or explicit solution schemes.

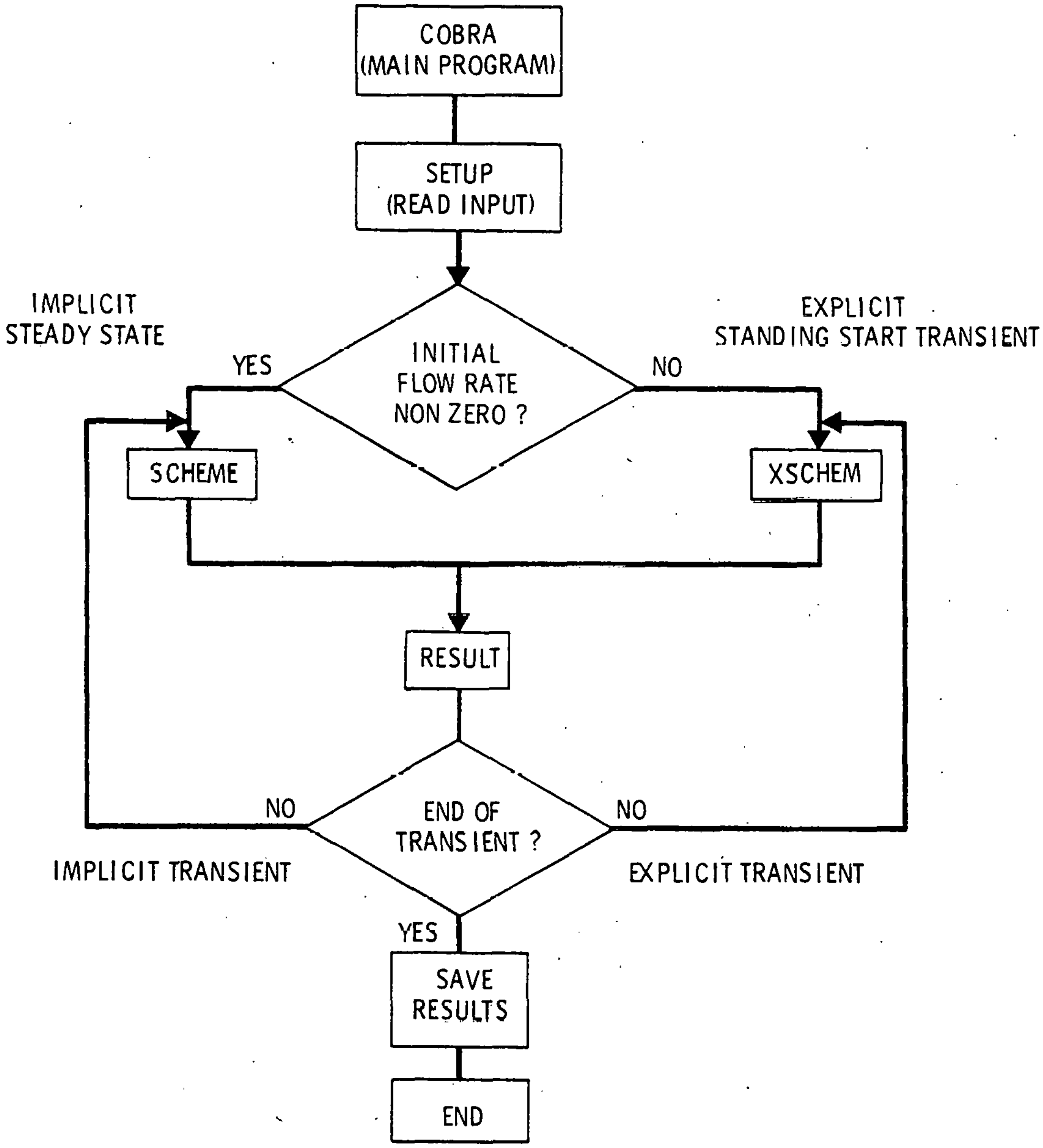

FIGURE 4. COBRA-IV-I Flow Diagram

When performing explicit transient calculations, subroutine XSCHEM is called. This new subroutine performs the calculations with either an inlet flow or pressure drop boundary condition, and can consider reverse flows not possible with the implicit solution scheme.

The results after user-selected intervals are printed in subroutine RESULT with the calculations continuing until the end of the transient. When the calculations are completed, the solution is saved on tape or disc for subsequent processing if desired.

A description of the subroutines used in COBRA is given in Appendix A, along with flow charts of the implicit and explicit solution schemes.

6.2 LARGE BUNDLE CAPABILITY

One of the main objectives of the COBRA-IV developmental effort was to decrease the computer core storage requirements and execution time of COBRA-IIIC in order to handle large bundles. This has been accomplished through the use of a number of storage compaction schemes and code optimization techniques, including:

- elimination of the large triple-nested DO loops from COBRA-IIIC;
- replacement of many external subroutine calls with more efficient internal statement functions;
- replacement of the implicit matrix crossflow solution with an iterative solution;
- an option to use peripheral storage devices (disc or drum) to temporarily store most of the calculational variables.

The following sections describe some of the specific changes made to reduce storage and running time.

6.2.1 Allocation and Compaction

Storage within COBRA has been compacted significantly by using EQUIVALENCE statements and by reducing the size of matrices containing a significant number of zeros. Tables 2 and 3 summarize the present EQUIVALENCE relationships used in the main storage area of COBRA. They are listed in blocks since portions of the core are overwritten several times with variables as required during input, execution, and output.

The first block is used to store input. Once input is read and printed, the DATIN vector is written to disc (or drum) to be saved for later use if needed. In the second block, variables dimensioned in the axial direction are equivalenced to a large vector SAVEAL. This vector is also equivalenced in Block 4 to SAVEA1, SAVEA2 and SAVEA3 which correspond to the spatial variables at axial positions J-1, J and J+1, respectively. SAVEAL and the equivalenced variables in Block 4 are used to transfer the axially dimensioned variables between core and disc (or drum) for large problems.

In the third block, arrays required for temporary variable storage are equivalenced to Block 2 variables not required during intermediate calculations. A significant reduction in core storage requirements has been achieved through this procedure.

One other type of equivalencing, not shown in Table 2, is the case where doubly-dimensioned arrays are equivalenced to singly-dimensioned variables having the same definition as the doubly-dimensioned array. This procedure significantly reduces the running time on a CDC-7600 machine because much of the arithmetic needed to locate the variable can be done outside of DO loops.

The layout of the common storage area LARGE 1, which contains most of the variables discussed in Table 2, is shown in Table 3.

TABLE 2. EQUIVALENCE Relationships

BLOCK	EQUIVALENCE		DESCRIPTION
	DATIN(1)	UB(1,61)(1)	BLOCK 1
	AC(1)	DATIN(1)	Input Data
	PW(1)	STUW(1,61)	
	PH(1)	AP(1,61)	Dimensioned by Channels (MC)
	DC(1)	QPRIM(1)	MC(2) = 18
1	DR(1)	V(1)	Dimensioned by Rods MR = 7
	HINLET(L)	VPA(1)	Dimensioned by Channels
	FINLET(1)	VISC(1)	MC = 18
	TINLET(1)	VISW(1)	
	LC(1,1)	HFILM(1)	Dimensioned by Channels
	GAPS(1,1)	PERIM(1)	and 4 Connections
	DIST(1,1)	AAA(1,4)	(18 x 4)
	W(1,1)	SAVEAL(1)	
	WOLD(1,1)	SAFEAL(25)	BLOCK 2
	BETA(1,1)	SAFEAL(49)	Axially Dependent
	BSAVE(1,1)	SAVEAL(73)	Variables
	PSI(1,1)	SAVEAL(97)	Dimensioned by Gaps (MG)
	GAP(1,1)	SAVEAL(121)	MG = 24
	TRF(1,1)	SAVEAL(145)	
	TWALL(1,1)	SAVEAL(169)	Dimensioned by Wall Connections (MW)
	TWOLD(1,1)	SAVEAL(172)	MW = 3
	CHFR(1,1)	SAVEAL(175)	
	CCHANL(1,1)	SAVEAL(193)	Dimensioned by Rods
2	FLUX(1,1)	SAVEAL(211)	MR = 18
	HSURF(1,1)	SAVEAL(229)	
	MODE(1,1)	SAVEAL(247)	
	TROD(1,1,1)	SAVEAL(265)	Dimensioned by Rods and Fuel Nodes (MN = 6) (6 x 18) = 100
	P(1,1)	SAVEAL(373)	
	F(1,1)	SAVEAL(391)	
	RHO(1,1)	SAVEAL(409)	
	HOLD(1,1)	SAVEAL(427)	
	A(1,1)	SAVEAL(445)	
	DHYD(1,1)	SAVEAL(463)	Dimensioned by Channels
	H(1,1)	SAVEAL(481)	MC = 18
	FOLD(1,1)	SAVEAL(499)	
	RHOOLD(1,1)	SAVEAL(517)	
	RHOBAR(1,1)	SAVEAL(535)	
	UB(1,1)	SAVEAL(553)	
	STUW(1,1)	SAVEAL(571)	
	AP(1,1)	SAVEAL(589)	

(1) For location in Common Storage Area see Block 2 and Table 3.
(2) See Program SPECSET (Appendix D) for description of dimensioning parameters.

TABLE 2. Continued

BLOCK	EQUIVALENCE		DESCRIPTION
	MARK(1,1)	BETA(1,1)	
	DTII(1)	BSAVE(1,1)	
	US(1,1)	PSI(1,1)	
	USW(1,1)	PSI(1,1)	
	SP(1,1)	TRF(1,1)	
	IFTYP(1,1)	CHFR(1,1)	
	RSTW(1,1)	P(1,1)	
	TERM2(1)	STUW(1,1)	
	DTJJ(1)	BSAVE(1,2)	
	DPK(1)	STUW(1,2)	
	WSAVE(1)	BSAVE(1,3)	BLOCK 3
	FLOW(1)	STUW(1,3)	<u>Temporary Variable Storage</u>
3	SUML(1)	VISC(1)	
	SUMX(1)	VISCW(1)	(In order as variables are stored in COMMON, see Table 3)
	TERM1(1)	VISCW(1)	
	DPDX(1)	CON(1)	
	STWJM1(1)	CON(1)	
	DHDX(1)	CP(1)	
	SUMR(1)	CP(1)	
	DFDX(1)	FSP(1)	
	DPWP(1)	FSP(1)	
	HJMO(1)	FSP(1)	
	STWJ(1)	FSP(1)	
	PHI(1)	FSP(1)	
	B(1)	WP(1)	
	CIJ(1)	WP(1)	
	WPP(1)	WP(1)	
	WPP(1)	WP(1)	
	AAH(1)	AAA(1,1)	
	ISTAR(1)	FDIV(1)	COMMON/BGRID/
	IFDIV(1)	FDIV(1)	
	SAVEA1(1)	SAVEAL(1)	BLOCK 4
	SAVEA2(1)	SAVEAL(607)	<u>SAVEAL Storage variables</u>
4	SAVEA3(1)	SAVEAL(1213)	Used to store axial information at the J-1, J and J+1 axial levels.
	SAVERES(1)	SAVEA2(1)	

TABLE 3. Storage Location of EQUIVALENCE Variables

Common / LARGE 1 / SAVEAL(36966),(1) QPRIM(18), V(18), VPA(18), VISC(18), VISW(18), HFILM(18), CON(18), CP(18), FSP(18), PERIM(18), HPERIM(18), WP(24), AAA(7,24)

Number Axial Levels (MX)	= 61	Number Gap Connections (MG)	= 24
Number Channels (MC)	= 18	Geometry, Square Array (MO)	= 7

(1) The size of SAVEAL is computed as the number of storage locations needed to accommodate all equivalenced variables (W through AP) at one axial level (606), times the total number of Axial Levels (61).

6.2.2 Iterative Solution

Another significant compaction of storage is the reduction of the crossflow coefficient matrix AAA(K,K) to an equivalent AAA(L,K) matrix, where K is the number of gap connections and L is either 7 for square arrays or 5 for hexagonal arrays. This was made possible by replacing the matrix solution algorithm with an iterative solution technique. Any row of AAA has no more than 7 nonzero elements. The diagonal elements AAA(K,K) are transferred to AAA(1,1) and succeeding nonzero values fill in rows 2 through 7 by using the gap location array LOCA.

The array LOCA, dimensioned as LOCA(L+1,K), is used to store gap connection information. The first row, LOCA(1,K), is the gap number K. The next rows, LOCA(2,K) through LOCA(L,K), give the adjacent gap numbers. The last row, LOCA(L+1,K), gives the number of gaps adjacent to gap k; or, in terms of the array, it gives the number of nonzero elements in LOCA(1,K) through LOCA(L,K) for each K. The storage savings resulting from this technique can be appreciated when it is realized that the storage requirements for AAA are reduced from $419,904_{10}$ to 3240_{10} for a full 217-pin LMFBR bundle.

6.2.3 External Devices

The user has the option of "rolling" axially dimensioned variables between core and disc (or drum) as the iteration procedure successively sweeps the channel. This is required for large problems to keep core storage within present machine capability. The rolling procedure is accomplished by using two storage devices. One disc is read for previous iterate information while updated information is written to the other. The input/output identification is then swapped for the next iteration. The same discs used to store the first record are used for DATIN array storage.

6.3 USER CONVENIENCE FEATURES

Several user-related features have been added to COBRA, which simplify the operation and handling of the code. Several of these are discussed here.

6.3.1 Dump and Restart Option

A problem "dump and restart" option incorporated in COBRA-IV-I allows the calculated solution to be saved (dumped) and retrieved (restarted). This option can be used either to continue calculations on a solution or to use a previous solution as an intitial guess in a new calculation.

This option is valuable when performing parametric studies because it greatly reduces the number of calculations for subsequent runs. Many types of restarts are possible; however, the bundle geometry must be the same between the saved and restarted run. The restart options are illustrated in the discussion of subroutine RESTRT in Appendix A.

6.3.2 Program SPECSET - Code Redimensioning Program

To minimize the computer core storage requirements of COBRA, an auxiliary program was developed to redimension the code. Program SPECSET performs this function by redefining the dimension statements used by the code. Input to SPECSET defines the maximum problem size and desired code options used in determining the size of COBRA's dimensioned arrays. SPECSET generates card images of COBRA's common blocks and dimension statements and also calculates the necessary parameters for a complete set of equivalence statements consistent with the new dimensions. The program is described in detail in Appendix D.

6.3.3 Program GEOM - Code Input Generation

The auxiliary program GEOM calculates COBRA input for hexagonal rod bundles. Input to the program defining the bundle geometry is used to generate cards or card images of a majority of the required COBRA input. The subchannel and rod layouts (Groups 4 and 8) and the wire wrap information (Group 7) are all calculated by the GEOM routine. An option in COBRA allows this input to be read from an alternate device on which the GEOM output may be stored. A description of the program and the input instructions are given in Appendix E.

6.4 MACHINE REQUIREMENTS

The machine size requirements for COBRA are problem-dependent due to the code redimensioning and peripheral storage options available. The code has been set up and run on CDC-6000 and 7000 machines using FORTRAN-IV.

The central memory requirement for the published version is $202{,}000_8$ words. In addition, peripheral devices are required for input, output and four scratch units. The largest version of the code executed to date was dimensioned for a full 217-pin wire-wrapped bundle requiring $275{,}000_8$ words of central memory. The code is also set up to utilize large core memory (LCM) on CDC-7600 machines so that central memory requirements do not represent a practical limit to problem size.

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7.0 COBRA INPUT DESCRIPTION

The COBRA-IV-I input has expanded to accommodate the increased capabilities and options in the code. An attempt was made to make IIIC input decks compatible with COBRA-IV-I; in most instances, a few card changes will suffice in converting IIIC decks.

The input instructions in this section are ordered as the input is encountered by the code. An identifying label is assigned to each data card or card type (if multiple cards read). A list of the variables and the format under which they are read follows. The label is composed of the name of the subroutine where the read takes place and the relative order of occurrence in that subroutine, (e.g., COBRA.1). Optional data are included in the order they are encountered, with the criterion for inclusion into the data deck stated in the description.

Beginning with card label SETUP.1, the data are clustered into 12 groups similar to the IIIC groups. Each group is accessed by reading a group control card of the form

READ(I2,1), NGROUP, N1,N2,N3,N4,N5,N6,N7,N8,N9
where NGROUP = Group number
N1-N9 = integer options used in the group.

The group cards are labeled in the usual way, (e.g., SETUP.2). The labeling of data read within that group follows the convention of appending a sequence number to the group label, (e.g., SETUP.2.3 is the label of the third card or card type read in Group 2).

Several user-specified empirical correlations are input to COBRA. To clarify which correlation is desired, the empirical correlations are described in Appendix B. To further assist the user in setting up the input, many of the calculation parameters have been set to a default value which will be used by the code if the user leaves the parameter input field blank. The parameters which have defaulted values are specified in the input instructions and the default value is given. Since most parameters with default values affect the "stability" of the solution, it is recommended that the default value be used until familiarity with each parameter is reached. As an aid to the user, a description of the important code variables is presented in Appendix F. Finally, a number of sample problems have been included in Appendix G showing many of the options described in this report.

It is hoped that the information provided will aid the user in utilizing COBRA-IV-I to its fullest potential.

INPUT INSTRUCTIONS

DATA CARD OR GROUP CONTROL CARD

Card Label	Variables	Format and Explanation
COBRA.1	MAXT	FORMAT (I5)
		Must be the first data card of the input deck. Read only once.
	MAXT	= The computer time limit (sec$_8$) allowed for problem calculations. Computer CP time limit must be greater than MAXT to allow for printing of results if MAXT is exceeded. Negative MAXT indicates a "Restart" problem from a previously stored solution.
RESTRT.1	NJUMP, NA, IT, NTT, TTT	Format (4I5, F5.0)
→	Optional input - MAXT negative	
	Restart options, where:	
	NJUMP	= Restart flag. NJUMP = 0; continue calculations on a previous steady-state or transient solution, do not read in any additional data. NJUMP = 1, new problem calculation with a previous solution as the first computational guess or continue calculations on a previous solution reading additional data from subroutine setup. NJUMP = 2, read dump tape, print input and results then STOP. NJUMP = 3, same as NJUMP = 0, but all the input data is printed.

Card Label	Variables	Format and Explanation
	NA	= Number of additional iterations for implicit solution scheme. May be reset in setup if NJUMP = 1.
	IT	= 1, begin a transient solution at time zero from a previous steady-state solution, must read in transient data from setup. For other restart cases, IT = 0.
	NTT	= Number of additional time steps allowed, regardless of IT. May begin a transient or continue a transient.
	TTT	= Total additional transient time (sec).
SETUP.0	KASE, J1, TEXT Format (2I5,17A4)	
	Case control card, where:	
	KASE	= Problem case number. K > 0, begin case with core initialized to zero. K < 0, use previous case solution as first guess. K = 0, STOP.
	J1	= Print option for input data. J1 = 0, print only new input data. J1 = 1, print all input data. J1 = 2, print only operating conditions. J1 = 10, print all input data, then stop.

Card Label	Variables	Format and Explanation
	TEXT	= Output text for problem identification, maximum 68 characters.

* * * * BEGIN GROUP INPUT DATA * * * *

SETUP.1 GROUP 1 PROPERTY TABLE Format (10I5)

	N1	= NPROP, number of property cards to be read.
	N2	= ISTEAM. N2 = 0, no superheated steam properties. N2 = 1, N1 superheated steam properties are calculated.
	N3	= Superheated steam property range. Not applicable if N2 = 0. Default, for N3 = 0, Code calculates N1 superheated steam properties from the saturation temperature at the system pressure to 1500°F. For N3 = 1, Code calculates N1 properties over a temperature range specified by DTMAX (SETUP.1.2).

SETUP.1.1 PP(I), TT(I), VVF(I), VVG(I), HHF(I), HHG(I), UUF(I), KKF(I), SSIGMA(I)

(I = 1 to N1) Format (E5.2, F5.1, 7F10.0)

Read in N1 saturated liquid and vapor property cards, where

	PP	= system pressure (psia)
	TT	= Temperature (°F)
	VVF	= Liquid specific volume (ft^3/lb)
	VVG	= Vapor specific volume (ft^3/lb)

Card Label	Variables	Format and Explanation
	HHF	= Liquid enthalpy (Btu/lb)
	HHG	= Vapor enthalpy (Btu/lb)
	UUF	= Liquid viscosity (lb/ft-hr)
	KKF	= Liquid thermal conductivity (Btu/hr-ft-°F)
	SSIGMA	= Surface tension (lb_f/ft)
SETUP.1.2	DTMAX Format (F5.3)	
→	Optional Input - N2 = 1 and N3 = 1	
	DTMAX	= The temperature range over which the superheated steam properties are to be calculated. DTMAX = (T - T saturation), where T is the maximum temperature desired. Default for N3 = 0 is T = 1500°F.
SETUP.2	GROUP 2 FRICTION FACTOR AND TWO PHASE FLOW CORRELATION Format (10I5)	
	N1	= J2. The Subcooled Void Formation Correlation. N1 = 0, no subcooled voids. N1 = 1, subcooled voids are calculated using Levy's subcooled void model.
	N2	= J3. The Void Fraction Correlation. N2 = 0, the homogeneous model. N2 = 1, Modified Armand Model. N2 = 5, the slip model, must read in a slip ratio. N2 = 6, read in number of terms and coefficient for up to a 6th order polynomial function of void fraction versus steam quality.

Card Label	Variables	Format and Explanation
	N3	= J4. Two Phase Friction Multiplier. N3 = 0, The Homogenous Model. N3 = 1, Armand Model. N3 > 4, read in number of terms and coefficients for up to 6th order polynomial function of the two phase multiplier versus quality.
	N4	= NVISCW. Wall Viscosity Correlation. N4 = 0, no heated wall correlation in friction factor. N4 = 1, include heated wall correlation in friction factor.
	N5	= LAMNF, laminar friction factor. N5 = 0, no laminar correlation. N5 = 1, read in up to 4 sets of laminar friction factor correlation constants.
	N6	= Rod-to-coolant single phase heat transfer coefficient option. N6 = 0, Dittus-Boelter Correlation used. N6 > 0, read a user-supplied correlation.
SETUP.2.1	AA(I), BB(I), CC(I) (I = 1 to 4) Format (12F5.3)	

Turbulent friction factor coefficients. Read up to 4 sets where:

AA, BB, CC = the constants of the correlation in the form $f = AA(R_e)^{BB} + CC$. The 4 sets correspond to up to 4 subchannel types.

DATA CARD OR GROUP CONTROL CARD (Continued)

Card Label	Variables	Format and Explanation
SETUP.2.2	AAL(I), BBL(I), CCL(I) (I = 1 to 4) Format (12F5.3)	
→	Optional input - N5 = 1.	
	Laminar friction factor coefficients.	
	AAL, BBL, CC1	= Constants for laminar friction factor correlation. Same specification as SETUP.2.1.
SETUP.2.3	AH(I) (I = 1 to 4) Format (12F5.3)	
→	Optional Input - N6 > 0	
	AH	Coefficients for a single phase heat transfer correlation of the form: $h = (K/D)\ (AH(1)\ R_e^{AH(2)} Pr^{AH(3)} + AH(4))$ For N6 $\leq$ 0, AH(I) defaults to 0.023, 0.8, 0.4 and 0.0 for AH(1) through AH(4), respectively.
SETUP.2.4	NV, AV(I) (I = 1 to 7) Format (I5, 7E10.5)	
→	Optional Input N2 > 4.	
	Slip ratio and void fraction correlation, where:	
	NV	= polynomial order for the void fraction correlation if N2 = 6. If N2 = 5, NV is not used.
	AV	= If N2 = 5, AV(1) is a single term slip ratio. If N2 = 6, read AV(I), I = 1 to NV coefficients for up to 6th order polynomial function of void fraction versus steam quality.

DATA CARD OR GROUP CONTROL CARD (Continued)

Card Label	Variables	Format and Explanation
SETUP.2.5	NF, AF(I) (I = 1 to 7) Format (I5, 7E10.5)	
→	Optional Input - N3 > 4	
	Two phase friction multiplier, where:	
	NF	= The number of terms for the polynomial function of quality.
	AF	= Constants for up to 6th order polynomial function of the two-phase friction multiplier versus steam quality.
SETUP.3	GROUP 3 AXIAL HEAT FLUX TABLE Format (10I5)	
	N1	= NAX, number of entries in heat flux table.
SETUP.3.1	Y(I), AXIAL(I) (I = 1 to N1) Format (12F5.3)	
	Axial heat flux table, where:	
	Y	= Relative position (X/L) at which heat flux is given, where L is the total length of the bundle. Must include 0.0 and 1.0 as end points.
	AXIAL	= Relative heat flux at (X/L). (Local flux/ average flux).
SETUP.4	GROUP 4 CHANNEL LAYOUT AND DIMENSIONS Format (10I5)	
	N1	= Number of data cards of subchannel information to be read. One card for each subchannel, unless already assigned (e.g., restart case).

Card Label	Variables	Format and Explanation
	N2	= Total number of subchannels, regardless of N1.
	N3	= Option to specify N3 relative direction angles for crossflow between adjacent subchannels.
	N4	= Number of thermal connections.
	N5	= Logical unit from which card set SETUP.4.1 is to be read. N5 = 0, read from input deck. N5 > 0, read cards from logical unit N5. Recommend N5 = 9 if cards are not specified.
	N6	= Logical unit from which card set SETUP.4.3 is to be read. N6 = 0, read from input deck. N6 > 0, read cards from logical unit N6. Recommend N6 = 9 if cards are not specified.
SETUP.4.1	[N, I, AC(I), PW(I), PH(I), [LC(I,L), GAPS(I,L), DIST(I,L), L = 1 to 4], I = 1 to N1] Format [I1, I4, 3E5.2, 4(I5, 2E5.2)]	
	Read N1 cards of Channel Geometry, where:	
	N	= Subchannel type. If blank or zero, type 1 is assigned. If N > 0, type N is assigned. N $\neq$ 4. The subchannel type indicates the appropriate friction factor correlations to be used. (SETUP.2.1, SETUP.2.2).
	I	= Subchannel identification number.
	AC	= Nominal subchannel area (in^2).
	PW	= Nominal subchannel wetted perimeter (in).

Card Label	Variables	Format and Explanation
	PH	= Nominal subchannel heated perimeter (in).
	LC	= Adjacent subchannel identification number, for up to 4 subchannels adjacent to subchannel I. If the subchannels are input with ascending identification numbers, only connections LC(I,L) > I need be read in.
	GAPS	= The nominal GAP width between subchannel I and the adjacent subchannel specified by LC (in).
	DIST	= Centroid-to-centroid distance between the adjacent subchannels specified by LC (in). Required only if N1 = 3 in Group 10 (SETUP.10).

SETUP.4.2 [KW, RHOLCP(KW), WIDTH(KW), IKW(KW), RWALL(1,KW), JKW(KW) RWALL(2,KW), KW = 1 to N4] Format [2X, I3, 2E5.2, 2(I5,E5.2)]

Optional Input - N4 > 0

Thermal connection data for subchannels with thermal wall connections.†

Variables	Format and Explanation
KW	= Thermal connection number.
RHOLCP	= Wall heat capacity parameter (Btu/ft^2-°F).
WIDTH	= Width of wall (in). Heat conduction area = WIDTH x DX.
IKW,JKW	= Subchannel numbers adjacent to wall.

†See Appendix B for definitions.

DATA CARD OR GROUP CONTROL CARD (Continued)

Card Label	Variables	Format and Explanation
	RWALL(1,KW),	
	RWALL(2,KW)	= Conductive resistance of the wall associated with the IKW and JKW subchannels, respectively (ft^2-sec-°F/Btu).
SETUP.4.3	K, ANGLE(K) Format [5(I5, F5.0)]	
	Optional Input - N3 > 0	
	Read N3 pairs of values, where:	
	K	= GAP no. for which the directed cross-flow is specified.
	ANGLE	= Relative direction of positive cross-flow through GAP K, in positive degrees.
SETUP.5	GROUP 5 SUBCHANNEL AREA VARIATION Format (10I5)	
	N1	= NAFACT, number of subchannels for which area variation tables are to be read.
	N2	= NAXL, number of axial locations for subchannel area variation.
	N3	= NARAMP, the number of iterations for gradual insertion of area variations. If blank or zero, NARAMP = 1. For a "restart" case, NARAMP must be reread if desired.

Card Label	Variables	Format and Explanation
SETUP.5.1	AXL(I) (I = 1 to N2) Format (12F5.3)	
	Table of axial locations, where:	
	AXL	= Axial location (X/L) where subchannel area variations will be specified. Read in N2 values which apply to all subchannels specified in SETUP.5.2.
SETUP.5.2	[I,(AFACT(L,J), L = 1 to N2), J = 1 to N1] Format (I5/(12F5.3))	
	For N1 subchannels read area variation factors at N2 axial locations corresponding to (AXL), where:	
	I	= Identification Number of a subchannel for which area variations are being specified. Read according to (I5) format, then skip to the next card and read a complete set of factors (AFACT) corresponding to the AXL locations. Repeat until factors for N1 subchannels are read.
	AFACT	= Relative subchannel area ($Ai/A_{nominal}$) at each axial level (AXL).
SETUP.6	GROUP 6 GAP SIZE VARIATION TABLE Format (2I5)	
	N1	= NGAPS, number of GAPS for which GAP variation tables are to be read.
	N2	= NGXL, number of axial locations for GAP variation.

Card Label	Variables	Format and Explanation
SETUP.6.1	GAPXL(L) (L = 1, N2) Format (12F5.3)	
	Table of axial locations, where:	
	GAPXL	= Axial locations (X/L) where GAP variations will be specified. Read N2 values which apply to all GAPS K specified in SETUP.6.2.
SETUP.6.2	[K,(GFACT(L,LL), L = 1 to N2), LL = 1 to N1] Format (I5/(12F5.3))	
	For N1 GAPS read GAP variations at N2 axial locations (GAPXL), where:	
	K	= GAP identification number of GAP to be varied. Read K [Format(I5)], then skip to next card and read N2 GAP variation factors. Repeat until factors for N1 GAPS are read.
	GFACT	= GAP variation factors for GAP K. Read N2 values for each K corresponding to each GAPXL location. GFACT = $(GAP_i/GAP_{nominal})$
SETUP.7	GROUP 7 WIRE WRAP AND SPACER DESIGN INFORMATION Format (10I5), where:	
	N1	= J6. N1 = 1 specifies wire wrap input only. N1 = 2 specifies grid spacer input only. N1 = 3 specifies both wire wrap input and grid spacer loss coefficient input.
	N2	= Number of GAPS for which wire wrap crossing data is supplied.

DATA CARD OR GROUP CONTROL CARD (Continued)

Card Label	Variables	Format and Explanation
	N3	= NGRID, number of axial locations for grid spacers.
	N4	= NGRIDT, number of grid types for which data will be supplied.
	N5	= NRAMP, number of iterations over which the grid loss terms are to be ramped into the solution. For a "restart" case, NRAMP must be reread if desired.
	N6	= Logical unit that card sets SETUP.7.2 and SETUP.7.3 are to be read. N6 = 0, read from input deck. N6 > 0, read from logical unit N6. Recommend N6 = 9 if cards are not specified.
SETUP.7.1	PITCH, DIA, THICK Format (3E10.5)	
⟶	Optional Input - N1 = 1 or 3	
	Wire wrap specifications, where:	
	PITCH	= Wire wrap pitch (in).
	DIA	= Rod or cladding outer diameter (in).
	THICK	= Wire wrap diameter (in).
SETUP.7.2	K, DUR(K), XCROSS(K,L) (L = 1 to 2) Format (I5, 2E5.2)	
⟶	Optional Input - N1 = 1 or 3	
	Wrap crossing data, where:	
	K	= GAP number.

Card Label	Variables	Format and Explanation
	DUR	= The effective fraction of a pitch length for forcing crossflow. Recommended value is derived from the equation DUR = ΔX/PITCH where ΔX = the axial node length (in). PITCH = the wire wrap pitch (in).
	XCROSS	= The wire wrap crossing angle. XCROSS is calculated by dividing the angle (θ) between the GAP and wire (at the bundle inlet) by 360°. The value is positive if the wrap is moving from a smaller to a higher number subchannel and negative if otherwise. If the wire wrap is on a GAP boundary at the bundle inlet, XCROSS = ±1.0 not zero.
SETUP.7.3 →	NWRAPS(I) (I = 1 to NCHANL) Format (10I5) Optional Input - N1 = 1 or 3 Wrap inventory where:	
	NWRAPS	= The number of wires initially in each subchannel. Read an integer value of the number of wires present at the bundle inlet. For wires located on the GAP boundary, the wrap is assumed to be in the subchannel into which it is proceeding. Read 10 values per data card until the inventory for all subchannels are read.

Card Label	Variables	Format and Explanation
SETUP.7.4	GRIDXL(I), IGRID(I) (I = 1 to N3) Format [6(E5.2.I5)]	

Optional Input - N1 = 2 or 3

Axial location of grids and the type of grid at each axial location

GRIDXL = The relative location (X/L) of grid spacers.

IGRID = The grid type at axial location GRIDXL.

SETUP.7.5 — [(J, CD(J,I), K, FXFLOW(K,I) , II = 1 to NCHNL), I = 1 to N4] Format (I5, E5.2, I5, E5.2)

Optional Input - N1 = 2 or 3

Read the loss coefficient and forced crossflow, if desired, in each subchannel for each grid type.

NCHANL = Total number of subchannels. Read data for all subchannels for grid type 1, then repeat for succeeding grid types.

J = Identification number of subchannel for which data are being supplied.

CD = Loss coefficient in subchannel J for grid type I.

K = GAP associated with subchannel J, through which forced diversion crossflow is specified. If blank, no forced crossflow.

FXFLOW = Fraction of axial flow which is diverted through GAP K for grid type I. If blank, no forced crossflow.

Card Label	Variables	Format and Explanation
SETUP.8	GROUP 8 ROD LAYOUT AND FUEL PROPERTIES Format (10I5)	
	N1	= The number of cards of rod data to be read. One card for each rod modeled. For RESTART cases or multiple case runs, it is only necessary to read new rod input.
	N2	= NROD, the total number of rods to be modeled regardless of N1.
	N3	= NC, order of approximation used in fuel model. N3 = 0, no fuel model. N3 = 2, 2nd order collocation solution. N3 = 3, 3rd order collocation. N3 > 3 or N3 = 1 is illegal.
	N4	= NFUELT, the number of fuel materials for which thermal properties are to be specified. Not applicable if N3 = 0. If blank, NFUELT = 1 is assigned.
	N5	= NCHF, critical heat flux option. N5 = 0, No CHF calculations are performed. N5 = 1, BAW-2 correlation is used. N5 = 2, the W-3 correlation is used.
	N6	= NQAX, additional fuel model options. Not applicable if N3 = 0. N6 = 0, no additional options. N6 = 1, variable thermal conductivity only. N6 = 2, axial conduction only. N6 = 3, both axial conduction and variable thermal conductivity. N6 = 2 or 3 also specifies fluid axial conduction.

Card Label	Variables	Format and Explanation
	N7	= NHTC, heat transfer correlation option. N7 = 0, Dittus and Boelter or other correlation specified in SETUP.2.2 input is used throughout. N7 = 1, use a complete boiling and nonboiling correlation package similar to that of the RELAP-4 computer code.
	N8	= NRODTP, option for axially varying fuel material. N8 = 0, each fuel rod is constructed of a single material and no axially varying data are read. N8 > 0, must read fuel zone information (SETUP.8.4), for each fuel type N.
	N9	= Logical unit from which card set SETUP.8.1 is to be read. N9 = 0, read from input deck. N9 > 0, read from logical unit N9. Recommend N9 = 9 when not reading from cards.
SETUP.8.1	N, I, DR(I), Radial, [LR(I,L), PHI(I,L) (L = 1 to 6)] Format [I2, I3, 2E5.2, 6(I5, E5.2)]	
	Read in N1 cards of rod input data, where:	
	N	= The fuel shape and fuel material options. N = 0 or positive, cylindrical fuel specified. N = negative, plate fuel specified. The absolute value of N determines the material property configuration of Fuel I.

Card Label	Variables		Format and Explanation
			For N8 = 0 (Axially uniform fuel) ABS (N) corresponds to one of N4 materials (SETUP.8.2) of which Rod I is made.
			For N8 > 0 (Axially varying fuel zones) ABS (N) corresponds to one of N8 material configurations specifying the fuel material versus axial height (SETUP.8.4).
			Note: If any rod is specified to have axially varying properties (N8 > 0), all rods (including axially uniform rods) must have an axial configuration specified (SETUP.8.4).
	I	=	Rod identification number.
	DR	=	Outer rod diameter (in). If cladding around rod, DR is the cladding outer diameter.
	RADIAL	=	The radial power factor for rod (I) as a fraction of the average rod power (Group 11).
	LR	=	Identification numbers of subchannels surrounding rod (I). Read in up to 6 subchannels.
	PHI	=	The fraction of the total rod power input to adjacent subchannel (i.e., fraction of the outer rod perimeter facing subchannel identified by LR).

Card Label	Variables	Format and Explanation

SETUP.8.2 KFUEL(I), CFUEL(I), RFUEL(I), DFUEL(I), KCLAD(I), CCLAD(I), RCLAD(I), TCLAD(I), HGAP(I) (I = 1 to N4) Format (9E5.2)

Optional Input N4 > 0 and NC > 0

Material properties. Read N4 cards corresponding to N4 materials for which thermal properties are specified. Each fuel rod consists of one or more of these materials. For N8 = 0, the fuel type N (SETUP.8.1) corresponds to the material type(I).

KFUEL	=	The thermal conductivity of the fuel (Btu/hr-ft-°F).
CFUEL	=	Specific heat of fuel (Btu/lb-°F).
RFUEL	=	Fuel density (lb/ft^3).
DFUEL	=	The fuel diameter (in).
KCLAD	=	Thermal conductivity of cladding (Btu/hr-ft-°F).
CCLAD	=	Specific heat of clad (Btu/lb-°F).
RCLAD	=	Density of cladding (lb/ft^3).
TCLAD	=	Cladding thickness (in).
HGAP	=	Fuel-Clad Gap conductance coefficient (Btu/hr-ft^2-°F).

Card Label	Variables	Format and Explanation

SETUP.8.3 → TREF, BK(I) (I = 2 to 4) Format (F10.0, 3E10.4)

Optional Input - NC > 0 and NQAX = 1 or 3

Variable thermal conductivity. Only applies to the material specified by the first card of SETUP.8.2.

TREF = The reference temperature where K = KFUEL(1) (°F)

BK = The coefficients for up to 3rd order polynomial approximation for thermal conductivity versus temperature of the form:

$$K(I) = KFUEL(1) * [1 + BK(2) * (T - TREF) + BK(3)\ (T - TREF)^2 + BK(4)\ (T - TREF)^3]$$

SETUP.8.4 → [NZONE(I), (ZEND(I,K), IZTYP(I,K), K = 1 to NZONE(I)), I = 1 to N8] Format [I5/(6(E5.2,I5))]

Optional Input - N8 > 0

Option to specify axially varying fuel materials. Must read in a fuel zone configuration table for each rod type N (SETUP.8.1).

NZONE = The number of axial zones to be read for a table of fuel material versus axial distance for fuel type I.

ZEND = Relative axial location (X/L) of the end of a fuel zone. If fuel type I is axially uniform, ZEND(I,1) = 1.0.

Card Label	Variables	Format and Explanation
	IZTYP	= Type of material in fuel zone ending at ZEND. Each IZTYP corresponds to a material specified in SETUP.8.2. Only material type 1 can have variable thermal conductivity.
SETUP.9	GROUP 9 CALCULATIONAL VARIABLES	Format (10I5)
	N1	= NSKIPX, output print option. N1 = 0 or 1, print all axial levels. N1 > 1, print every N1 axial levels.
	N2	= NSKIPT, output print option. N2 = 0 or 1, print all time steps. N2 > 1, print every N2 time steps.
	N3	= K11, specifies the solution algorithm to solve the problem. N3 = 0 specifies the III-C implicit solution scheme for both steady-state and transient calculations. N3 = 1 specifies an implicit steady-state and an explicit transient with a ΔP boundary condition. N3 = 2 specifies a standing start explicit transient with a zero flow initial condition, and a ΔP boundary condition. N3 = 3 specifies an implicit steady-state and an explicit transient with the inlet flow boundary condition. N3 = 4 specifies a standing start explicit transient with a zero flow initial condition, and an inlet flow boundary condition.

Card Label	Variables	Format and Explanation
	N4	= IROLL, problem roll option. N4 = 0, no roll option, all variables reside in core at all times. N4 = 1, only 3 axial levels of information -- J - 1, J and J + 1 -- are stored in core at one time.
	N5	= ITSTEP, maximum time step table. N5 = 0, maximum transient time step is FDT (SETUP.9.3) for all time. For N5 > 0, read in N5 pairs of (time. vs. max. time step) information for variable maximum time steps. Used only for K1170.
SETUP.9.1	Z, TTIME, WERRX, WERRY, FERROR, KIJ, SL, FTM, THETA, USDON, DAMPNG, ACCELY, ACCELF Format (16 E5.0)	
	Z	= The total axial length (in).
	TTIME	= Total transient time (sec).
	WERRX	= The external crossflow convergence limit. Defined for implicit crossflow solution as the maximum allowable error in iterative crossflows at any axial level. If any error is greater than WERRX, the solution proceeds through another iterative sweep over the entire bundle. Default is 1.E-2.
	WERRY	= The internal crossflow convergence limit. Convergence limit for the iterative Gauss-Seidel solution scheme at axial level J. Default is 1.E-3.

Card Label	Variables	Format and Explanation
	FERROR	= The external axial flow convergence limit. Defined for the implicit axial momentum equation as the maximum allowable error for iterative axial flows. If error is greater than FERROR, another iterative sweep of the entire bundle is made. Default is 1.E-3.
	KIJ	= Turbulent crossflow resistance factor. Default is 0.5.
	SL	= Transverse momentum parameter. Default is 0.5.
	FTM	= Turbulent momentum factor. Default is 0.0.
	THETA	= The bundle orientation. Blank or zero is vertical, otherwise read in to the nearest degree the angle away from the vertical (degrees).
	USDON	= Specifies the contribution of velocity from the donor and receiver subchannels in U* calculation. USDON = 0, U* = 1/2 [U(J) + U(I)] where J and I are donor and receiver subchannels. USDON = 1.0, U* = U(J) where J is the donor subchannel. Any value between 0.0 and 1.0 is acceptable. Default, USDON = 0.0.

Card Label	Variables	Format and Explanation
	DAMPNG	= DAMPNG factor for iterative SP term. $SP(I,J)^N = DAMPNG*SP(I,J)^N + (1 - DAMPNG)*SP(I,J)^{N-1}$ where N and N-1 are the present and previous iterations, respectively.
	ACCELY	= Crossflow solution accelerator. $W(K,J)^N = ACCELY*W(K,J)^N + (1 - ACCELY)*W(K,J)^{N-1}$ where N is the iteration no. Default is 1.0.
	ACCELF	= DAMPNG factor for iterative axial flow. $F(I,J)^N = ACCELF*F(I,J)^N + (1 - ACCELF)*F(I,J)^{N-1}$ where N is the iteration no. Default is 1.0.
SETUP.9.2	NDX, NDT, NTRIES, ITRY, ITRYM	Format (5I5)
	NDX	= Number of axial nodes.
	NDT	= Total number of time steps allowed. For implicit transients the time step size is (TTIME/NDT). For explicit transients, the time step size is problem-dependent with NDT and TTME being the limits on the total number of time steps and length of the transient.
	NTRIES	= The maximum number of external iterations allowed in implicit solution scheme, regardless of WERRX and FERROR. Default is 20.
	ITRY	= The maximum number of internal iterations allowed in implicit solution scheme, regardless of WERRY. Default is the maximum of 20, 2 * number of gaps.

Card Label	Variables	Format and Explanation
	ITRYM	= The minimum number of iterations in the internal crossflow solution for implicit solution scheme, regardless of convergence. Default is 5.

SETUP.9.3 FCOUR, FDT, XZERR, YZERR, THX, THD, ACCEL1, ACCEL2 Format (12E5.0)

Optional Input - K11 > 0

Parameters for the explicit solution scheme

FCOUR	=	The courant time step limitation parameter. Default is 0.5. FCOUR = $\frac{(\text{velocity})\ \Delta T}{\Delta X}$
FDT	=	The maximum time step regardless of FCOUR. Must read in. No default.
XZERR	=	The iterative flow field convergence limit in the explicit solution scheme. Default is 1.E-2.
YZERR	=	The iterative energy equation convergence limit in the explicit solution scheme. Default is 1.E-4.
THX	=	1. The integrated liquid level is printed for each channel at each time step. THX=0. No liquid level printout. Default is THX=0.
THD	=	1. Optional interface sharpening parameter, equivalent to the downward liquid velocity. Default is 0.
ACCEL1	=	Acceleration factor on current pressure change. Default is 1.3.

Card Label	Variables	Format and Explanation
	ACCEL2	= Acceleration factor on pressure change from last iteration. Default is 0.
SETUP.9.4	NTRYX, NTRYY, KNOFLO, JNOFLO Format (10IJ)	
	Optional Input - K11 > 0	
	Additional parameters for explicit solution	
	NTRYX	= The maximum number of allowable iteration in the flow solution of XZERR. Default is 50.
	NTRYY	= The maximum number of allowable iterations in the energy equation regardless of YZERR. Default is 20.
	KNOFLO, JNOFLO	= No crossflow permitted through gap number KNOFLO or less at and above the axial node JNOFLO. Default for both is 0.
SETUP.9.5	YT(I), FT(I) (I = 1 to N5) Format (12E5.0)	
	Optional Input - N5 > 1	
	Read in N5 pairs of values for a table of time step size versus time, where:	
	YT	= Time (sec) for maximum time step. Must include time = 0.
	FT	= Maximum time step (sec) allowed at this time.

SETUP.10 GROUP 10 TURBULENT MIXING CORRELATION Format (10I5)

N1 = NSCBC. Single-phase turbulent mixing option. Several forms of the equation for turbulent crossflow W' are possible:†

1) W'_K = ABETA * $(S_K\overline{G})$

2) W'_K = ABETA * Re ** BBETA * $(S_K\overline{G})$

3) W'_K = ABETA * Re ** BBETA * $(\overline{DG})$

4) W'_K = ABETA * Re ** BBETA * $(S_K/Z_K)(\overline{DG})$

where the constants ABETA and BBETA (SETUP.10.1) are applied to the equation selected by N1. (See Appendix D for definition of variables.)

N1 = 0, use equation 1
N1 = 1, use equation 2
N1 = 2, use equation 3
N1 = 3, use equation 4

N2 = NBCC, the option for two-phase mixing. N2 = 0 or 1, two-phase mixing assumed to be the same as subcooled. N2 > 1, read in N2 pairs of data for a table of two-phase mixing Beta versus steam quality.

†For discussion of empirical correlations see Appendix B.

Card Label	Variables	Format and Explanation
	N3	= J5, an option for radial thermal conduction mixing. N3 = 0, no thermal conduction. N3 = 1, read thermal geometry factor, GK for radial thermal conduction.
SETUP.10.1	ABETA, BBETA Format (12F5.3)	
	ABETA, BBETA	= Constants coefficients for the turbulent mixing correlation selected, (see N1). BBETA is blank if N1 = 0.
SETUP.10.2	XQUAL(I), BX(I) (I = 1 to N2) Format (12F5.3)	
	Optional Input - N2 > 1	
	Read in table of values of mixing Beta versus steam quality, where:	
	XQUAL	= Steam quality.
	BX	= The mixing Beta at the corresponding steam quality.
SETUP.10.3	GK Format (F5.3)	
	Optional Input - N3 = 1	
	GK	= Geometry factor for radial thermal conduction mixing.
SETUP.11	GROUP 11 OPERATING CONDITIONS AND TRANSIENT FORCING FUNCTIONS Format (10I5)	
	N1	= IH, option for specified inlet enthalpy or temperature. N1 = 0, HIN (SETUP.11.1) is the inlet enthalpy. N1 = 1, HIN is the inlet temperature. N1 = 2, read in an inlet enthalpy for each subchannel. N1 = 3, read in an inlet temperature for each subchannel.

Card Label	Variables	Format and Explanation
	N2	= IG, option to specify inlet mass flux. N2 = 0, GIN (SETUP.11.1) is the inlet mass flux for each subchannel. N2 = 1, GIN is the average bundle mass flux but the subchannel flow is split to give equal DP/DX across the first axial node. N2 = 2, GIN is the average bundle mass flux, but flow is split by flow fractions supplied in (SETUP.11.3).
	N3	= Transient forcing function for system pressure. Read in NP pairs or values for a table of system pressure factor versus time.
	N4	= Transient forcing function for inlet enthalpy or temperature. Read in NH pairs of values for a table of inlet H or T factor versus time.
	N5	= Transient forcing function for inlet mass flux or pressure drop. Read in NG pairs of values for a table of mass flux factor or ΔP versus time.
	N6	= Transient forcing function for average heat flux. Read in NQ pairs of values for a table of heat flux factor versus time.
	N7	= K10, an option for pressure drop boundary condition transients. If K11 (SETUP.9) is equal to 1 or 2, the transient forcing function for inlet mass flux (N5) becomes a transient pressure drop table. If K10 = 1, the tabular values are a fraction of the steady-state pressure drop.

Card Label	Variables	Format and Explanation
	N8	= Transient forcing function for exit enthalpy. Read in NHX pairs of values for a table of exit enthalpy factor versus time.
SETUP.11.1	PEXIT, HIN, GIN, AFLUX, HOUT, DPS Format (6F10.0)	
	Operating conditions, where:	
	PEXIT	= The system pressure, (psia).
	HIN	= Inlet enthalpy (Btu/lb) or temperature (°F) depending on N1. If HIN is negative, the inlet enthalpy will be either the absolute value of HIN or the last calculated first node enthalpy if the flow has reversed.
	GIN	= The inlet mass flux (MLB/hr-ft^2) to be distributed by the N2 option.
	AFLUX	= The average heat flux (MBtu/hr-ft^2).
	HOUT	= The exit enthalpy. If HOUT is specified, and the flow reverses, the "new" exit enthalpy will be HOUT. Otherwise, for HOUT blank, the "new" exit enthalpy will be the calculated exit enthalpy before reversal (Btu/lb).
	DPS	= An option to specify a pressure drop rather than a flow boundary condition in the steady-state implicit solution scheme. The code iterates on the total inlet flow rate until the calculated pressure drop is close to DPS (psi).

Card Label	Variables	Format and Explanation
SETUP.11.2	HINLET(I) (I = 1 to NCHANL) Format (12E5.0)	
→	Optional Input N1 = 2 or 3	
	Inlet enthalpy or temperature, where:	
	HINLET	= The inlet enthalpy (N1 = 2) or inlet temperature (N1 = 3) of each individual subchannel; read one value for each subchannel.
SETUP.11.3	FINLET(I) (I = = 1 TO NCHNL) Format (12E5.0)	
→	Optional Input - N2 > 2	
	Inlet flow rate, where:	
	FINLET	= The individual subchannel inlet flow (F(I)/FTOTAL) for each individual subchannel.
SETUP.11.4	YP(I), FP(I) (I = 1 to N3) Format (12E5.0)	
→	Optional Input - N3 > 1	
	Pressure transient table, where:	
	YP	= Transient time (sec) when factor is applied.
	FP	= Fraction of steady-state System Pressure at transient time (YP).
SETUP.11.5	YH(I), FH(I) (I = 1 TO N4) Format (12E5.0)	
→	Optional Input N4 > 1	
	Enthalpy or temperature transient table.	
	YH	= The transient time (sec) when factor is applied.
	FH	= The fraction of inlet enthalpy (N1 = 0 or 2) or the fraction of inlet temperature (N1 = 1 or 3) at the transient time (YH).

Card Label	Variables	Format and Explanation
SETUP.11.6	YG(I), FG(I) (I = 1 to N5) Format (12E5.0)	
→	Optional Input - N5 > 1	
	Inlet flow or pressure drop boundary condition transient table.	
	YG	= The transient time (sec) when factor is applied.
	FG	= The fraction of steady-state inlet flow at the transient time (YG) if inlet flow boundary condition is specified [K11 (Group 9) = 0, 3 or 4]. For pressure drop boundary conditions (K11 = 1 or 2), FG is either the fraction of the steady-state pressure drop (N7 = 1) or FG is the pressure drop in psi (N7 = 0) at the transient time (YG).
SETUP.11.7	YQ(I), FQ(I) (I = 1 to N6) Format (12E5.0)	
→	Optional Input N6 > 1	
	Heat flux transient table.	
	YQ	= The transient time (sec) when factor is applied.
	FQ	- The fraction of steady state heat flux at the transient time (YQ).

Card Label	Variables	Format and Explanation
SETUP.11.8	YHX(I), FHX(I) (I = 1 to NHX)	
	Optional Input N8 > 1	
	Exit enthalpy transient table.	
	YHX	= The transient time (sec) when factor is applied.
	FHX	= The fraction of steady state exit enthalpy (HOUT) at the transient time (YHX) to be used if the flow reverses.
SETUP.12	GROUP 12 OUTPUT OPTIONS FOR CALCULATIONS Format (10I5), where:	
	N1	= NOUT, print option. N1 = 0, print subchannel data only. N1 = 1, print subchannel data and crossflows only. N1 = 2, print subchannel data and fuel rod temperatures only. N1 = 3, print subchannel data, crossflows and fuel rod temperatures.
	N2	= NPCHAN, an option for subchannel data printout. N2 = 0, print all subchannel data. N2 > 0, read N2 subchannel identification numbers of subchannels to be printed.
	N3	= NPROD, an option for fuel rod heat flux and/or temperature printout. N3 = 0, data for all rods are printed if called for by N1. N3 > 0, read in N3 rod identification numbers of rods to be printed. If NCHF (SETUP.8) is >0, CHF data is also printed along with the rod data.

Card Label	Variables	Format and Explanation
	N4	= NPNODE, an option for interior fuel node temperature printout for all rods specified by N3. Option only applies if interior rod temperatures are calculated using the fuel model (GROUP 8). N4 = 0, print rod centerline, rod surface and cladding surface temperature. N4 = 3 to 7, N4 equally spaced interior rod temperatures are printed along with the cladding surface temperature.
	N5	= NPGAP, an option for GAP crossflow printout if called for by N1. N5 = 0, print crossflow for all GAPS. N1 > 0, read GAP numbers of GAPS to be printed.
	N6	= NSKPLT, an option for transient plotting. N6 = 0, no plots are printed. N6 > 0, plot data every N6 time steps. Must read 4 sets of maximum and minimum coordinates for the four variables plotted. (SETUP.12.6).
	N7	= NPLTCH, option to plot channels if called for by N6. N7 = 0, plot all subchannels. N7 > 0, read subchannel numbers of those plotted.
	N8	= NPLTGP, an option for GAP crossflow plotting if called for by N6. N8 = 0, plot all gaps. N8 > 0, read GAP numbers to be plotted.

DATA CARD OR GROUP CONTROL CARD (Continued)

Card Label	Variables	Format and Explanation
SETUP.12.1	PRINTC(I) (I = 1 to N2) Format (24I3)	
	Optional Input N2 > 0	
	PRINTC	= Read subchannel identification numbers of N2 subchannels for which data is to be printed. N2 = 0, print all subchannels.
SETUP.12.2	PRINTR(I) (I = 1 to N3) Format (24I3)	
	Optional Input - N3 > 0	
	PRINTR	= Read rod numbers of N3 rods for which heat flux and temperatures are to be printed if called for by N1.
SETUP.12.3	PRINTG(I) (I = 1 to N5) Format (24I3)	
	Optional Input - N5 > 0	
	PRINTG	= Read GAP numbers of N5 for which crossflows are to be printed if called for by N1.
SETUP.12.4	IPLITCH(I) (I = 1 to N7) Format (24I3)	
	Optional Input - N7 > 0	
	IPLITCH	= Read subchannel numbers of N7 subchannels for which line plots are to be printed if called for by N6.
SETUP.12.5	IPLTGP(I) (I = 1 to N8) Format (24I3)	
	Optional Input - N8 > 0	
	IPLTGP	= Read GAP numbers of those GAPS for which crossflows are to be plotted, if called for by N6.

DATA CARD OR GROUP CONTROL CARD (Continued)

Card Label	Variables	Format and Explanation
SETUP.12.6	HIP(I),ZPT(I) (I = 1 to 4)	Format (12F5.0)
	Optional Input - N6 > 0	
	HIP, ZPT	= The maximum and minimum plot coordinates for the four kinds of plots available. The maximum and minimum are in the units of the variable plotted which are:

HIP(1), ZPT(1) } Mass flux (million lb/hr-ft^2)

HIP(2), ZPT(2) } Enthalpy (1000 Btu/lb)

HIP(3), ZPT(3) } Pressure Drop (psi)

HIP(4), ZPT(4) } Crossflow (lb/sec-ft)

Mass flow rate, enthalpy and pressure drop are plotted for each subchannel specified (see N6 and N7). Crossflow is plotted for each GAP specified (see N6 and N8). If HIP(I) = 0, that quantity is not plotted.

8.0 NOMENCLATURE†

A	Axial flow area, (ft^2)
A'	Average area, $(A_j + A_{j-1})/2$, (ft^2)
C	Axial thermal conduction coefficient, (Btu/ft-sec-°F)
c	Thermal conduction coefficient, (Btu/ft-sec-°F)
c_p	Heat capacity, (Btu/lb-°F)
[DC]	Difference operator for subchannels
[DW]	Difference operator for subchannels and thermal-conducting walls.
$[DC]^T$,$[DW]^T$	Transpose of difference operator
E	Dilation or continuity error, (lb/sec)
E'	Volume dilation or volumetric error, (ft^3/sec)
f	Friction factor based on all liquid flow
G	Mass velocity, (lb/sec-ft^2)
g_c	Gravitational constant, (lb-ft/lb_f-sec^2)
h, h_{gap}	Heat transfer coefficient, (Btu/sec-ft^2-°F)
h	Subchannel enthalpy, (Btu/lb)
h_g, h_f	Saturated vapor and liquid enthalpy, (Btu/lb)
K	Spacer loss coefficient
K_g	Geometry factor for conduction
L	Channel length, (ft)
ℓ	Characteristic gap length in transverse momentum equation, (ft)
m	Flow rate, (lb/sec)
P	Subchannel pressure, (lb_f/ft^2) = (lb/sec^2-ft)

†Dimensions are those used during calculations in the code.

P_h	Heated perimeter, (ft)
P_w	Wetted perimeter, (ft)
P_r	Prandtl number
Q	Specific power-to-flow ratio, q'_i/m_i, (Btu/lb-ft)
q	Heat rate, (Btu/sec-ft^3)
q'	Heat flux per unit length, (Btu/sec-ft)
Re	Reynolds number
r	Radial coordinate
s	Subchannel gap spacing, (ft)
[S]	Summing operator - similar to [DC]
T	Temperature, (°F)
t	Time, (sec)
t_{clad}	Cladding thickness, (ft)
u	Axial subchannel velocity, (ft/sec)
U	Overall heat transfer coefficient, (Btu/sec-ft^2-°F)
v	Mixture specific volume, (ft^3/lb)
v'	Effective two-phase specific volume (equals v if subcolled), $(1-X)^2/\rho_f(1-\alpha) + X^2/\rho_g\alpha$ (ft^3/lb)
v_l	Specific volume of liquid, (ft^3/lb)
v_y	Transverse velocity in subchannel, (ft/sec)
w	Diversion crossflow between adjacent subchannels per unit length, (lb/sec-ft)
w'	Turbulent (fluctuating) crossflow per unit length, (lb/sec-ft)
X	Quality, $mg/(mg + m_f)$
Δx	Axial node length, (ft)

ΔY	Width of thermally-conducting wall, (ft)
Z_{ij}	Effective centroid distance, (ft)
α	Void fraction, $A_g/(A_g + A_f)$
β	Turbulent mixing parameter, (Dimensionless)
γ	Slip ratio, (u_g/u_f)
ρ	Two-phase density, $\rho_g\alpha + \rho_f(1-\alpha)$, (lb/ft^3)
ρ_g, ρ_f	Saturated vapor and liquid density, (lb/ft^3)
τ_w	Wall shear stress, (lb_f/ft^2)
ϕ	Two-phase friction multiplier
μ	Viscosity, $(lb_f/ft\text{-}sec)$

Superscripts

*	Convected quantity
—	Previous time quantity
n, n+1	Time step index

Subscripts

j-1, j, j+1	Axial levels
k	Laterally convected quantity
w	Thermal wall property

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APPENDIX A

SUBROUTINE DESCRIPTION

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SUBROUTINE DESCRIPTION

Subroutine AREA (J, JX)

This subroutine calculates subchannel area and gap spacings by using the tabular list of area and gap variations supplied as input. A linear interpolation is used to select values from these tables. When wire wrap mixing is included AREA corrects the subchannel flow area and hydraulic diameter according to the wire wrap inventory. J and JX are the calculation level and the axial node. For nonrolled problems J = JX, for rolled problems $J \leq 2$.

Subroutine BVOID (I)

This subroutine calculates the bulk void fraction used in the implicit solution scheme according to a correlation selected by the user. Several correlation forms are provided requiring arbitrary constants read from input. These are provided so that the user can select the correlation form and coefficients that are most applicable to the particular problem.

This subroutine is not used in the explicit solution because there the homogeneous model is used exclusively.

Subroutine CHF (JSTART, JEND)

At the completion of the subchannel flow and enthalpy calculation an optional call to subroutine CHF is provided to calculate critical heat flux ratios over the portion of the channel denoted by J = JSTART through J = JEND. The critical heat flux ratio CHFR(N,J) and critical channel CCHANL(N,J) are calculated for each rod N at position J. CHFR(N,J) is also searched to determine the minimum critical heat flux ratio MCHFR(J), critical rod MCHFRR(J) and critical channel MCHFRC(J) at each axial location J. The data is printed as part of the fuel temperature and heat flux output.

Subroutine CHF1 (N, I, J, JX)

CHF1 uses the B&W-2 correlation and the coolant properties of the Ith channel to calculate the critical heat flux of the Nth rod at the JXth axial node.

Subroutine CHF2 (N, I, J, JX)

CHF2 uses the W-3 correlation and the coolant properties of the Ith channel to calculate the critical heat flux of the Nth rod at the JXth axial node.

Subroutine CHRCOR (I, N, J, JX)

CHFCOR calculates the critical heat flux used by HCOOL. Three correlations are included, and the system pressure is used as the basis for selecting the appropriate correlation.

Subroutine CLEAR (STATUS)

Subroutine CLEAR is used to zero COMMON prior to execution. It is not called for each case. The size of any common area to be zeroed is computed using a system routine LOCF (for CYBER). Other machines will need to compensate for the use of LOCF in order to zero core, if necessary.

STATUS = Identifies a flag which may be selectively used to zero common for each case in multiple case execution passes.
= "YES", common is zeroed
= "NO", common is not zeroed.

PROGRAM COBRA

The main program performs variable initialization either by setting the variable to zero or by calling the RESTRT routine which initializes variables to the values saved from a previous run. It also controls input and output via the subroutine SETUP and RESULT, and it directs the solution approach by calling either SCHEME (steady-state and implicit transient) or XSCHEME (explicit transient). The transient boundary conditions and forcing functions are also set in COBRA at the beginning of each time step.

Subroutine CURVE (FX, X, F, Y, N, J, ISAVE)

This subroutine performs linear interpolation of tabulated data. The variables in the argument list are defined as:

FX = Quantity to be found
X = Independent variable
F = Input array of values of the dependent variable
Y = Input array of values of the independent variable
N = Number of F values in table
J = Error signal
ISAVE = Table search switch. For ISAVE = 1, a complete table search on the independent variable is done. For ISAVE = 2, the location in the table which brackets the independent variable is known from a previous call to curve and the table search is not performed.

Subroutine DIFFER (IPART, J, JX)

Subroutine DIFFER is divided into 4 parts as indicated by the variable IPART.

Part 1 is used to calculate the right hand side of equation (7) which is designated DHDX(F) and is an initial estimate of the enthalpy gradient {dh/dx}. For the steady-state and scheme transient calculations, dh/dx consists only of the energy change due to axial conduction and energy transport from the rods. For the XSCHEME transient, dh/dx contains all forms of energy transport and is truly the steady-state energy gradient dh/dx. When the wall heat transport model is used the overall wall-to-coolant heat transfer coefficient UWALL along with a coefficient to convert coolant temperature to enthalpy is also calculated in Part 1.

Part 2 calculates the crossflow resistance C_{ij} and the transverse momentum flux term.

Part 3 calculates the pressure coefficient K used in equation (9) and designates it DPK(I). It also calculates the other components of the pressure gradient without the division crossflow terms as defined by equation (9) and designates it as DPDX(I).

Part 4 calculates the complete pressure gradient {dp/dx} including the crossflow terms and designates it DPDX(I).

Subroutine DIVERT (J, JX)

This subroutine sets up the coefficient matrix [AAA] and the vector {B} such that

$$[AAA] * \{w_j\} = \{B\}$$

and then solves the set of equations for w. The solution is performed in DIVERT using the Gauss-Siedel iterative solution method. The convergence criterion used is that, if all w_k satisfy

$$\frac{|w_k - w'_k|}{(\bar{w}/|w_k|)^2 + |w_k| + .001} \leq e$$

where w_k = most recent estimate of w

w' = previous estimate of w

$\bar{w} = \sum_{k=1}^{nk} w_k/n_k$ = average cross flow in a given plane

then it is assumed that the solution has converged. This criterion was chosen because it allows for tight convergence on the relatively large crossflows while maintaining loose convergence on the relatively small crossflows.

Subroutine DUMPIT

This subroutine is used to store all labeled and blank common on logical unit 8. This routine allows the user to save the current computed values, look at the results and, then, if desired, continue the solution.

Subroutine FORCE (J, JX)

Subroutine FORCE is provided to specify forced diversion crossflow at selected gaps and at selected axial positions. If a forced crossflow is specified, the variable FDIV = 1.0; otherwise, FDIV = 0. Subroutine FORCE includes two options for forced crossflow mixing. One option is the wire wrap mixing model for which FORCE computes a forced crossflow when a wire crosses a gap. The other option is for a specified flow fraction diverted from one subchannel to an adjacent subchannel by grid spacers.

Subroutine HCOOL (I, N, J, JX, HTC, IMODE)

HCOOL is the primary subroutine used in the determination of a heat transfer coefficient. As such, it contains the logic to determine which regime on the boiling curve is appropriate. HCOOL calls HTCOR to obtain the surface coefficient from specific correlations, and CHFCOR to obtain the critical heat flux.

The variables in the call list are given below:

- I - channel number
- N - rod number
- J - calculation level
- JX - axial location
- HTC - heat transfer coefficient calculated in HTCOR
- IMODE - flag to designate regions on the boiling curve

Subroutine HEAT (NSS, JB, NHT, JX3)

Subroutine HEAT consists of three parts indicated by NHT. Part 1 calculates the heat flux of each rod at all axial levels based on the rod power. If the fuel model is used, the internal rod temperatures are also calculated here. Part 2 calculates the heat input to each individual subchannel using the heat flux from Part 1. Part 3 calculates the average fluid temperature and average heat transfer coefficient used in the fuel conduction model. NSS indicates from which routine HEAT is called. NSS = 0, SCHEME, NSS = 1, XSCHEM. NSS = 2, initialization in COBRA. JB = the calculation level and JX3 is the axial location.

Subroutine HTCOR (HTC, TSURF, IN, N, J, RE, DE, IPART)

HTCOR calculates a heat transfer coefficient by the correlation specified in the call list.

The arguments in the call list are:

HTC - heat transfer coefficient
TSURF - rod surface temperature
I - channel number
N - rod number
J - calculation level
RE - Reynolds number
DE - hydraulic diameter
IPART - flag to designate a particular correlation

Subroutine ISWAP (I, J, K)

This routine is used in conjunction with the roll option to interchange the input and output logical unit designations; i.e., logical unit I becomes logical unit J, and logical unit J becomes I. K is a file positioning switch. If K equals 1, then both I and J are positioned at the beginning of the first record. If K is not equal to one, then both I and J are positioned at the start of the second record.

Subroutine LOAD (X, Y, Z, MIN, MAX, LIMIT, STEP, IMAGE, CARD, LU)

LOAD is used to replace redundant logic within subroutine SETUP. It is designed to allow the loading of input data only after the group card parameters have been verified.

X = First variable to be loaded. (Step = 1)
Y = Second variable to be loaded. (Step = 2)
Z = Third variable to be loaded. (Step = 3)
STEP = The number of variables to be loaded sequentially. ($1 \leq STEP \leq 3$)
MIN = The maximum allowable sets of (X,Y,Z) which can be loaded.
MAX = Identifies the number of sets of (X,Y,Z) the user attempts to load.
If (MAX>MIN), then a dummy read is used to account for remaining cards. This allows subsequent input to be edited.
LIMIT = Identifies the maximum number of data values per card which can be loaded via the formatted IMAGE.
IMAGE = Identifies the variable FORMAT to be used for loading input data.
CARD = Input card counter; for labeling which card may be in error.
LU = Input device used for reading input data.

Subroutine LOADL (X, Y, Z, MIN, MAX, LIMIT, STEP, IMAGE, CARD, LU)

LOADL is identical in function to subroutine LOAD, except that (X,Y,Z) are variables which may be allocated to Level 2, (large core memory) on a CYBER-7600 system. This routine is used regardless of the system on which COBRA is being run and the necessary storage allocations are provided by Program SPECSET.

Subroutine LIMITS (NUM, MIN, MAX, GROUP, CARD, ERROR)

This routine is designed for use within subroutine SETUP to enhance the editing of input data. Its function is to guarantee that the number of values read into an array are within the dimensioned limits of the code. If not, the parameter, NUM, is changed only for the convenience of editing; however, the case will be terminated after the input is edited. In addition, a limit of twenty-five accumulated errors are allowed, after which the editing will cease.

NUM = Input parameter to be checked
MIN = Minimum allowable value for NUM
MAX = Maximum allowable value for NUM
GROUP = Card group identifier for editing diagnostics
CARD = Input card counter; for labeling which card may be in error
ERROR = Alphanumeric flag for editing. If ERROR = "yes", the code will terminate following the editing of input data.

Subroutine MIX

Subroutine MIX calculates the thermal mixing parameters w', which is designated by WP(k). Since completely general correlations for mixing have not been developed for single and two-phase mixing, this subroutine is set up so that improved correlation functions can be included when they become available. The approach used is to separate the mixing into boiling and nonboiling regions. For nonboiling conditions, several correlation forms are included as shown in Appendix F. For two-phase flow, the single phase correlations may be assumed, or the mixing rate may be specified as a function of quality.

Subroutine PBOUND (JUMP)

This routine is used to modify the inlet flow rate for the steady-state solution until all subchannel pressure drops are approximately equal to the specified pressure drop DPS. JUMP is the convergence indicator. For JUMP not equal to 2, the inlet flows are modified by the following algorithim:

$$\text{FINLET}(I) = 1 + \frac{(\text{DPS} - \Delta P(I))}{2(\text{DP}(I) - \bar{h})} \text{ FINLET }(I)$$

where:

$\Delta P(I)$ = overall pressure drop of the Ith channel
$\bar{h}$ = average gravational head of all channels.

Subroutine PROP (IPART, J, JX)

This subroutine consists of two parts. The first part calculates the saturated fluid properties as a function of the system reference pressure.

2

The second part calculates all the liquid or superheated fluid properties as a function of temperature and limits these to saturated values during boiling. The second part also calculates, if called for, the convection heat transfer coefficient used in Levy's subcooled void model.

Subroutine RESTRT (NTSTRT, ISTART)

This routine initializes variables to the values that were saved by subroutine DUMPIT from a previous solution.

The first function of RESTRT is to retrieve the previously saved solution and initialize common to the stored values. Next, a RESTRT data card is read defining the type of restart desired. In addition to the restart data read, certain values from the previous solution dictate how the solution may be restarted. The flow chart in Figure A-1 illustrates the RESTRT options available in the code.

Subroutine RESULT (NT)

All printing and/or line plotting of the results is done by this subroutine. NT is the current time increment number.

Subroutine ROLLIT (J, JX, SAVEA1, SAVEA2, SAVEA3, NWR, NDXP1, LUO, LUI)

This subroutine is used in conjunction with the roll option to input and output temporary storage values of the axial dependent variables. J is the current calculation level, and JX is the physical axial level. The variables SAVEA1, SAVEA2 and SAVEA3 are vectors of length NWR, which are equivalenced to the axial dependent variables at the axial levels J-1, J, and J+1, respectively. NDXP1, LUO, and LUI are the number of axial nodes plus one, the output logical unit and the input logical unit, respectively.

Subroutine SCHEME (NTRIES, JUMP, ISTART, MAXT, NJUMP)

This subroutine performs the steady-state and implicit transient numerical solution. Given a set of boundary and initial conditions, it carries the calculations through the bundle in a stepwise manner.

The calculational procedure is best illustrated by the flow chart shown in Figure A-2. First the enthalpy h(x) is calculated and an estimate for m(x) is made for the first iteration only. The crossflow w(x) and axial flow m(x) are then calculated. Any value of w(x) or m(x) not converged to within a selected tolerance is sufficient to set the nonconvergence flag JUMP to 1. Following the flow and crossflow calculations, the pressure P(x) and pressure difference [D]P(x) is calculated. The procedure is repeated stepwise up the bundle until the exit is reached. If the flows and crossflows have converged (JUMP = 2) or the maximum allowable number of iterations is reached, control is returned to the main program. Otherwise the bundle is swept again using new estimates for flows in the calculations.

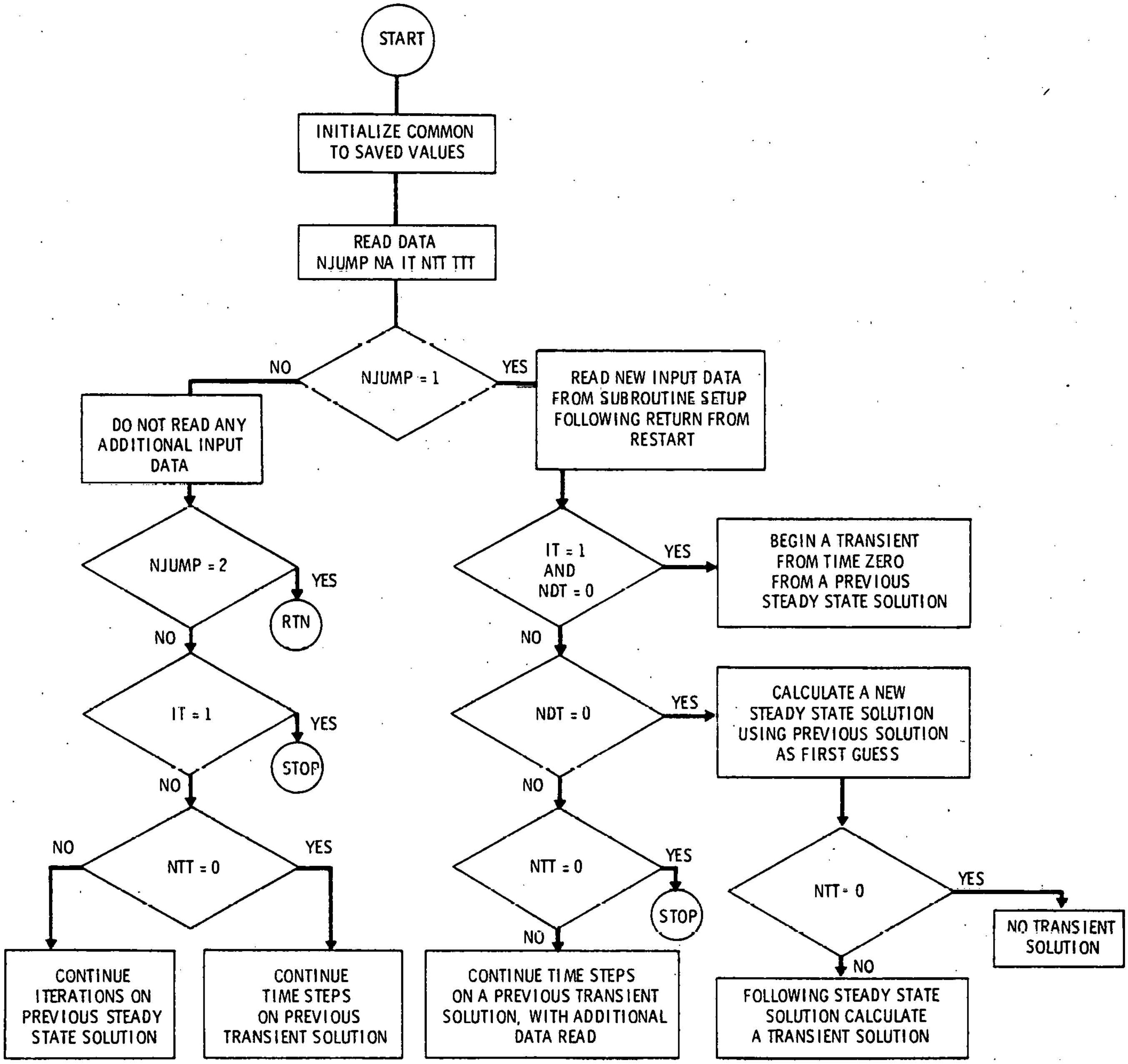


FIGURE A-1. Subroutine RESTRT Available Code Options

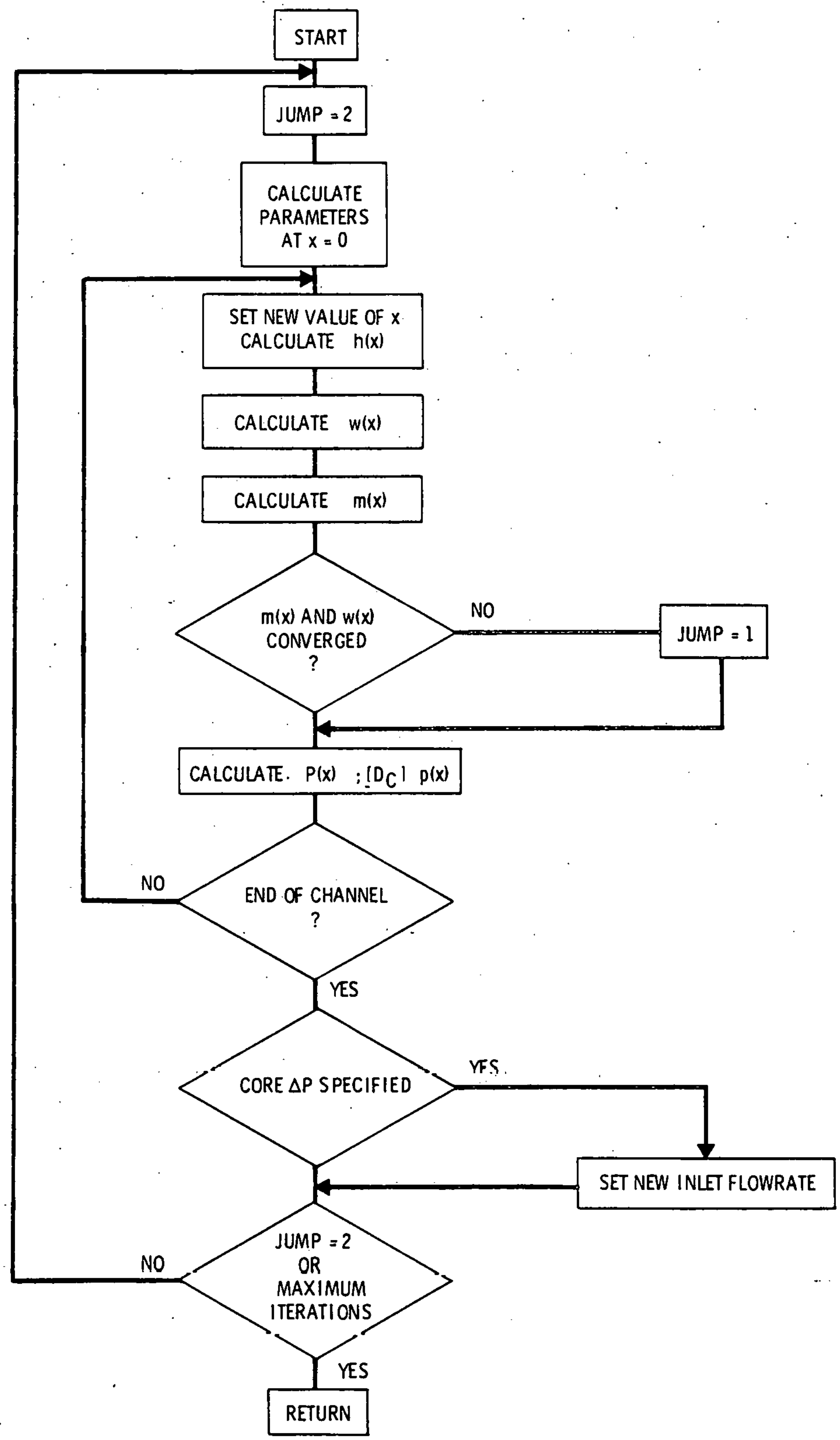


FIGURE A-2. Subroutine SCHEME Calculation Procedure

Regardless of convergence, a minimum number of iterations is required depending on the fuel model options employed:

Minimum Number Iterations	Fuel Model Options
2	No fuel model
3	Fuel model without RELAP type heat transfer package
4	Fuel model with heat transfer package

The variables in the argument list are defined as:

NTRIES - Maximum number of iterations allowed. If the solution has not converged after NTRIES the results are output and the calculations stop.

JUMP - Convergence indicator

ISTART - Starting iteration number. May be other than 1 for restart cases.

MAXT - Maximum allowed elapsed real time. If computer CP time exceeds MAXT, the results are output following the current iteration sweep of the bundle.

NJUMP - Procedure indicator. If NJUMP = 0, the run is a standard run or simple restart; if it equals 1, then the run is a restart run with new input.

Function SCQUAL (I, J)

This routine is used to calculate the subcooled quality for the Ith channel at the Jth axial node using Levy's subcooled void model.

Subroutine SETUP

This subroutine is used to input data, check the input data against dimension limits and produce a listing of the input.

Subroutine SPLIT

Subroutine SPLIT divides the subchannel flow rates at the inlet of the bundle to give equal pressure gradients across the first node by assuming that there is no spatial acceleration component of pressure drop.

Subroutine TEMP (TT, N, JJ, IFLAG, ISS, JXX)

Subroutine TEMP calculates internal rod temperatures based on a thermal conduction model, using the orthogonal collocation method of weighted residuals. For rod N at axial level JXX, the conduction equation is solved for the unknown rod temperatures TT. Either the cylindrical (JJ = 1) or plate (JJ = 2) fuel option is used and either steady-state (ISS = 1) or transient (ISS = 0) calculations are performed. Convergence errors are signified by IFLAG.

Subroutine VOID

Subroutine VOID calculates the subcooled void fraction, bulk void fraction, density, effective specific volume for momentum, two-phase friction gradient multiplier velocity and energy transport velocity. Several correlations are included in this subroutine that the user can select by option. These are provided as an example with the thought that the users will set up correlations that are most applicable to their particular problems. This subroutine is not called from the explicit solution scheme.

Subroutine XSCHEM (IPART)

Subroutine XSCHEM carries out the explicit transient solution. Its function is equivalent to SCHEME for the implicit solution. A normal call to XSCHEM (IPART = 2) advances the solution one complete time step and computes the duration of the next time step. For the running start options, the steady-state implicit solution is first calculated. The resulting subchannel flows are then used to determine the maximum time step allowed for the explicit transient by a call to XSCHEM (IPART = 1). Otherwise, an input value for the maximum allowable time step is used for the first time step.

One pass through XSCHEM with IPART = 2 results in three channel sweeps. The first computes tentative flows and also updates fuel temperatures, if a fuel model is used. The second sweep is iterated for the actual flow/pressure field solution until the maximum dilation in any one cell is sufficiently small. The last channel sweep finds the maximum Courant number in the mesh for computing the next time step. The flow chart in Figure A-3 illustrates the computational procedure in XSCHEM.

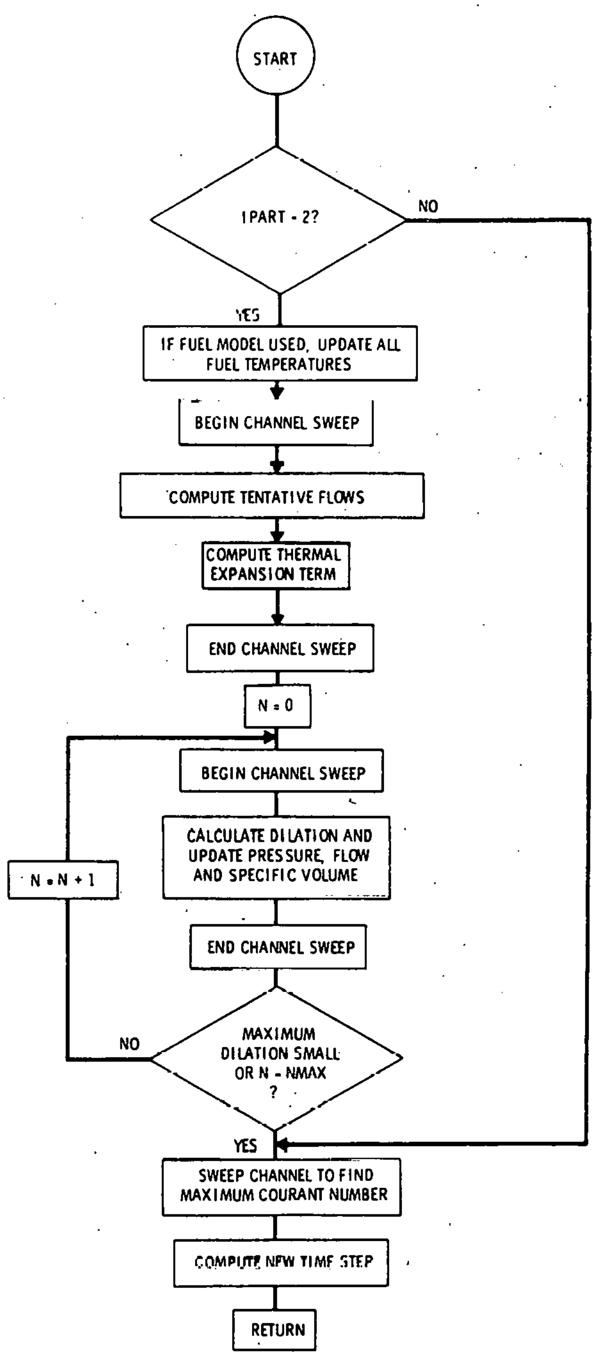


FIGURE A-3. Subroutine XSCHEME Computational Procedure

APPENDIX B

CONSTITUTIVE RELATIONSHIPS

APPENDIX B

CONSTITUTIVE RELATIONSHIPS

SUPERHEATED STEAM PROPERTIES

A subroutine has been added to COBRA to calculate the properties of superheated steam from atmospheric pressure to 2400 psia and from the saturation temperature to 1500°F.

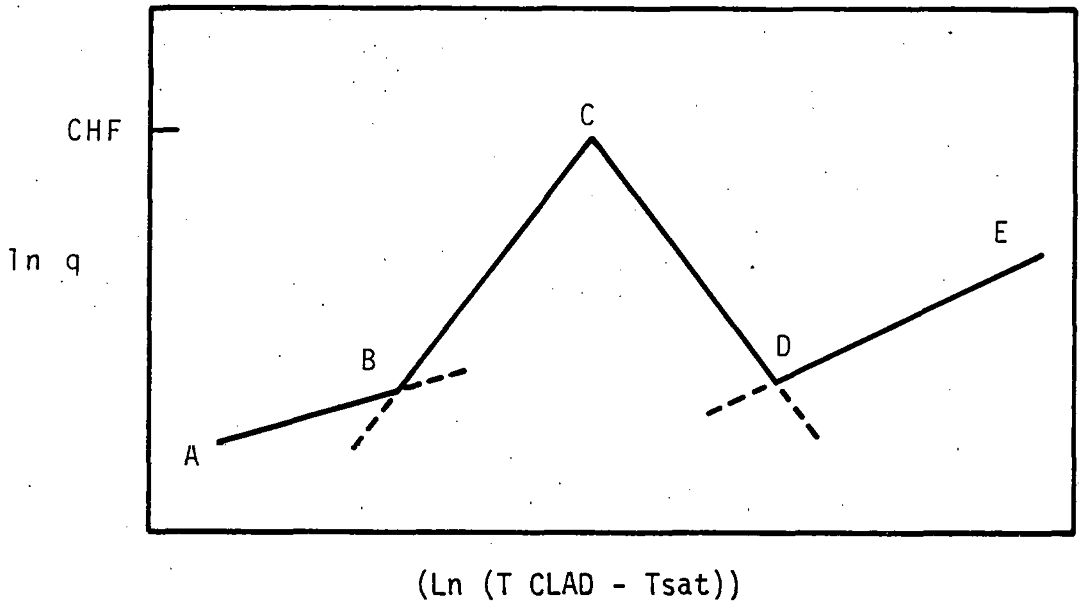
Calculation methods from several sources have been used to evaluate enthalpy, specific volume, specific heat, saturation temperature, thermal conductivity, and viscosity as functions of pressure and temperature. It is assumed that local pressures are sufficiently near the reference pressure such that the properties are a function of reference pressure and temperature only. Given the reference pressure, arrays for the properties are evaluated from the saturation temperature to 1500°F. Subchannel properties are evaluated by interpolation of the property arrays during computation. When reference pressure transients occur, the steam property arrays are reinitialized at prescribed percent changes in reference pressure.

Enthalpy and specific volume are evaluated with the relationships used in the Keenan and Keys tables of 1936,(1) and the specific heat is evaluated as $\Delta h/\Delta T$. Agreement with the 1967 ASME STEAM TABLES(2) is within 1% for enthalpy and specific volume, and within 4% for the specific heat. The viscosity and thermal conductivity are calculated by the equations listed in the 1967 ASME Tables where applicable. In regions not covered by these relationships, the recommended data interpolation given by McClintock and Silvestri(3) is used. The equations are also extended in use from the recommended temperature limit of 1292°F to 1500°F. Agreement with tabular values in the 1967 ASME Tables is within the ±6% range established for these curves.

The calculation of fuel rod temperatures in COBRA requires the specification of heat transfer coefficients at the clad surface. To meet this requirement, the correlations and basic selection logic contained in the RELAP4 computer program have been used.(4)

Seven regions are considered: forced convection, subcooled and nucleate boiling, forced convection vaporization, transition boiling, transition pool boiling, film boiling, and pool film boiling. The schematic in Figure B-1 shows the relative regions of applicability for each on a heat flux versus temperature plot. The correlations used for each regime are listed in Table B-1.

In addition to the stated correlations, a minimum heat transfer coefficient of 5 Btu/hr-ft^2-°F is assumed.



A - B Forced convection

B - C Subcooled and nucleate boiling, and forced convection vaporization

C - D Transition boiling and transition pool boiling

D - E Film boiling, low pressure film boiling and pool film boiling

FIGURE B-1. Regional Application of Heat Transfer Correlations

Three critical heat flux correlations are used. The correlations and criteria for selection are shown in Table B-1. Additionally, a minimum value of 90,000 Btu/hr-ft^2, the presumed value for a stagnant fluid, is assumed. When the mass flux is less than 2x10^5 lbm/hr-ft^2, the critical heat flux is interpolated between 90,000 Btu/hr-ft^2 and the value calculated via the appropriate correlation at a mass flux of 2x10^5 lbm/hr-ft^2.

The selection of the appropriate heat transfer correlation is based on three conditions. The first is an evaluation of the physical state. For example, if the clad temperature is below the saturation temperature, the forced convection regime is appropriate. The second is the evaluation of the critical heat flux and the clad temperature that would exist at this heat flux. Comparison determines whether pre-CHF or post-CHF correlations are appropriate. The third criterion is the comparison of two or more calculated heat transfer coefficients in order to select the proper coefficient in regions where correlations overlap.

TABLE B-1. Heat Transfer and Critical Heat Flux Correlations

HEAT TRANSFER CORRELATIONS

PRE CHF

forced convection - Dittus and Boelter[a]

subcooled and nucleate boiling - Thom[b]

forced convection vaporization - Schrock and Grossman[c]

POST CHF

transition boiling - McDonough, Milich and King[d]

stable film boiling - Groeneveld[e]

low pressure film boiling - Dougall and Rohsenow[f]

pool film boiling - Berenson[g]

transition pool boiling[h]

CRITICAL HEAT FLUX CORRELATIONS

1. P/psia < 725
   Modified Barnett[i]
2. 725 < P/psia < 1000
   interpolation between Barnett[j] and modified Barnett
3. 1000 < P/psia < 1300
   Barnett[j]
4. 1300 < P/psia < 1500
   interpolation Barnett[j] and B and W-II[k]
5. P/psia > 1500
   B and W-II[k]

(a) M. Jacob, Heat Transfer, vol. 1, New York, Wiley & Sons, 1957.

(b) J. S. Thom, et.al., 'Boiling in Subcooled Water During Flow Up Heated Tubes or Annuli', Proc. Instn. Mech. Engrs., vol. 180, part 36, 1966, pp. 226-246.

(c) V. E. Schrock and L. M. Grossman, Forced Convection Boiling Studies, Final Report on Forced Convection Vaporization Project, TID-14632, 1959.

(d) J. B. McDonough, W. Milich, and E. C. King, Partial Film Boiling with Water at 2000 psig in a Round Vertical Tube, MSA Research Corp., Technical Report 62, NP-6976, 1958.

(e) D. C. Groeneveld, An Investigation of Heat Transfer in the Liquid Deficient Regime, AECL-3281 (Rev.) December 1968; revised August 1969.

(f) R. S. Dougall and W. M. Rohsenow, Film-Boiling on the Inside of Vertical Tubes with Upward Flow of the Fluid at Low Qualities, MIT-TR-9079-26, 1963.

(g) P. J. Berenson, 'Film-Boiling Heat Transfer from a Horizontal Surface,' J. of Heat Transfer, vol. 83, August 1961, pp. 553-558.

(h) K. V. Moore and W. H. Rettig, 'RELAP-4: A Computer Program for Transient Thermal-Hydraulic Analysis' Aerojet Nuclear Co., ANCR-1127, December 1973.

(i) E. D. Hughes, A Correlation of Rod Bundle Critical Heat Flux for Water in the Pressure Range 150-725 psia, IN-1412, July 1970.

(j) P. G. Barnett, A Correlation of Burnout Data for Uniformly Heated Annuli and Its Use for Predicting Burnout in Uniformly Heated Rod Bundles, AEEW-R 463, 1966.

(k) J. S. Gellerstedt et.al., 'Correlation of Critical Heat Flux in a Bundle Cooled by Pressurized Water; Two Phase Flow and Heat Transfer in Rod Bundles, Symposium proceedings of Winter Annual Meeting of the American Society of Mechanical Engineers, Los Angeles, California, November 1966, pp. 63-71.

COMPUTER PROGRAM CORRELATIONS

To carry out a solution, empirical and semiempirical correlations must be selected for input to the computer program.

Friction Factor

The friction factor correlation is assumed to be of the form

$$f_i = a(R_{e_i})^b + c \tag{B-1}$$

where a, b, and c are specified constants that depend upon the subchannel roughness and geometry.[5] Since these constants can be influenced by different subchannel roughnesses and the pitch-to-diameter ratio,[6] the program can accept up to four sets of constants that correspond to four subchannel types which may be assigned to the subchannels of the bundle. For example, subchannels next to a flow housing may be given a different friction factor from those subchannels within the bundle.

The friction factor is also corrected for wall viscosity by using the relationship[6]

$$\frac{f}{f_{iso}} = 1 + \frac{P_h}{P_w}\left[\frac{\mu_{wall}}{\mu_{bulk}}^{.6} - 1\right] \tag{B-2}$$

where μ_{wall} is evaluated at the wall temperature which is calculated from

$$T_{wall} = T_{bulk} + \frac{q'}{P_h h}. \tag{B-3}$$

This correction is based on the assumption that the total perimeter consists of two regions--one heated and the other unheated--and that the heated portion has uniform heat flux. The heat transfer coefficient is calculated from

$$\frac{hD}{k} = 0.023\left(\frac{GD}{\mu}\right)^{0.8}\left(\frac{C_p\mu}{k}\right)^{0.4} \tag{B-4}$$

where bulk fluid properties are used. Alternate forms for equation (B-4) may be specified from input. (See SETUP.2.3.)

Two-Phase Friction Multiplier

Several correlations are available for the two-phase friction multiplier. Three are presently included in the program.

Homogeneous Model

$$\phi = 1.0 \quad X < 0.$$
$$\phi = \frac{\rho_f}{\rho} \quad X > 0. \qquad \text{(B-5)}$$

Armand[7]

$$\phi = 1.0 \qquad \alpha \leq 0$$
$$\phi = \frac{(1-X)}{(1-\alpha)^{1.42}} \qquad 0.39 < (1-\alpha) \leq 1.0$$
$$\phi = 0.478 \frac{(1-X)^2}{(1-\alpha)^{2.2}} \qquad 0.1 < (1-\alpha) \leq 0.39 \qquad \text{(B-6)}$$
$$\phi = 1.730 \frac{(1-X)^2}{(1-\alpha)^{1.64}} \qquad 0. < (1-\alpha) \leq 0.1$$

Polynomial Function

$$\phi = 1.0 \qquad X < 0$$
$$\phi = a_o + a_1 X + a_2 X^2 + \ldots a_n X^n \qquad X > 0 \qquad \text{(B-7)}$$

where the coefficients are supplied as input.

Spacer Loss Coefficient

The pressure drop from spacers is lumped into an effective loss coefficient which may be defined[6] in terms of all liquid flow as

$$\Delta P = \frac{K}{2\rho} \left(\frac{m}{A}\right)^2 \qquad \text{(B-8)}$$

For two-phase flow, the same coefficient is used but is modified by the two-phase specific volume for momentum. This pressure drop loss coefficient is converted to a pressure gradient loss coefficient at the location of the spacer by dividing the calculation increment Δx; therefore,

$$K_i = \frac{K}{\Delta x} \qquad \text{(B-9)}$$

Void Fraction

Four ways of specifying void fraction are presently included in the program:

Homogeneous Model

$$\alpha = 0 \qquad X \le 0.$$

$$\alpha = \frac{Xv_g}{(1-X)v_f + Xv_g} \qquad X > 0. \qquad \text{(B-10)}$$

Slip Model

$$\alpha = 0. \qquad X \le 0.$$

$$\alpha = \frac{Xv_g}{(1-X)v_f\gamma + Xv_g} \qquad X > 0. \qquad \text{(B-11)}$$

where γ is a specified slip ratio.

Modified Armand(7,8)

$$\alpha = 0. \qquad X \le 0.$$

$$\alpha = \frac{(0.833 + 0.167\ X)Xv_g}{(1-X)v_f + Xv_g} \qquad X > 0. \qquad \text{(B-12)}$$

Polynomial Function

$$\alpha = 0. \qquad X > 0.$$

$$\alpha = a_o + a_1X + a_2X^2 + \ldots a_nX_x \qquad X < 0. \qquad \text{(B-13)}$$

Subcooled Void Fraction

Two options are presently included. Subcooled void formation may be ignored or it may be included by using Levy's subcooled void model.(9) Levy's model calculates the true quality in terms of the equilibrium quality and the quality at which bubble departure starts. It is given by:

$$X = 0 \qquad X_e < X_d$$

$$X = X_e - X_d \exp\left(\frac{X_e}{X_d} - 1\right) \qquad X_e/X_d < 1 \qquad \text{(B-14)}$$

where X_e is the equilibrium quality and

$$X_d = \frac{C_p \Delta T}{h_{fg}}$$

$$\Delta T = \frac{q'}{P_h h} - QP_r Y_B \qquad 0 < Y_B \leq 5 \qquad \text{(B-15)}$$

$$\Delta T = \frac{q'}{P_h h} - 5Q(P_r + \log(1 + P_r(\frac{Y_B}{5} - 1))) \qquad 5 < Y_B \leq 30$$

$$\Delta T = \frac{q'}{P_h h} = 5Q(P_r + \log(1+5P_r) + \frac{1}{2}\log(\frac{Y_B}{30})) \qquad 30 < Y_B \qquad \text{(B-16)}$$

$$Q = \frac{q'}{P_h v} C_p \sqrt{\tau_w v} \qquad \text{(B-17)}$$

$$\tau_w = \frac{fv}{8}\left(\frac{m}{A}\right)^2 \qquad \text{(B-18)}$$

$$Y_B = \frac{0.015}{\mu} \quad \frac{\sqrt{\sigma D}}{v} \qquad \text{(B-19)}$$

The heat transfer coefficient h is calculated from equation (B-4). The use of Levy's model may not apply universally since the use of a single phase heat transfer coefficient is not always compatible with experimental measurements.(10)

Single-Phase Turbulent Mixing

Several forms of equations for specifying the turbulent crossflow are included. The presently available forms in COBRA for calculating w' include:

$$w'_k = \beta\, s_k\, \bar{G} \qquad \text{(B-20)}$$

$$w'_k = a\, Re^b s_k\, \bar{G} \qquad \text{(B-21)}$$

$$w'_k = a\, Re^b\, \bar{D}\, \bar{G} \qquad \text{(B-22)}$$

$$w'_k = a\, Re^b \frac{s_k}{z_k} \bar{D}\, \bar{G} \qquad \text{(B-23)}$$

where $Re = \frac{\bar{G}\,\bar{D}}{\bar{\mu}}$ (B-24)

$$\bar{D} = 4\,(A_{i(k)} + A_{j(k)})/(Pw_{i(k)} + Pw_{j(k)}) \qquad \text{(B-25)}$$

$$\bar{G} = (m_{i(k)} + m_{j(k)})/(A_{i(k)} + A_{j(k)}) \qquad \text{(B-26)}$$

$$\bar{\mu} = \frac{1}{2} (\mu_{i(k)} + \mu_{j(k)}) \quad \text{(B-27)}$$

and a and b are input constants. Since a definitive mixing correlation does not exist and other forms are available,[11,12,13] the user should set up correlations of his choice.

Also included in the subcooled mixing is the thermal conduction. When it is included, the conduction coefficient is given by

$$c_k = \left(\frac{k_{i(k)} + k_{j(k)}}{2}\right) \frac{s_k}{z_k} K_g \quad \text{(B-28)}$$

where K_g is a geometric correction factor. Note that the distance z_k is used in both equations (B-23) and (B-28). This is the centroid-to-centroid distance between subchannels. Care should be taken to select this value for its intended use. For example, z_k could be selected as the effective mixing distance.

Two-Phase Turbulent Mixing

Complete information concerning mixing during boiling is not available. It is known, however, that mixing is strongly dependent on quality; therefore, COBRA is set up to accept β as a tabular function of quality. When the quality of two adjacent subchannels is different, the calculations use a quality calculated from the mean mixed enthalpy of the two subchannels.

Transient Correlations

In the present version of COBRA, steady-state correlations are assumed to apply to transients. This assumption should be thoroughly evaluated for transient analyses.

Critical Heat Flux Correlations

Subroutine CHF presently contains two internal functions denoted CHF1 and CHF2 which calculate the critical heat flux by using the B&W-2 and W-3 heat flux correlations,[14] respectively. An input option is provided to allow the user to select either of these correlations. Reference 14 summarizes the details of these two correlations. Other correlation options can be easily set up the same way.

To implement the nonuniform axial flux factor into COBRA a finite increment integration scheme is used. Given the axial flux factor at location X_j of the form,

$$F = \frac{C}{q'(X_j)(1-e^{-C(X_j-X_{jo})})} \int_{X_o}^{X_j} q''(X)e^{-(X_j-X)}dX \tag{B-29}$$

where C is a constant, consider the integral to be a summation of finite integrals each taken over the calculation increment ΔX. Over each ΔX assume a constant value of the heat flux q"(X). The integral from X - ΔX to X is

$$q'(X)\int_{X-\Delta X}^{X} e^{-C(X_j-X)}dX = \frac{q''(X)}{C} e^{-CX_j} [e^{CX}-e^{C(X-\Delta X)}] \tag{B-29}$$

and the entire integral taken as a summation over the increments of ΔX from X_{jo} to X_j is

$$F = \frac{e^{-CX_j} \sum_{j=J_o+1}^{J} q''(X_j)(e^{CX_j}-e^{CX_{j-1}})}{q''(X_j)[1-e^{-C(X_j-X_{Jo})}]} \tag{B-31}$$

where X_{Jo} = 0 is the axial location of the start of integration. For B&W-2 it is the channel inlet and for W-3 it is the start of local boiling defined by the Jens-Lottes correlation.[14]

APPENDIX B

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8. W. A. Messena, Steam-Water Pressure Drop and Critical Discharge Flow - A Digital Computer Program, HW-65706. Hanford Atomic Products Operation, Richland, Washington, June 17, 1960.

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APPENDIX C

TRANSVERSE MOMENTUM FLUX MODEL

APPENDIX C

TRANSVERSE MOMENTUM FLUX MODEL

An optional transverse momentum flux term is included in COBRA-IV-I. The form of this term is still experimental and it should be used with caution.

In the derivation of the transverse momentum equation for COBRA-IIIC, the flux of transverse momentum through the sides of the control volume was neglected. Physically, however, at least part of the crossflow carries (jets?) across intervening channels and acts as an additional momentum source to adjacent crossflows.

Consider the control volume for gap K in Figure C-1. To evaluate the transverse momentum flux term, it is assumed that the total momentum flux through the lateral surfaces A and B is equal to the sum of the K direction momentum flux through gaps L, M, N and O. This assumption becomes increasingly approximate as the axial-to-lateral flow area ratio increases. The flux of K momentum through gap L can be computed by

$$\text{Flux} = \left(\frac{s}{\ell}\right) \frac{w_L^2}{\rho_L S_L^2} \cos\theta_L$$

where

$\theta_L = \alpha_L - \alpha_K$

$\alpha_i = i^{th}$ gap direction angle (See Figure C-2 for definitions.)

For a given gap K, the vector operator $\{S\}\{DC\}^T$ collects the contribution from all adjacent gaps

$$\text{Total} = \left(\frac{S}{\ell}\right)\{S\}\{DC\}^T \frac{w^2}{\rho_s 2} \cos\theta$$

In regular cartesian geometry, this operation forms the exact centered finite difference analog to $\partial\rho v^2/\partial y$. In a rod bundle, it is only an approximation which is most accurate when the gap space is close to the subchannel hydraulic diameter. Test runs have shown that the use of the transverse momentum term produces an effect in the right direction but the results have not been compared to experimental data.

An example of the way the gap direction angles must be input is shown in Figure C-2.

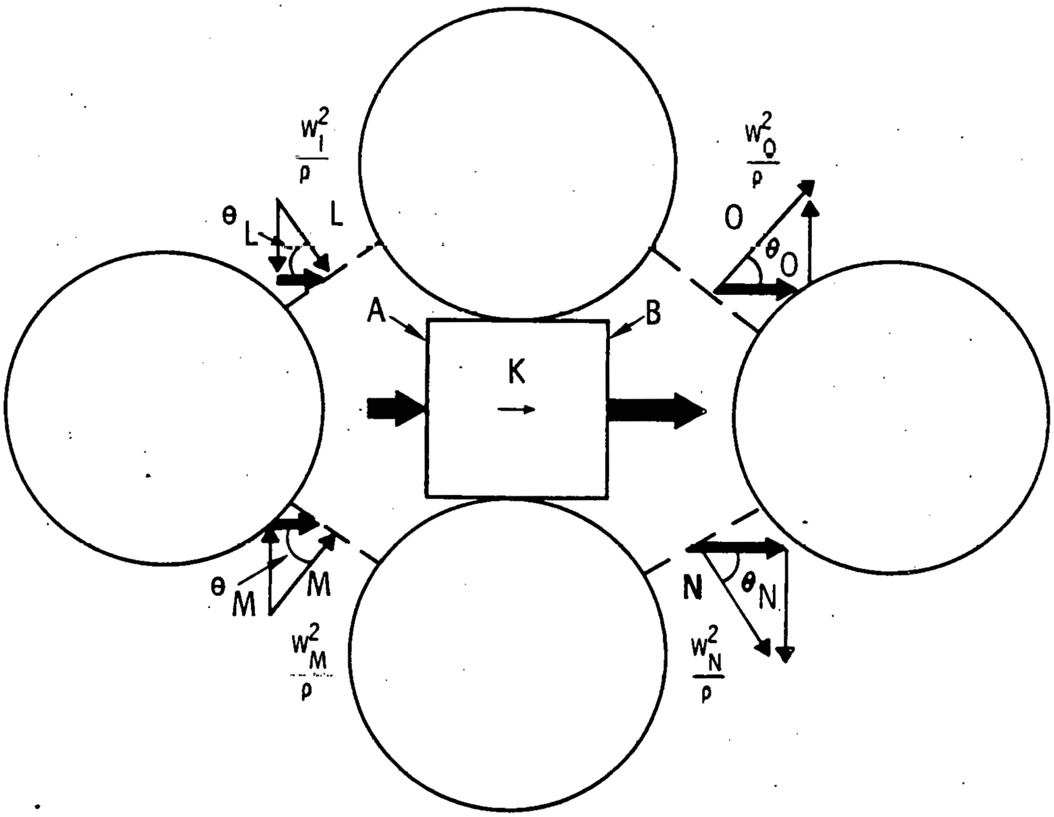
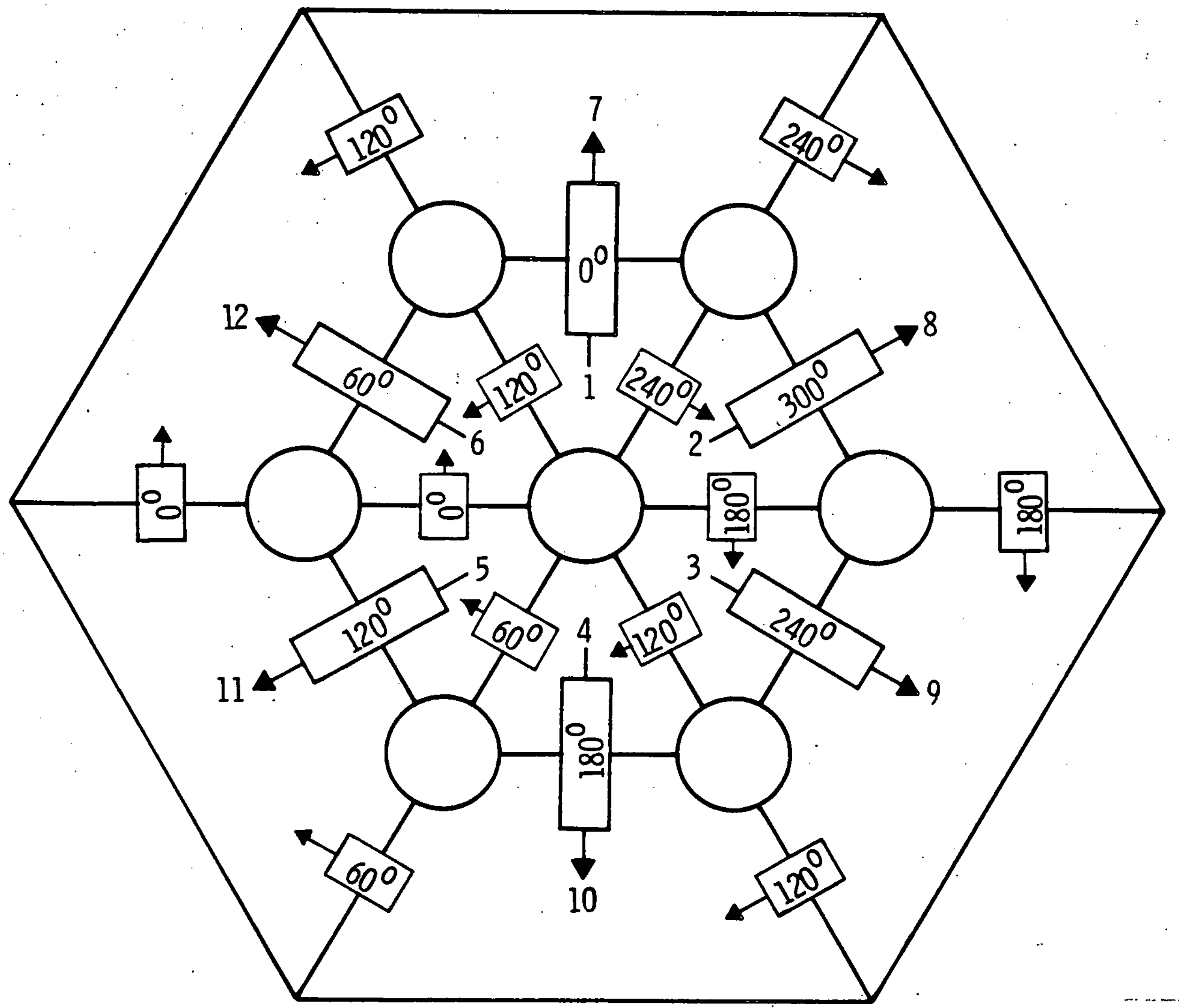


FIGURE C-1. Transverse Momentum Flux Geometry*

*Transverse momentum flux through gap K calculated as the sum of momentum flux through gaps L, M, N and O in the direction of gap K.



RULES

1. Choice of 0^0 direction is arbitrary.
2. Choice of positive angle clockwise or counterclockwise is arbitrary.
3. Gap direction vector must be from subchannel i to j where $i < j$.
4. Gap must be specified in positive degrees.
5. Once 0^0 and positive angle direction are chosen, all other gap direction angles must be consistent and conform to Rule 3.

FIGURE C-2. Example of Gap Direction Angles

APPENDIX D

PROGRAM SPECSET

APPENDIX D

PROGRAM SPECSET

This auxiliary program is used to redimension COBRA in order to minimize the computer core storage requirements. In this way, COBRA utilizes only that portion of core necessary to solve a particular problem. The SPECSET routine has three main functions:

1. to automatically set up a consistent set of dimensions for COBRA compatible with the user-specified problem size;

2. to calculate the relative storage location of the variables equivalenced to the vector SAVEAL;

3. to allocate storage in large core memory (LCM) on CDC-7600 machines, if desired.

The first function is accomplished by performing a character-by-character search through a complete set of COBRA specification statements for dummy dimension parameters. Each statement is written to an output file with the dummy parameters replaced by integer values calculated or specified from the user-supplied input defining the problem size.

The second function is required because the storage scheme in COBRA uses equivalencing to overlap array storage. The storage scheme is best explained by a simple example.

Consider two doubly-dimensioned arrays, A and B, which must be physically dimensioned A(2,2) and B(2,2). These arrays could be stored using a statement of the form

```
COMMON A(2,2), B(2,2)
```

which would store the data sequentially in the following manner:

A(1,1), A(2,1), A(1,2), A(2,2), B(1,1), B(2,1), B(1,2), B(2,2).

However, to transfer data easily between peripheral storage and core, arrays are overlapped so that they are stored as

A(1,1), A(2,1), B(1,1), B(2,1), A(1,2), A(2,2), B(1,2), B(2,2)

This is accomplished by using the following "code" dimensions and equivalence statements:

```
COMMON        SAVEAL(8)

DIMENSION     A(4,2), B(4,2)

EQUIVALENCE   (SAVEAL(1), A(1,1)), (SAVEAL(3), B(1,1))
```

Since many variable arrays are stored in this manner, SPECSET is required to calculate the required "code" dimensions and equivalence starting locations which are consistent with the "physical" dimensions.

The third function is accomplished by simply removing a C from column 1 on all level 2 statements if storage in LCM is desired. If not, the level 2 statements are considered to be comments.

The input to SPECSET is in two sections. The first section contains dummy card images of all COBRA COMDECKS, as shown at the end of this appendix in Table D-1. This data set must be available for input from logical Unit 10.

The data in the second section consist of 18 parameters which define the problem size and code options required. With the exception of the first data card, the order in which the data are specified is immaterial.

The first card must contain the characters LCM in the first three columns if large code memory on a CDC-7600 is to be utilized for variable storage. If large core memory is not desired or the code is to be run on some other system, the first card can be blank. The remaining 17 cards specify the value of the dimensioning parameters using the form

Columns 1 and 2	3	4 through 8
"parameter"	=	"x x"

where "parameter" consists of a two-letter code and "x x" is its required numerical value. All 17 parameters must be specified and the numerical values must be greater than zero.

The required parameters are:

MP - Maximum number of cards in property table, axial heat flux table, and forcing function versus time tables

MC - Maximum number of subchannels

MG - Maximum number of subchannel gap connections

ML - Maximum number of axial locations for gap and area variation

MX - Maximum number of axial nodes plus one

MN - Number of fuel collocation points plus three

MT - Maximum number of fuel types

MR - Maximum number of fuel rods

ME = MX if no storage on peripherals

ME - 3 for storage on peripherals (this implies that axial values will be rolled in COBRA)

MZ - Maximum number of axial locations for grid spacers

MK - Maximum number of grid spacer types

MA - Maximum number of subchannels that can have area variations

MW - Maximum number of wall connections

MY - Maximum number of axial fuel type divisions

MO - Maximum width of AAA array (7 for square arrays, 5 for triangular)

MI - Maximum number of connections to a channel (thermal + flow)

MS - Maximum number of gaps that can have gap spacing variations.

TABLE D-1. Listing of SPECSET Fixed Input

```
*AF NEWPL,YANK$$$
*CD SPECS
      MC=
      MG=
      MX=
      MN=
      MR=
      ME=
      MP=
      ML=
      MZ=
      MW=
      MV=
      MI=
      MO=
      NI=
      N1=
      MK=
      MA=
      MT=
      MS=
      M1=
*CD SPEC1
      DIMENSION    AC(MC),PW(MC),PH(MC),DC(MC),DR(MR),
     1             HINLET(MC),FINLET(MC),TINLET(MC),
     2             LC(MC,4),GAPS(MC,4),DIST(MC,4),
     3             DATIN(N2)
      EQUIVALENCE    (DATIN(1),UB(1,ME)),(DATIN(1),AC(1)),
     1               (PW(1),STUW(1,ME)),(PH(1),AP(1,ME)),
     2               (CC(1),QPRIM(1)),(DR(1),V(1)),(HINLET(1),VPA(1)),
     3               (FINLET(1),VISC(1)),(TINLET(1),VISCW(1)),
     4               (LC(1,1),HFILM(1)),(GAPS(1,1),PERIM(1)),
     5               (DIST(1,1),AAA(1,N3))
CLCM  LEVEL 2,DATIN,AC,PW,PH,DC,DR,HINLET,FINLET,TINLET,LC,
CLCM 1       GAPS,DIST
*CD SPEC2
      COMMON    IK(MG),JK(MG),X(MX),ANGLE(MG),FACTOR(MG),LENGTH(MG),
     1          AXIAL(MP),Y(MP),UH(MC),ALPHA(MC),QUAL(MC),NHTC,TMH(MC),
     2          SURFH(MC),WIDTH(MW),IKW(MW),JKW(MW),UWCP(2,MW),
     3          UWALL(2,MW),HWALL(2,MW),RHOLCP(MW)
     *,        KIJ,AFLUX,Z,THETA,PI,NAX,I3,I2,IERROR,J1,J2,J3,J4,
     1         J7,ATOTAL,GAX,ELEV,FERROR,ITERAT,SLDX,DTGC,CXGC,IDTGC,GC,
     2         SL,CX,SLDXI,SLGOX,SLGOX2,DX4I,SLCXDT,DX2,DXCT,PIN,PCUT,FDT,
     3         FCCUR,K11,ITRAP,XZERR,YZERR,LUO,LUI,IROLL,DT,PEXIT,K12,DXI,
     4         SLDT,SLDT2,SLGC,AP2IDT,DXIDT,NWR,WERRX,WERRY,ITRY,ITRYM,
     5         ACCELY,ACCEL1,ACCEL2,ISTORE,NAAA,NAAAP1,ACCELF,DAMPNG,
     6         NAAH,NAAHP1,HININ,USDON,ITUP,DPS,FCHK,FCHK1,EXTRA(100)
     *,END1
      COMMON /LCCP/ NCHANL,NK,NDXP1,NTRYX,NTRYY,NWK,NROD,NDX
     *,END2
      COMMON /LARGE1/ SAVEAL(M2),QPRIM(MC),V(MC),VPA(MC),VISC(MC),
     1                VISCW(MC),HFILM(MC),CON(MC),CP(MC),FSP(MC),
     2                PERIM(MC),HPERIM(MC),WP(MG),AAA(MU,MG)
     *,END3
      COMMON /LARGE3/ AN(MC),DHYDN(MC),LOCA(NI,MG),NWRAP(MC),
     1                NWRAPS(MC),VP(MC),T(MC),ILOCS(N1,MC)
     *,END4
      INTEGER LAEVAS(M2)
      EQUIVALENCE (SAVEAL,LAEVAS)
      REAL IDTGC,LENGTH,KIJ
```

TABLE D-1. Continued

```
CLCM  LEVEL 2, SAVEAL
CLCM  LEVEL 2,LAEVAS
CLCM  LEVEL 2, AN
*CD SPEC3
      DIMENSION     P(M1,ME),H(M1,ME),F(M1,ME),RHO(M1,ME),
     1              HOLD(M1,ME),FOLD(M1,ME),RHOOLD(M1,ME),
     2              A(M1,ME),DHYD(M1,ME),UB(M1,ME),
     3              STUW(M1,ME),AP(M1,ME),RHOBAR(M1,ME)
      EQUIVALENCE   (P(1,1),SAVEAL(MU)),(F(1,1),SAVEAL(NP)),
     1              (RHO(1,1),SAVEAL(NC)),(HOLD(1,1),SAVEAL(NG)),
     2              (A(1,1),SAVEAL(NS)),(DHYD(1,1),SAVEAL(NL)),
     3              (H(1,1),SAVEAL(NA)),(FOLD(1,1),SAVEAL(NX)),
     4              (RHOOLD(1,1),SAVEAL(NN)),(RHOBAR(1,1),SAVEAL(NT)),
     5              (UB(1,1),SAVEAL(NH)),(STUW(1,1),SAVEAL(NE)),
     6              (AP(1,1),SAVEAL(NZ))
CLCM  LEVEL 2, P
CLCM  LEVEL 2, H
CLCM  LEVEL 2, F
CLCM  LEVEL 2, RHO
CLCM  LEVEL 2, HOLD
CLCM  LEVEL 2, FOLD
CLCM  LEVEL 2, RHOOLD
CLCM  LEVEL 2, A
CLCM  LEVEL 2, DHYD
CLCM  LEVEL 2, UB
CLCM  LEVEL 2, STUW
CLCM  LEVEL 2, AP
CLCM  LEVEL 2, RHOBAR
*CD SPEC4
      DIMENSION     W(M1,ME),WOLD(M1,ME),BETA(M1,ME),
     1              BSAVE(M1,ME),PSI(M1,ME),TRF(M1,ME),
     2              GAP(M1,ME),TWALL(M1,ME),TWOLD(M1,ME)
      EQUIVALENCE   (W(1,1),SAVEAL(1)),(WOLD(1,1),SAVEAL(M3)),
     1              (BETA(1,1),SAVEAL(M4)),(BSAVE(1,1),SAVEAL(M5)),
     2              (PSI(1,1),SAVEAL(M6)),(GAP(1,1),SAVEAL(M7)),
     3              (TRF(1,1),SAVEAL(M8)),(TWALL(1,1),SAVEAL(NY)),
     4              (TWOLD(1,1),SAVEAL(NO))
CLCM  LEVEL 2, W
CLCM  LEVEL 2, WOLD
CLCM  LEVEL 2, BETA
CLCM  LEVEL 2, BSAVE,PSI
CLCM  LEVEL 2, GAP,TRF
CLCM  LEVEL 2,TWALL,TWOLD
*CD SPEC5
      DIMENSION     CHFR(M1,ME),CCHANL(M1,ME),FLUX(M1,ME),
     1              TROD(MN,N4,ME),HSURF(M1,ME),IFTYP(M1,ME),
     2              MODE(M1,ME)
      EQUIVALENCE   (CHFR(1,1),SAVEAL(M9)),(CCHANL(1,1),SAVEAL(MB)),
     1              (FLUX(1,1),SAVEAL(MD)),(HSURF(1,1),SAVEAL(MF)),
     2              (MODE(1,1),SAVEAL(MH)),(TROD(1,1,1),SAVEAL(MQ)),
     3              (IFTYP(1,1),CHFR(1,1))
      INTEGER CCHANL
CLCM  LEVEL 2, CHFR
CLCM  LEVEL 2, CCHANL
CLCM  LEVEL 2, FLUX
CLCM  LEVEL 2, TROD
CLCM  LEVEL 2, HSURF
CLCM  LEVEL 2, IFTYP
CLCM  LEVEL 2, MODE
*CD SPEC6
      LOGICAL GRID
      COMMON /BGRID/ IGRID(MZ),NGRID,NGRIDT,J6,NGTYPE,NRAMP,THICK,DIA,
     1               GRIDXL(MZ),CD(MC,MK),FCIV(MG),FXFLOW(MG,MK),
     2               DUR(MG),PITCH,WBAR(MX),XCROSS(MG,2),GRID
     *,ENDS
```

TABLE D-1. Continued

```
      DIMENSION       DNBFLX(MX)
      EQUIVALENCE  (DNBFLX(1),WBAR(1))
      COMMON/ICONT/ ICOUNT
CLCM  LEVEL 2, DNBFLX
CLCM  LEVEL 2, IGRID
*CD SPEC7
      COMMON /BAREA/ AFACT(ML,MA),GFACT(ML,MS),AXL(ML),GAPXL(ML),
     1               NARAMP,NAFACT,NAXL,NGXL,NGAPS,NCH(MA),NGAP(MS)
     *,END6
      COMMON /LARGE4/ IDAREA(MC),IDGAP(MG),GAPN(MG)
     *,END7
CLCM  LEVEL 2, IDAREA
*CD SPEC8
      DIMENSION     DPDX(MC),DHDX(MC),DFDX(MC),RSTW(M1,ME)
      EQUIVALENCE  (DHDX(1),CP(1)),(DFDX(1),FSP(1)),(DPDX(1),CON(1)),
     1             (P(1,1),RSTW(1,1))
CLCM  LEVEL 2, DPDX,DHDX,DFDX,RSTW
*CD SPEC9
      COMMON /PRCP1/ PP(MP),TT(MP),VVG(MP),HHF(MP),HHG(MP), VVF(MP),
     1               KKF(MP),SSIGMA(MP),AA(4),BB(4),CC(4),UUF(MP),
     2               HGPT(MP),TPCUT(MP),CPPOUT(MP),KPOUT(MP),UPOUT(MP),
     3               VPOUT(MP),DTMAX,PREFUL,GCRIT,AAL(4),BBL(4),CCL(4),
     4               NPROP,NVISCW,NTYPE(MC),ISTEAM,LAMNF
     *,END8
      REAL KPOUT,KKF
*CD SPEC10
      COMMON /PRCP2/ PREF,TF,VF,VG,HF,HG,UF,KF,SIGMA,HFG,VFG,RHOF,
     1               RHOG,AF(7),AV(7),NV,NF,JBOIL(MC),AH(4)
     *,END9
      REAL  KF
*CD SPEC11
      COMMON /MIXI/ ABETA,BBETA,XQUAL(MP),BX(MP),GK,FTM,NBBC,J5,NSCBC
     *,END10
*CD SPEC12
      COMMON /FUEL/  KFUEL(MT),KCLAD(MT),RFUEL(MT),RCLAD(MT),CFUEL(MT),
     1               CCLAD(MT),TCLAD(MT),TFLUID,HGAP(MT),LR(MR,6),
     2               PHI(MR,6),RADIAL(MR),D(MR),POWER,CFUEL(MT),BK(4),
     3               FLXX(MR),TREF,ZEND(MT,MY),TCLDR(MN,MR),IDFUEL(MR),
     4               NDAX,NC,IDTYP(MR),NZONE(MT),IZTYP(MT,MY),NRCDTP
     *,END11
      REAL KFUEL,KCLAD
CLCM  LEVEL 2, KFUEL
*CD SPEC13
      COMMON /BCHF/ MCHFR(MX),MCHFRC(MX),MCHFRR(MX),NCHF,NCHFX
     *,END12
      REAL MCHFR
*CD SPEC14
      DIMENSION       US(M1,ME),USW(M1,ME),TERM1(MC),TERM2(MC),
     1                DPK(MC),APP(M1,ME),FLOW(MC),B(MG),CIJ(MG),
     2                MARK(M1,ME),SP(M1,ME),DPWP(MC),IFDIV(MG),
     3                ISTAR(MG),HJMC(MC),AAH(N7),ILCC(N8),WPP(MG)
      EQUIVALENCE     (US(1,1),USW(1,1),PSI(1,1)),(TERM1(1),VISCW(1)),
     1                (TERM2(1),STUW(1,1)),(DPK(1),STUW(1,2)),
     2                (APP(1,1),AP(1,1)),(FLOW(1),STUW(1,3)),
     3                (B(1),WP(1),CIJ(1),WPP(1)),(MARK(1,1),BETA(1,1)),
     4                (SP(1,1),TRF(1,1)),(AAH(1),AAA(1,1)),
     5                (ILCC(1),ILCCS(1,1)),(DPWP(1),FSF(1),HJMO(1)),
     6                (ISTAR(1),IFDIV(1),FDIV(1))
CLCM  LEVEL 2, US,USW,TERM1,TERM2,DPK,APP,FLOW,B,CIJ,MARK,WPP
CLCM  LEVEL 2, SP,AAH,ILCC,DPWP,HJMO
CLCM  LEVEL 2, ISTAR,IFDIV
```

TABLE D-1. Continued

```
*CD SPEC15
      DIMENSION     SAVEA1(M1),SAVEA2(M1),SAVEA3(M1),
     1              SAVRES(N5)
      EQUIVALENCE   (SAVEA1(1),SAVEAL(1)),(SAVEA2(1),SAVEAL(NK)),
     1              (SAVEA3(1),SAVEAL(NW)),(SAVRES(1),SAVEA2(1))
CLCM  LEVEL 2, SAVEA1,SAVEA2,SAVEA3
CLCM  LEVEL 2, SAVRES
*CD SPEC16
      DIMENSION SUMX(MC),SUML(MC),SUMR(MC),STWJ(MC),STWJM1(MC)
      EQUIVALENCE   (SUML(1),VISC(1)),(SUMR(1),CP(1)),
     1              (SUMX(1),VISCW(1)),(STWJ(1),FSP(1)),
     2              (STWJM1(1),CON(1))
CLCM  LEVEL 2,SUML,SUMR,SUMX,STWJ,STWJM1
*CD SPEC17
      DIMENSION AAAPRM(N7),WPRM(M2),LOCA1(N6)
      EQUIVALENCE (AAA(1,1),AAAPRM(1)),(W(1,1),WPRM(1)),
     1              (LOCA(1,1),LOCA1(1))
CLCM  LEVEL 2,AAAPRM,WPRM,LOCA1
      DIMENSION      USWPRM(MG),USPRM(MG),BETPRM(MG),SPPRM(MG),
     1               WOLDPM(MG),UBPRM(MC),APPPRM(MC),WSAVE(MG),
     2               DTII(MG),DTJJ(MG)
      EQUIVALENCE    (WSAVE(1),BSAVE(1,3)),(DTII(1),BSAVE(1,1)),
     1               (DTJJ(1),BSAVE(1,2)),(USWPRM(1),USW(1,1)),
     2               (USPRM(1),US(1,1)),(BETPRM(1),BETA(1,1)),
     3               (SPPRM(1),SP(1,1)),(WOLDPM(1),WOLD(1,1)),
     4               (UBPRM(1),UB(1,1)),(APPPRM(1),APP(1,1))
CLCM  LEVEL 2,USWPRM,USPRM,BETPRM,SPPRM
CLCM  LEVEL 2, WOLDPM,UBPRM,APPPRM,WSAVE
CLCM  LEVEL 2,DTII,DTJJ
*CD SPEC18
      DIMENSION A1(M2),AAA1(N7),BSAVE1(M2),PSI1(M2),LOCA1(N6),
     1         B(MG),BETA1(M2)
      EQUIVALENCE (A1(1),A(1,1)),(AAA1(1),AAA(1,1)),
     1              (BSAVE1(1),BSAVE(1,1)),(PSI1(1),PSI(1,1)),
     2              (B(1),WP(1)),(LOCA1(1),LOCA(1,1)),(BETA1(1),BETA(1,1))
CLCM  LEVEL 2,A1,AAA1,BSAVE1,PSI1,LOCA1,B,BETA1
*CD SPEC19
      COMMON/INMAIN/  OUTPUT(12),PRINT(12),TEXT(17),DATE(2),TIME(2),
     1               TDUMY(10),PHTOT,TTIME,ETIME,HIF(4),ZPT(4),
     2               YP(MP),FP(MP),YG(MP),FG(MP),YH(MP),FH(MP),
     3               YO(MP),FO(MP),YT(MP),FI(MP),FMX(MP),YMX(MP),
     4               HOUT,NHX,NCUT,NPCHAN,NPGAP,NPNODE,NPROD,NPLTCH,
     5               PRINTN(10),NPLTGP,NSKPLT,NSKIPT,NSKIPX,MN,MR,
     6               MC,MG,MP,MX,MW,MY,ME,MZ,MK,MS,MA,M1,MT,ML,NP,
     7               NG,NQ,NH,ICKT,IM(MS),JM(MS),MAXT,NJUMP,
     8               IMP(10),JMP(10),IB,IH,IG,IFINH,IFOUTH,K10,
     9               NOT,NOTP1,KASE,NTRIES,ITSTEP,THX,THO,KNOFLC,JNOFLO
     *,HIN,TIN,GIN,ZZ,DXX
     *,END13,SIGNAL(18),H1,H2,H3,H4,H5,H6,H7,H8
      COMMON /LARGE2/  PRINTC(MC),PRINTG(MG),PRINTR(MR),IPLTCH(MC),
     1                IPLTGP(MG),HEXIT(MC),ABAR(MC)
     *,END14
      INTEGER PRINTC,PRINTG,PRINTN,PRINTR
      LOGICAL PRINT
CLCM  LEVEL 2,PRINTC
*CD SPEC20
      DIMENSION SAVEA1(M1),SAVEA2(M1),SAVEA3(M1)
CLCM  LEVEL 2,SAVEA1,SAVEA2,SAVEA3
```

TABLE D-1. Continued

```
*CD SPEC21
      DIMENSION PHI(MC)
      EQUIVALENCE(PHI(1),FSP(1))
CLCM  LEVEL 2,PHI
*CD SPEC22
      DIMENSION F(MP),Y(MP)
*COMDECK SPEC23
CLCM  LEVEL 2,SPC23,ISPC23,SPC24,ISPC24,SPC61,ISPC61
CLCM  LEVEL 2,SPC72,ISPC72,SPC12,ISPC12,SPC20,ISPC20
*CD SPEC24
CLCM  LEVEL 2,X,Y,Z
*CD SPEC25
CLCM  LEVEL 2,VARS
*CD SPEC26
CLCM  LEVEL 2,ISTORE,STORE,STORES,LOGICL
*CD SPEC27
CLCM  LEVEL 2,A,B
LAST
```

APPENDIX E

PROGRAM GEOM

APPENDIX E

PROGRAM GEOM

Program GEOM automatically calculates, and makes card images of, COBRA input data for input card groups 4, 7, and 8, for hexagonal rod bundles. It can be used to generate:

- subchannel areas, wetted perimeters, heated perimeters and the subchannel connection logic required in Group 4;
- the gap direction angles input in Group 4 when the transverse momentum flux model is used;
- the relative wirewrap crossing information for the wire wrap model in Group 7;
- the initial wire wrap inventory for Group 7;
- the fuel rod diameter, radial power factor (if supplied) and rod-to-channel connection data for Group 8;
- an option to calculate geometries that either include or omit the corner subchannels.

The input to this program consists of a maximum of eight data cards plus an optional rod power distribution. The subchannel and rod numbering scheme and by GEOM is demonstrated in Figure E-1.

There are two general input forms available to the user. Under the first option, the user specifies the subchannel area, wetted perimeter, and heated perimeter for typical internal, side and corner subchannels. Under the second option, the code calculates the areas and perimeters from the overall bundle geometry. A description of the GEOM input follows.

OPTION 1 - USER SPECIFIES AREA AND PERIMETER DATA

Card 1 (I5,18A4)

This is a header card and contains a 1 in column 5 and an alpha-numeric title in columns 6 through 77.

Card 2 (3F5.3)

This card contains the area (in.^{2}), wetted perimeter (in.) and heated perimeter (in.) of an interior subchannel.

Card 3 (3F5.3)

This card is the same as Card 2 but the information is for the side subchannel.

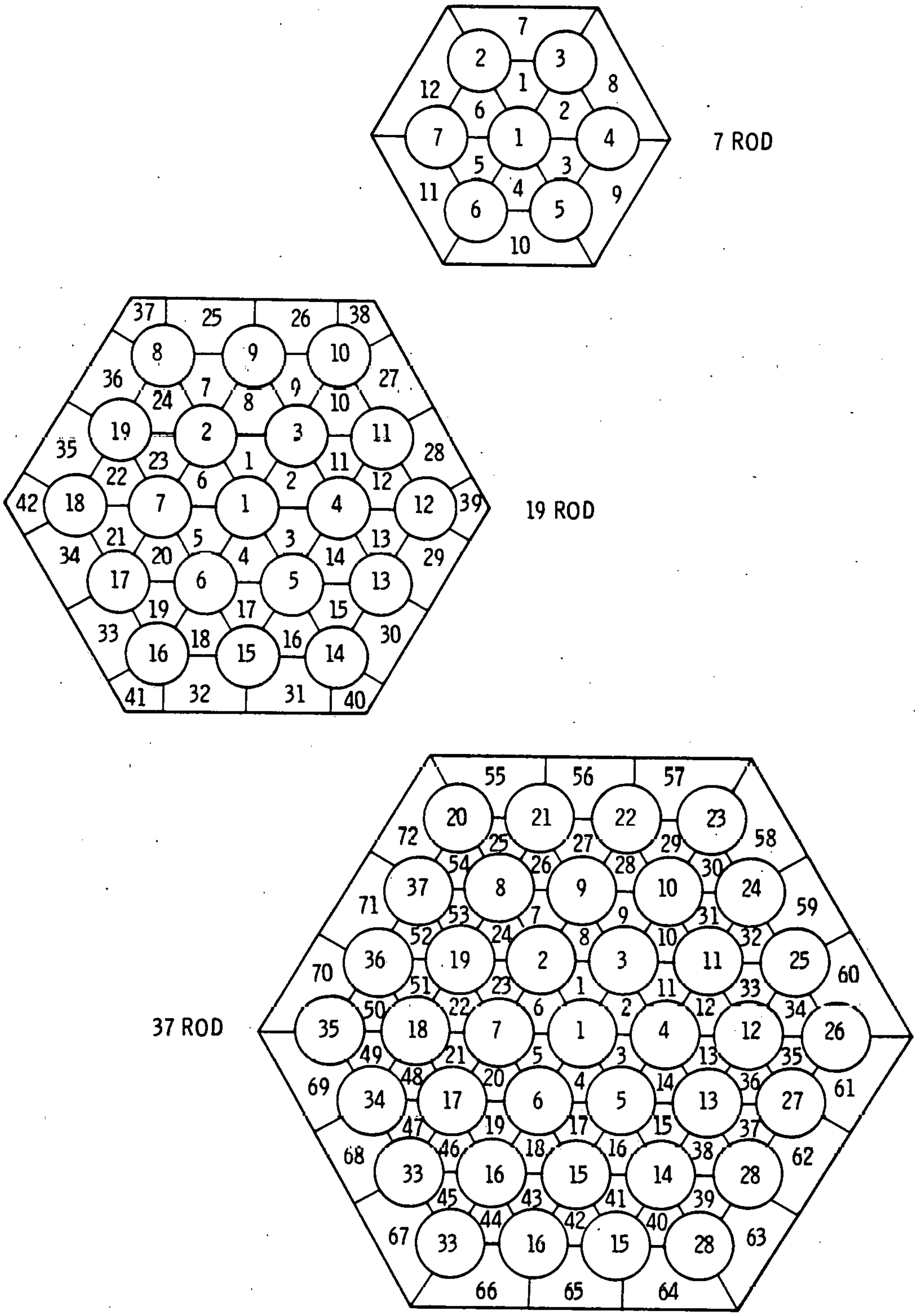


FIGURE E-1. Samples of GEOM Rod and Channel Numbering Scheme

Card 4 (3F5.3)

Same as the above but for a corner subchannel.

Card 5 (4(2F5.3))

This card contains the gap width (in.) and the centroid-to-centroid distance (in.) for

1. interior - interior connections
2. interior - side connections
3. side - side connections
4. corner side connections

Card 6 (6I1)

This card contains six switches which specify the amount and form of the output from GEOM. The name, value, and function of each switch is shown below.

Name	Value	Function
IOUT(1)	.GT.0	Area and gap connection data for COBRA Group 4 are output.
IOUT(2)	.GT.0	Gap direction angles for COBRA Group 4 are output.
IOUT(3)	.GT.0	COBRA Group 7 wire wrap data are output.
IOUT(4)	.GT.0	Rod to channel connection data for Group 8 are output.
NPUN	.EQ.0	The output is to be on the line pringer and on logical Unit 9.
	.NE.L	The output is on the punch as well as the above.
IRODP	.NE.0	Individual relative rod powers for Group 8 are to be read sequentially from logical unit IRODP. The card reader is logical unit 5. Logical unit 9 is also available.

Card 7 (I5, 2F5.3, 3I5, F5.3, I5)

This card specifies additional model geometry information consisting of

1. number of rods in the bundle;
2. nominal rod diameter (in.);
3. nominal value of the rod power factor;

4. the subchannel friction factor typing parameter. If the typing parameter is zero, then all subchannels are assigned zero as the subchannel type. If it is one, then interior subchannels are TYPE 1, edge subchannel TYPE 2, and corner subchannel TYPE 3. If it is 2, then the subchannels are typed via the information supplied in the optional eighth data card;
5. the wire wrap direction indicator. One represents clockwise wrapping and zero, counterclockwise wrapping;
6. wire wrap starting angle (degrees). This is an integer value and therefore only valued to the nearest degree. The angle is measured counterclockwise from zero as shown in Figure E-2;
7. the effective wire pitch fraction for forcing crossflow (δ in COBRA Group 7);
8. corner subchannel switch. If it is zero, then the corner subchannels are omitted; if it is one, they are included.

Card 8 (I5, 4(2I5))

This card is needed only if the subchannel friction factor typing parameter of card 7 is 2. It contains the number of subchannel types to be specified and the minimum and maximum subchannel number for each type.

Card 9

A blank card is read as the last data card to terminate the GEOM run.

OPTION 2 - AREA AND PERIMETER DATA CALCULATED IN GEOM

Card 1

Same as card 1 under Option 1.

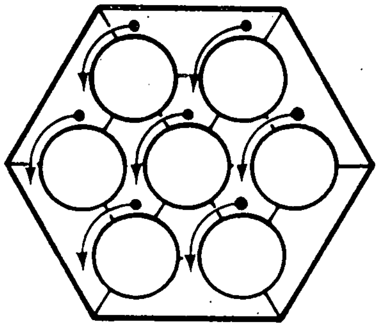
Card 2

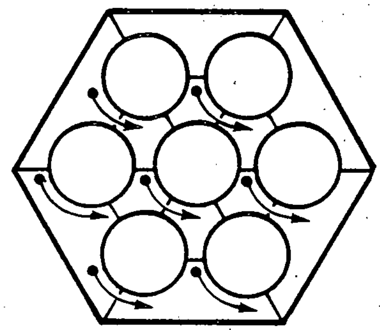
This is a blank card and signifies that Option 2 is to be used.

Card 3 (5E5.3)

This card contains

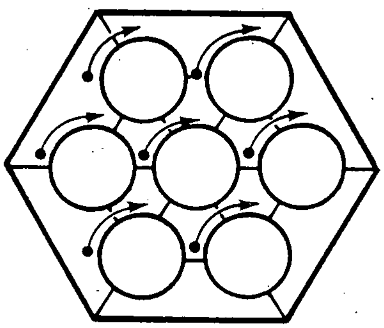
1. the rod pitch (in.)
2. rod diameter (in.)
3. pitch to diameter ratio
4. flat-flat I.D. duct dimension
5. Rod Packing Factor. This variable is limited to the range from zero to one. If it is one, then assembly tolerances are applied uniformly and the peripheral and interior gaps have the same dimensions. If it is zero, then the tolerances are applied only to the peripheral gaps and the interior gaps are assumed to have a width defined as the rod pitch minus the rod diameter.

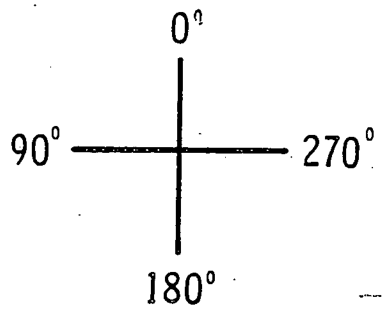




a) Wire wrap starting angle = 0°
counterclockwise rotation

b) Wire wrap starting angle = 90°
counterclockwise rotation*





c) Wire wrap starting angle = 90°
clockwise rotation*

d) Wire wrap starting angle
convention

*NOTE: When a wrap is initially on a gap the initial wrap inventory is determined by moving the wrap completely into the channel toward which it is moving. Compare b and c above.

FIGURE E-2. Definition of Wrap Starting Angle and Rotation Direction

Only two of the first three variables of card 3 are needed and any one may be omitted.

Card 4

Same as card 6 under Option 1.

Card 5

Same as card 7 under Option 1.

Card 6

Same as card 8 under Option 1.

Card 7

Blank terminator card.

Under either of the above input options, the rod power distribution for the COBRA Group 8 cards will be uniform, and will have the value specified on card 7 under Option 1. The power distribution can be modified by sequentially reading in the relative rod powers under a 12F5.3 format from the logical unit specified in card 6 from Option 1 or card 4 under Option 2. If the card reader is selected, these data are read immediately preceding the blank terminator card in the input deck.

APPENDIX F

COBRA VARIABLES DESCRIPTION

COBRA-IV-I VARIABLES DESCRIPTION

Variable (Dimension)	Comdeck	Subroutine	Definition
A(M1,ME)	SPEC 3	AREA	Local subchannel area, ft^2.[a]
AA(4), BB(4), CC(4)	SPEC 9	input	Coefficients for up to 4 turbulent friction factor correlations. (Group 2)[b]
AAA(MO,MG)	SPEC 2	COBRA	Crossflow coefficient matrix for the equation: [AAA]*{W} = {B}
AAAPRM (N7)	SPEC 17	DIVERT	Vector storage of AAA.
AAH (N7)	SPEC 14	SCHEME	Term used in solution of energy equation.
AAL(4), BBL(4), CCL(4)	SPEC 9	input	Coefficient for up to 4 laminar friction factor correlations. (Group 2)
ABAR (MC)	SPEC 19	XSCHEM	Exit density, lb/ft^3.
ABETA, BBETA	SPEC 11	input	Mixing parameters used in calculating turbulent crossflow. (Group 10)
ACCEL1	SPEC 2	input	Acceleration factor used in explicit transient flow field solution. (Group 9)
ACCEL2	SPEC 2	input	Acceleration factor used in explicit transient flow field solution. (Group 9)
ACCELF	SPEC 2	input	External acceleration factor for axial flow. (Group 9)
ACCELY	SPEC 2	input	Internal acceleration factor for crossflow solution. (Group 9)
AC(MC)	SPEC 1	input	Subchannel area, in^2. (Group 4)
AF (7)	SPEC 10	input	Coefficients of NF^{th} order polynomial function of two-phase friction multiplier versus quality. (Group 2)
AFACT (ML,MA)	SPEC 7	input	Relative subchannel area variation. (Group 5)
AFLUX	SPEC 2	DIFFER	Average heat flux, $MBtu/hr\text{-}ft^2$. (Group 11)
AH(4)	SPEC 10	input	Constants for heat transfer coefficient equation. (Group 2)
ALPHA (MC)	SPEC 2	VOID	Bulk void fraction in two-phase flow.
ANGLE (MG)	SPEC 2	input	Gap orientation angle, radians. (Group 4)
AN (MC)	SPEC 2	SETUP	Subchannel area, AC/144, ft^2.
AP2IDT	SPEC 2	XSCHEM	0.5 * AP2(I,J)/DT
AP(M1,ME)	SPEC 3	XSCHEM	Storage for channel heat input.
APP (M1,ME)	SPEC 14	DIFFER	Average of the area at the current node J and at the previous node, J-1, ft^2.
ATOTAL	SPEC 2	SETUP	Summation of subchannel flow areas, ft^2.
AV(7)	SPEC 10	input	Single term slip ratio or coefficients of NV^{th} order polynomial function of the bulk void fraction versus quality. (Group 2)
AXIAL (MP)	SPEC 2	input	Relative axial power distribution. (Group 3)
AXL(ML)	SPEC 7	input	Relative axial location of subchannel area variations. (Group 5)
B(MG)	SPEC 14	DIVERT	Implicit crossflow forcing function; see AAA.
BB(4)	SPEC 9	input	See AA
BBETA	SPEC 11	input	See ABETA
BBL(4)	SPEC 9	input	See AAL
BETA(M1,ME)	SPEC 3	DIFFER	Crossflow momentum flux and resistance.

(a) The dimensions listed represent the units employed during code calculations. The input instructions should be consulted for variable dimensions during input.

(b) See input instructions under specified group for more information.

Variable (Dimension)	Comdeck	Subroutine	Definition
BK(4)	SPEC 12	input	Coefficients for up to 3^{rd} order polynomial function of full thermal conductivity versus temperature. (Group 8)
BSAVE(M1,ME)	SPEC 4	XSCHEM	Not used.
BX(G)	SPEC 11	input	Tabulated β values for two-phase mixing versus quality. (Group 10)
CC(4)	SPEC 9	input	See AA
CCL(4)	SPEC 9	input	See AAL
CCHANL(M1,ME)	SPEC 5	CHF	Channel number in which minimum CHF ratio occurs for rod N at axial location J.
CCLAD(MT)	SPEC 12	input	Specific heat of cladding material, Btu/lb-°F. (Group 8)
CD(MC,MK)	SPEC 6	input	Loss coefficient across grid type N in Channel I. (Group 7)
CFUEL(MT)	SPEC 12	input	Specific heat of fuel material, Btu/lb-°F. (Group 8)
CHFR(M1,ME)	SPEC 5	CHF	Minimum CHF ratio for rod N facing Channel I.
CIJ(MG)	SPEC 14	DIFFER	Crossflow resistance.
CON(MC)	SPEC 2	PROP	Thermal conductivity of coolant based on enthalpy, Btu/sec-ft-°F.
CP(MC)	SPEC 2	PROP	Specific heat of coolant based on enthalpy, Btu/lb-°F.
CPPOUT(MP)	SPEC 9	STEAM	Specific heat of superheated steam for steam property table, Btu/lb-°F.
D(MR)	SPEC 12	SETUP	Rod Diameter, DR/12, ft^2.
DATE(2)	SPEC 19	DOY	Today's date.
DATIN(N2)	SPEC 1	SETUP	Peripheral storage vector for input variables.
DC(MC)	SPEC 1	SETUP	Hydraulic diameter of subchannel, 4*AC/PW, in.
DFDX(MC)	SPEC 8	SCHEME	df/dx, mass flow rate derivative.
DFUEL(MT)	SPEC 12	input	Diameter of fuel pellet, ft. (Group 8)
DHDX(MC)	SPEC 8	SCHEME	dh/dx, enthalpy derivative.
DHYD(M1,ME)	SPEC 2	AREA	Local subchannel hydraulic diameter, ft.
DHYDN(MC)	SPEC 2	SETUP	Nominal hydraulic diameter, DC/12, ft.
DIA	SPEC 6	input	Diameter of rod including clad, ft. (Group 7)
DIST(MC,4)	SPEC 1	input	Centroid-to-centroid distance between subchannels, in. (Group 4)
DPDX(MC)	SPEC 8	DIFFER	dP/dx, pressure derivative.
DPK(MC)	SPEC 14	DIFFER	Losses due to the frictional pressure drop and pressure drop across grid spacers.
DPWP(MC)	SPEC 14	DIFFER	Momentum exchange due to turbulent mixing.
DR(MR)	SPEC 1	input	Rod diameter including clad, in. (Group 8)
DT	SPEC 2	SETUP	Nominal time step, sec.
DTGC	SPEC 2	COBRA	DT*GC
DTII(MG)	SPEC 17	DIVERT	Temporary storage of coefficients of w in equation (9). Only values for subchannel IK(K) are stored.

Variable (Dimension)	Comdeck	Subroutine	Definition
DTJJ(MG)	SPEC 17	DIVERT	Same as DTII but for subchannel JK(K).
DTMAX	SPEC 9	input	Maximum temperature difference for superheated steam table, °F. (Group 1)
DTU	---	DIVERT	In line function which gathers all the coefficients of Wj in equation (11).
DUR(MG)	SPEC 6	input	Effective fraction of wrap pitch for forcing crossflow. (Group 7)
DX	SPEC 2	SETUP	Axial node length, ft.
DX2	SPEC 2	SETUP	DX*DX
DX41	SPEC 2	SETUP	0.25/DX
DXDT	SPEC 2	COBRA	DX*DT
DXGC	SPEC 2	SETUP	DX*GC
DXI	SPEC 2	SETUP	1/DX
DXIDT	SPEC 2	COBRA	DX/DT
ELEV	SPEC 2	SETUP	Gravity; cosine (THETA)
ETIME	SPEC 19	COBRA	Elapsed transient time, sec.
F(M1,ME)	SPEC 3	SCHEME	Local subchannel mass flow, lb/sec.
F(MP)	SPEC 22	CURVE	Array for dependent variable in CURVE
FCOUR	SPEC 2	input	Courant number, $U*\Delta t/\Delta x$. (Group 9)
FDIV(MG)	SPEC 6	FORCE	A forced diversion crossflow switch = 0, forced crossflow absent = 1, forced crossflow present
FDT	SPEC 2	input	Maximum time step, sec. (Group 9)
FERROR	SPEC 2	input	Flow convergence criterion. (Group 9).
FG(MP)	SPEC 19	input	Forcing function for change in inlet mass velocity or pressure drop at transient time Y. (Group 11)
FH(MP)	SPEC 19	input	Forcing function, fractional change in inlet enthalpy at transient time YH. (Group 11)
FHX(MP)	SPEC 19	input	Forcing function, fractional change in exit enthalpy at transient time YHX. (Group 11)
FINLET(MC)	SPEC 1	SETUP	Subchannel inlet flow, lb/sec.
FLOW(MC)	SPEC 14	DIFFER	Sum of flow at J and J-1 axial levels
FLUX(M1,ME)	SPEC 5	HEAT	Local heat flux, Btu/sec-ft^2.
FLXX(MR)	SPEC 12	TEMP	Local heat flux, Btu/sec-ft^2.
FOLD(M1,ME)	SPEC 3	COBRA	Mass flow from the previous time step, lb/sec.
FP(MP)	SPEC 19	input	Forcing function for system pressure at transient times YP. (Group 11)
FQ(MP)	SPEC 19	input	Forcing function, fractional change in average heat flux at transient times YQ. (Group 11)
FSP(MC)	SPEC 2	PROP	Friction factor
FTM	SPEC 11	input	Turbulent momentum factor. (Group 9)
FT(MP)	SPEC 19	input	Maximum permissible time step at transient time YT. (Group 9)
FXFLOW(MG,MX)	SPEC 6	input	Forced crossflow due to grid spacers. (Group 7)
GAP(M1,ME)	SPEC 4	SETUP	Local gap spacing between adjacent channels, ft.
GAPN(MG)	SPEC 7	SETUP	Gap spacing, GAPS/12, ft.
GAPS (MC,4)	SPEC 1	input	Gap spacing between adjacent subchannels, in. (Group 4)
GAPXL(ML)	SPEC 7	input	Relative axial locations of gap width variations. (Group 6)

Variable (Dimension)	Comdeck	Subroutine	Definition
GC	SPEC 2	COBRA	32.2 lbm-ft/lbf-sec^2
GFACT(ML,MS)	SPEC 7	input	Relative gap width variation. (Group 6)
GK	SPEC 11	input	Kg, geometry factor for conduction. (Group 10)
GRID	SPEC 6	SETUP	Grid spacer switch = .true. grids present = .false. grids absent
GRIDXL(MZ)	SPEC 6	input	Relative axial location of grid spacer. (Group 7)
H(ML,ME)	SPEC 3	SCHEME	Local subchannel enthalpy, Btu/lb
HEXIT(MC)	SPEC 19	COBRA	Enthalpy at the bundle exit, Btu/lb
HF	SPEC 10	PROP	Saturated liquid enthalpy at the reference pressure, Btu/lb.
HFG	SPEC 10	PROP	Latent heat of vaporization at the reference pressure, (HG-HF), Btu/lb.
HFILM(MC)	SPEC 2	PROP	Heat transfer coefficient.
HG	SPEC 10	PROP	Saturated vapor enthalpy at the reference pressure, Btu/lb.
HGAP(MT)	SPEC 12	input	Gap conductance between fuel and cladding, Btu/sec-ft^2-°F. (Group 8)
HGPT(MP)	SPEC 9	STEAM	Enthalpy of superheated steam for steam property table, Btu/lb.
HHF(MP)	SPEC 9	input	Enthalpy of liquid for fluid properties table, Btu/lb. (Group 1)
HHG(MP)	SPEC 9	input	Enthalpy of vapor for fluid properties table, Btu/lb. (Group 1)
HINLET(MC)	SPEC 1	SETUP	Subchannel inlet enthalpy, Btu/lb.
HIP(4)	SPEC 19	input	Maximum plot coordinates for the four types of plots; paired with ZPT(4). (Group 12)
HOLD(M1,ME)	SPEC 3	COBRA	Local enthalpy at previous time step, Btu/lb.
HOUT	SPEC 19	input	Enthalpy of upper plenum, Btu/lb. (Group 11)
HPERIM(MC)	SPEC 2	COBRA	Heated perimeter, PH/12, ft.
HSURF(M1,ME)	SPEC 5	HEAT	Average surface heat transfer coefficient surrounding rod, Btu/sec-ft^2-°F.
I2	SPEC 2	COBRA	Designates input device (read statements).
I3	SPEC 2	COBRA	Designates output device (write statements).
I8	SPEC 19	COBRA	I/O device to which current variables are dumped at end of job (see explanation of Dump and Restart option)
IDAREA(MC)	SPEC 7	SETUP	Identification number for a subchannel that has area variations.
IDFUEL(MR)	SPEC 12	input	Rod type for property designation. (Group 8)
IDGAP(MG)	SPEC 7	SETUP	Identification number for gap that has gap variation
IDTGC	SPEC 2	COBRA	1/(DT*GC).
IDTYP(MR)	SPEC 12	input	Fuel shape, cylinder or plate.
IERROR	SPEC 2	COBRA	Error flag: = 0, no problem > 1, print error messages
IFDIV(MG)	SPEC 14	SCHEME	Temporary storage for printing wire wrap forced crossflow data.
IFINH	SPEC 19	SETUP	Inlet enthalpy flag if flow reverses. 0 - inlet enthalpy specified 1 - inlet h floated (takes last exit value).

Variable (Dimension)	Comdeck	Subroutine	Definition
IFOUTH	SPEC 19	SETUP	Exit enthalpy flag defined like IFINH.
IFTYP(M1,ME)	SPEC 5	COBRA	Fuel type identifier.
IG	SPEC 19	input	Inlet mass velocity option. (Group 11, N2) = 0, GIN is inlet mass velocity for each channel = 1, GIN is average inlet mass velocity, but subchannel flows are split to give equal dp/dx = 2, individual subchannel flow fractions are read in
IGRID(MZ)	SPEC 6	input	Grid spacer type number.
IH	SPEC 19	input	Inlet enthalpy option. (Group 11, N1) = 0, HIN is inlet enthalpy = 1, HIN is inlet temperature = 2, the inlet enthalpy for each subchannel is read in = 3, the inlet temperature for each subchannel is read in
IK(MG)	SPEC 2	SETUP	Identifies subchannels on opposite sides of a gap paired with JK.
IKW(MW)	SPEC 2	input	Identified subchannels on opposite sides of a wall paired with JKW.
ILOC(N8)	SPEC 14	SETUP	Singly dimensioned ILOCS.
ILOCS(MC'NAAHP1)	SPEC 2	SETUP	Array to identify gaps and walls connected to subchannel I.
IM(MS)	SPEC 19	SETUP	Identifies subchannels on opposite sides of a gap that has gap variations. Paired with JM.
IMP(10)	SPEC 19	RESULT	Dummy variable used in printout of crossflow information.
IPLTCH(MC)	SPEC 19	input	Identification numbers of channels for which information will be plotted. (Group 12)
IPLTGP(MG)	SPEC 19	input	Identification numbers of gaps for which information will be plotted. (Group 12)
IROLL	SPEC 2	input	Data storage option. (Group 9, N4) = 1, ROLL option employed
ISTAR(MG)	SPEC 14	DIFFER	Number of the donor channel for crossflow through gap K.
ISTEAM	SPEC 9	input	Superheated steam properties table flag; = 0, no superheated properties = 1, superheated properties calculated. (Group 1, N2)
ITERAT	SPEC 2	SCHEME	Loop counter for the external iteration loop in SCHEME.
ITRAP	SPEC 2	XSCHEM	Calculational switch in XSCHEM.
ITRY	SPEC 2	input	Maximum number of Gauss-Siedel iterations. SCHEME. (Group 9)
ITRYM	SPEC 2	input	Minimum number of internal iterations, SCHEME. (Group 9).
ITSTEP	SPEC 19	input	Number of elements in variable maximum time step table. (Group 9, N5)
IZTYPE(MT,MY)	SPEC 12	input	Identification number of the fuel type in each fuel zone. (Group 8)
J1	SPEC 2	input	Directs print-out of input data, (case control card); = 0, print only new data = 1, print entire input = 2, print only operating conditions

Variable (Dimension)	Comdeck	Subroutine	Definition
J2	SPEC 2	input	Subcooled void option. (Group 2, N1) = 0, no subcooled voids = 1, Levy subcooled void model
J3	SPEC 2	input	Option for bulk void correlation. (Group 2, N2) = 0, homogenous bulk void model = 1, modified Armand, bulk void model = 5, homogenous model with specified slip ratio = 6, bulk void fraction input as an Nth order polynomial function of quality
J4	SPEC 2	input	Input data option for two-phase friction-multiplier, (group 2, N3) = 0, homogeneous model = 1, Armand friction multiplier = 5, friction multiplier input as an Nth order polynomial function of quality
J5	SPEC 11	input	Radial thermal conduction option. (Group 10, N3) = 0, conduction absent = 1, conduction present
J6	SPEC 6	input	Flags type of spacer design. (Group 7, N1) = 1, wire wraps = 2, grid spacers = 3, both
JBOIL(MC)	SPEC 10	PROP	Indicates axial location of onset of sub-cooled boiling in Subchannel I.
JK(MG)	SPEC 2	SETUP	see IK
JKW(MW)	SPEC 2	SETUP	see IKW
JM(MS)	SPEC 19	SETUP	see IM
JMP(10)	SPEC 19	RESULT	see IMP
K10	SPEC 19	input	Determines the type of ΔP transient. (Group 11, N7) = 0, pressure drop is given in psi = 1, pressure drop transient is a fraction of the steady-state pressure drop
K11	SPEC 2	input	Numerical solution option. (Group 9, N3) = 0, implicit solution = 1, explicit solution; pressure boundary condition, running start = 2, explicit solution, pressure boundary condition, standing start = 3, explicit solution, inlet flow specified running start = 4, explicit solution, inlet flow specified standing start
K12	SPEC 2	SETUP	Set to one if gap orientation angles are used.
KASE	SPEC 19	input	Case number, (case control card)
KCLAD(MT)	SPEC 12	input	Thermal conductivity of cladding material, Btu/sec-ft-°F. (Group 8)
KF	SPEC 10	PROP	Saturated liquid thermal conductivity at the reference pressure, Btu/sec-ft-°F.

Variable (Dimension)	Comdeck	Subroutine	Definition
KFUEL(MT)	SPEC 12	input	Thermal conductivity of fuel material, Btu/sec-ft-°F. (Group 8)
KIJ	SPEC 2	input	Crossflow resistance coefficient. (Group 9)
KKF(MP)	SPEC 9	input	Thermal conductivity of liquid for fluid properties table, Btu/hr-ft-°F. (Group 1)
KPOUT(MP)	SPEC 9	STEAM	Thermal conductivity of superheated steam for Steam Property Table, Btu/sec-ft-°F.
LAMNF	SPEC 9	input	>1, flags laminar flow friction factor correlation. (Group 2)
LC(MC,4)	SPEC 1	input	Adjacent subchannel number. LC(I,J) is the Jth subchannel adjacent to Subchannel I. (Group 4)
LENGTH(MG)	SPEC 2	SETUP	Centroid to centroid distance, DIST/12, ft.
LOCA1(N6)	SPEC 17	DIVERT	Equivalenced to the LOCA array.
LOCA(NO,MG)	SPEC 2	SETUP	Gap geometry array LOCA contains up to NAAA gap numbers adjacent to gap K.
LR(MR,6)	SPEC 12	input	Identification number of subchannel facing rod N. (Group 8)
LUI	SPEC 2	COBRA	READ/WRITE device for ROLL option.
LUO	SPEC 2	COBRA	READ/WRITE device for ROLL option.
M1	SPEC 19	COBRA	SPECSET paramenter, computed in SPECSET, width of SAVEA1, SAVEA2, and SAVEA3 arrays.
MA	SPEC 19	COBRA	SPECSET parameter, maximum number of subchannels that can have area variations.
MARK(M1,ME)	SPEC 14	DIVER	Forced gap identifiers.
MAXT	SPEC 19	input	Maximum execution time on the computer.
MC	SPEC 19	COBRA	SPECSET parameter, maximum number of subchannels.
MCHFRC(MX)	SPEC 13	CHF	Number of the subchannel in which the minimum CHF ratio occurs.
ME	SPEC 19	COBRA	SPECSET parameter, set to 3 for storage on peripherals (see explanation of ROLL option), otherwise equal to MX.
MG	SPEC 19	COBRA	SPECSET parameter, maximum number of gaps.
MK	SPEC 19	COBRA	SPECSET parameter, maximum number of grid spacer types.
ML	SPEC 19	COBRA	SPECSET parameter, maximum number of axial locations for gap and area variations.
MN	SPEC 19	COBRA	SPECSET parameter, number of fuel collocation points plus three.
MODE(M1,ME)	SPEC 5	HCOOL	Identifies heat transfer mode.
MP	SPEC 19	COBRA	SPECSET parameter, maximum number of cards in Steam Property Table.
MR	SPEC 19	COBRA	SPECSET parameter, maximum number of rods.
MS	SPEC 19	COBRA	SPECSET parameter, maximum number of gaps that can have gap spacing variations.
MT	SPEC 19	COBRA	SPECSET parameter, maximum number of fuel types.
MW	SPEC 19	COBRA	SPECSET parameter, maximum number of wall connections.
MX	SPEC 19	COBRA	SPECSET parameter, maximum number of axial nodes plus one.

Variable (Dimension)	Comdeck	Subroutine	Definition
MY	SPEC 19	COBRA	SPECSET parameter, maximum number of axial fuel type divisions.
MZ	SPEC 19	COBRA	SPECSET parameter, maximum number of axial locations for grid spacers.
NAAA	SPEC 2	COBRA	Maximum width of the AAA matrix, (five for hexagonal, seven for square arrays).
NAAAP1	SPEC 2	COBRA	NAAA + 1
NAAH	SPEC 2	COBRA	Maximum number of connections to a channel plus one.
NAAHP1	SPEC 2	COBRA	NAAH + 1
NAFACT	SPEC 7	input	Total number of subchannel area variations. (Group 5, N1)
NARAMP	SPEC 7	input	Number of iterations for inserting area variations. (Group 5, N3)
NAX	SPEC 2	input	Number of elements in axial heat flux table. (Group 3, N1)
NAXL	SPEC 7	input	Number of axial positions for subchannel area variations. (Group 5, N2)
NBBC	SPEC 11	input	Two-phase mixing option. (Group 10, N2) < 2, same as subcooled ≥ 2, β is a function of quality.
NC	SPEC 12	input	Fuel collocation option. (Group 8, N3) = 0, no fuel model = 2, second order collocation = 3, third order collocation.
NCHANL	SPEC 2	input	Number of subchannels. (Group 4, N2)
NCHF	SPEC 13	input	Input data option for CHF correlation. (Group 8, N5), = 0, no CHF calculations = 1, B&W-2 CHF correlation = 2, W-3 CHF correlation.
NCHFX	SPEC 13	COBRA	Selects the critical heat flux correlation on basis of system pressure for the RELAP4 boiling heat transfer correlations package.
NCH(MA)	SPEC 7	SETUP	Subchannel number in which area variation occurs.
NDT	SPEC 19	input	Number of time steps for transient. (Group 9)
NDTP1	SPEC 19	COBRA	Number of time steps plus one.
NDX	SPEC 2	input	Number of axial nodes. (Group 9)
NDXP1	SPEC 2	SETUP	Number of axial nodes plus one.
NF	SPEC 10	input	Number of coefficients of polynomial function expressing bulk void fraction; see AF.
NG	SPEC 19	input	Number of elements in mass velocity transient table (see YG, FG). (Group 11, N5)
NGAP(MS)	SPEC 7	SETUP	Gap number in which gap width variation occurs.
NGAPS	SPEC 7	input	Total number of gaps for which gap variations occur. (Group 6, N1)
NGRID	SPEC 6	input	Number of grid spacers. (Group 7, N3)

Variable (Dimension)	Comdeck	Subroutine	Definition
NGRIDT	SPEC 6	input	Number of grid spacer types. (Group 7, N4)
NGTYPE	SPEC 6	FORCE	Grid type number.
NGXL	SPEC 7	input	Maximum number of axial positions for gap variations. (Group 6, N2)
NHTC	SPEC 2	input	Heat transfer correlation option. (Group 8, N7) = 0, correlations based on subcooled flow = 1, RELAP boiling flow correlation package
NHX	SPEC 19	input	Number of elements in exit enthalpy transient table (see FHX, YHX). (Group 11, N8)
NJUMP	SPEC 19	RESTRT	Flag for restart option. = 0, no restart = 1, problem is restarted
NK	SPEC 2	SETUP	Number of gap connections.
NOUT	SPEC 19	input	Output option. (Group 12, N1) = 0, subchannels only = 1, subchannels and gaps = 2, subchannels and rods = 3, all three
NP	SPEC 19	input	Number of elements in pressure transient tables, (see YP, FP). (Group 11, N3)
NPCHAN	SPEC 19	input	Output option, number of channels to be printed (if zero, print all). (Group 12, N2)
NPGAP	SPEC 19	input	Output option, number of gaps for which information will be printed. (Group 12, N5)
NPLTCH	SPEC 19	input	Output option, number of channels for which information will be plotted. (Group 12, N7)
NPLTGP	SPEC 19	input	Output option, number of gaps for which information will be plotted. (Group 12, N8)
NPNODE	SPEC 19	input	Output option, radial nodes for which fuel temperatures will be printed (minimum = 3, (maximum = 7), or (NPNODE = 0). (Group 12, N4)
NPROD	SPEC 19	input	Output option, number of rods for which information will be printed. (Group 12, N3)
NPROP	SPEC 19	input	Number of cards in Steam Properties Table. (Group 1, N1)
NQ	SPEC 19	input	Number of elements in power transient table (see YG, FG). (Group 11, N6)
NQAX	SPEC 12	input	Input option for variable thermal conductivity of fuel and axial conduction. (Group 8, N6), = 0, no added options = 1, variable conductivity = 2, axial conduction = 3, variable conductivity and axial conduction
NRAMP	SPEC 6	input	Number of iterations to insert the affect of grids or wires. (Group 7, N5)
NROD	SPEC 2	input	Number of rods. (Group 8, N2)
NRODTP	SPEC 12	input	Axially varying fuel zone flag. (Group 8, N8) = 0, no axially varying zones > 0, axial zones present

Variable (Dimension)	Comdeck	Subroutine	Definition
NSCBC	SPEC 11	input	Subcooled mixing option, (Group 10, N1) = 0, β = W/SG = a = 1, W/GS - a(Re)^b = 2, W/GD - a(Re)^b = 3, W/GS - (S/ZIJ) a(Re)^b
NSKIPT	SPEC 19	input	Output option. Print every NSKIRT time steps. (Group 9, N1)
NSKIPX	SPEC 19	input	Output option. Print every NSKIPX axial nodes. (Group 9, N1)
NSKPLT	SPEC 19	input	Output option. Plot every NSKPLT time steps. (Group 12, N6)
NTRIES	SPEC 19	input	External iteration limit for implicit solution. (Group 9)
NTRYX	SPEC 2	input	Iteration limit for explicit flow field solution. (Group 9)
NTRYY	SPEC 2	input	Iteration limit for explicit energy solution. (Group 9)
NTYPE(MC)	SPEC 9	input	Flag for channel type for friction factor
NV	SPEC 10	input	Number of coefficients of polynomial function expressing two-phase friction multiplier; see AV.
NVISCW	SPEC 9	input	Option for wall viscosity correction to friction factor. (Group 2, N4) = 0, no correction = 1, correction used
NWK	SPEC 2	input	Number of wall connections. (Group 4, N4)
NWR	SPEC 2	COBRA	Maximum number of connections to a channel (thermal + flow).
NWRAP(MC)	SPEC 2	input	Initial wrap inventory for each subchannel.
NZONE(MT)	SPEC 12	input	Number of fuel zones.
OUTPUT(12)	SPEC 19	RESULT	Array used to print output.
P(M1,ME)	SPEC 3	SCHEME	Relative pressure at axial location J in subchannel I, lb/ft^2.
PERIM(MC)	SPEC 2	COBRA	Wetted perimeter, PW/12, ft.
PEXIT	SPEC 2	input	System operating pressure, psia. (Group 11)
PH(MC)	SPEC 1	input	Subchannel heated perimeter, in. (Group 4)
PHI(MC)	SPEC 21	VOID	Two-phase friction pressure gradient multiplier.
PHI(MR,6)	SPEC 12	input	Fraction of the heated perimeter of rod N facing subchannel I. (Group 8)
PHTOT	SPEC 19	SETUP	Total heated perimeter, ft.
PI	SPEC 2	COBRA	Constant π, PI = 355./113
PIN	SPEC 2	COBRA	Pressure drop (psi) for pressure boundary condition.
PITCH	SPEC 6	input	Pitch length of wire wrap, ft. (Group 7)
POUT	SPEC 2	XSCEM	Exit pressure, lb/ft^2.
POWER	SPEC 2	COBRA	Value of FQ at appropriate transient time.
PP(MP)	SPEC 9	input	Pressure array in the fluid property table, psia. (Group 1)
PREF	SPEC 10	input	System reference pressure, psia. (Group 11)

Variable (Dimension)	Comdeck	Subroutine	Definition
PREFOL	SPEC 9	COBRA	Reference pressure from previous time step.
PRINT(12)	SPEC 19	SETUP	Logical variable directs output of selected input data groups.
PRINTC(MC)	SPEC 19	input	Identification numbers of subchannels for which information will be printed. (Group 12)
PRINTG(MG)	SPEC 19	input	Identification numbers of gaps for which crossflow information will be printed. (Group 12)
PRINTN(10)	SPEC 19	SETUP	Array for radial fuel node printing.
PRINTR(MR)	SPEC 19	input	Identification numbers of rods for which information will be printed
PSI(M1,ME)	SPEC 4	XSCHEM	Lateral resistance coefficient storage array.
PW(MC)	SPEC 1	input	Subchannel wetted perimeter, in. (Group 4)
QAX	SPEC 2	HEAT	Local axial power factor, obtained by interpolation at (X-DX/2) from relative axial heat flux table.
QCRIT	SPEC 9	CHFCOR	Critical heat flux calculated using RELAP4 heat transfer correlation package for boiling flow.
QPRIM(MC)	SPEC 2	HEAT	Heat input to channel based on PHI and surface heat flux, Btu/sec-ft.
QUAL(MC)	SPEC 2	VOID	Local equilbrium quality based on enthalpy, $(h - h_f)/h_{fg}$.
RADIAL(ME)	SPEC 12	input	Radial power factor of rod N. (Group 8)
RCLAD(MT)	SPEC 12	input	Density of clad material, lb/ft^3. (Group 8)
RFUEL(MT)	SPEC 12	input	Density of fuel material, lb/ft^3. (Group 8)
RHOBAR(M1,ME)	SPEC 3	XSCHEM	Axial resistance coefficient storage.
RHOF	SPEC 10	PROP	Saturated liquid density at the reference pressure, 1/vf, lb/ft^3.
RHOG	SPEC 10	PROP	Saturatcd vapor density at the reference pressure, 1/vg, lb/ft^3.
RHOLCP(MW)	SPEC 2	DIFFER	Total wall heat capacity, Btu/ft^2-°F. (Group 4)
RHO(M1,ME)	SPEC 3	SCHEME	Density, lb/ft^3.
RHOOLD(M1,ME)	SPEC 3	COBRA	Density from the previous time step.
RWALL(2,MW)	SPEC 2	DIFFER	Wall thermal resistance, ft^2-sec-°F/Btu. (Group 4)
SAVEA1(M1)	SPEC 14	SETUP	Dummy array that stores the variables for the J - 1 level (see explanation of ROLL option).
SAVEA2(M1)	SPEC 14	SETUP	Dummy array that stores the variables for the J level in the ROLL.
SAVEA3(M1)	SPEC 14	SETUP	Dummy array that stores the variables for the J + 1 level in the ROLL.
SAVEAL(M2)	SPEC 2	SETUP	Equivalenced variable for peripheral storage of axially dimensioned variables.
SAVRES(M1)	SPEC 14	SETUP	Equivalenced to SAVEA2 and SAVEA3.
SIGMA	SPEC 10	PROP	Surface tension of saturated liquid at the reference pressure, lb_f/ft.
SIGNAL(18)	SPEC 19	SETUP	Alphanumeric variable that names the subroutine in which a program-detected error occurs.

Variable (Dimension)	Comdeck	Subroutine	Definition
SL	SPEC 2	input	Transverse momentum parameter. (Group 9)
SLDT	SPEC 2	COBRA	SL/DT
SLDT2	SPEC 2	COBRA	SL/DT/DT
SLDX	SPEC 2	SETUP	SL*DX
SLDXDT	SPEC 2	SETUP	(SL/DX)*0.5/DT
SLDXI	SPEC 2	SETUP	SL/DX
SLGC	SPEC 2	SETUP	SL*GC
SLGDX	SPEC 2	SETUP	(SL/DX)*GC
SLGDX2	SPEC 2	SETUP	SLGDX/DX
SP(M1,ME)	SPEC 14	SCHEME	Cumulative interchannel pressure difference.
SSIGMA(MP)	SPEC 9	input	Liquid surface tension for fluid property table, lb_f/ft. (Group 1)
STUW(M1,ME)	SPEC 3	XSCHEM	Calculation term in XSCHEM.
STWJM1(MC)	SPEC 16	XSCHEM	Intermediate calculation in XSCHEM.
STWJ(MC)	SPEC 16	XSCHEM	Intermediate calculation in XSCHEM.
SUML(MC)	SPEC 16	XSCHEM	Intermediate calculational variable in XSCHEM.
SUMR(MC)	SPEC 16	XSCHEM	Intermediate calculational variable in XSCHEM.
SUMX(MC)	SPEC 16	XSCHEM	Intermediate calculational variable in XSCHEM.
SURFH(MC)	SPEC 2	HEAT	Surface heat transfer coefficient, Btu/sec-ft^2-°F.
T(MC)	SPEC 2	PROP	Coolant temperature based on enthalpy, °F.
TCLAD(MT)	SPEC 12	input	Cladding thickness, ft. (Group 8)
TDUMY(10)	SPEC 19	RESULT	Output array of rod temperatures.
TERM1(MC)	SPEC 14	DIFFER	Temporary storage of the pressure loss coefficients K in equation (11).
TERM2(MC)	SPEC 14	DIFFER	Temporary storage of $v'_j/A_j/A'$ of equation (11).
TEXT(17)	SPEC 19	SETUP	Alphanumeric array; case title (case control card)
TF	SPEC 10	PROP	Saturated liquid temperature at the reference pressure, °F.
TFLUID	SPEC 12	HEAT	Average temperature of fluid surrounding rod.
THETA	SPEC 2	input	Orientation of subchannel, degrees. (Group 9) = 0°, vertical
THICK	SPEC 6	input	Diameter of wire wrap, ft. (Group 7)
TIME(2)	SPEC 19	TODS	Clock time.
TINLET(MC)	SPEC 1	SETUP	Subchannel inlet coolant temperature, °F.
T(MC)	SPEC 2	PROP	Coolant temperature based on enthalpy, °F.
TMH(MC)	SPEC 2	HEAT	Correction to coolant temperature for fluid conduction heat transfer, °F.
TOLDR(MN,MR)	SPEC 12	HEAT	Previous iteration rod temperatures for axial conduction, °F.
TPOUT(MP)	SPEC 9	STEAM	Temperature of superheated steam for steam property table, °F.
TREF	SPEC 12	input	Reference termperature for variable conductivity of fuel, °F. (Group 8)
TRF(M1,ME)	SPEC 4	XSCHEM	Equivalenced to SP, and calculated variable in XSCHEM
TROD(MN,N4,ME)	SPEC 5	HEAT	Fuel temperature of rod N, at fuel node M, at axial location J, °F.
TTIME	SPEC 19	input	Total transient time, sec. (Group 9)

Variable (Dimension)	Comdeck	Subroutine	Definition
TT(MP)	SPEC 9	input	Temperature for fluid properties table, °F.
TWALL(M1,ME)	SPEC 4	PROP	Temperature of the wall, °F.
TWOLD(M1,ME)	SPEC 4	COBRA	TWALL from previous time step, °F.
UB(M1,ME)	SPEC 3	SCHEME	Local velocity of coolant, ft/sec.
UF	SPEC 10	PROP	Saturated liquid viscosity at the reference pressure, lb/ft-sec.
UH(MC)	SPEC 2	VOID	Effective enthalpy transport velocity, ft/sec.
UPOUT(MP)	SEPC 9	STEAM	Viscosity of superheated steam for steam property table, lb/ft-sec.
US(M1,ME)	SPEC 14	DIVERT	Axial velocity transported by crossflow through Gap K, ft/sec.
USPRM(MG)	SPEC 17	DIVERT	Vector storage of US array.
USW(M1,ME)	SPEC 14	DIVERT	u*w of equation (12).
USWPRM(MG)	SPEC 17	DIVERT	Vector storage of USW array.
UUF(MP)	SPEC 9	input	Viscosity of liquid for fluid property table, lb/ft-hr. (Group 1)
UWALL(2,MW)	SPEC 2	DIFFER	Total wall resistance including surface coefficient, Btu/sec-ft^2-°F. (Group 4)
UWCP(2,MW)	SPEC 2	DIFFER	UWALL/heat capacity of coolant, lb/sec-ft^2. (Group 4)
V(MC)	SPEC 2	PROP	Liquid specific volume based on enthalpy, ft^3/lb.
VF	SPEC 10	PROP	Saturated liquid specific volume at the reference pressure, ft^3/lb.
VFG	SPEC 10	PROP	Difference of saturated vapor and liquid specific volumes at the reference pressure (VG-VF), ft^3/lb.
VG	SPEC 10	PROP	Saturated vapor specific volume at the reference pressure, ft^3/lb.
VISC(MC)	SPEC 2	PROP	Viscosity of the coolant, based on enthalpy, lb/ft-sec.
VISCW(MC)	SPEC 2	PROP	Wall viscosity correction to friction factor, lb/ft-sec.
VPA(MC)	SPEC 2	SCHEME	Two-phase specific volume divided by the subchannel area at the previous node, ft/lb.
VP(MC)	SPEC 2	VOID	Two-phase specific volume for momentum, ft^3/lb.
VPOUT(MP)	SPEC 9	STEAM	Specific volume of superheated steam for Steam Property Table, ft^3/lb.
VVF(MP)	SPEC 9	input	Specific volume of liquid for fluid properties table, ft^3/lb.
VVG(MP)	SPEC 9	input	Specific volume of vapor for fluid properties table, ft^3/lb.
W(M1,ME)	SPEC 4	DIVERT	Crossflow, lb/ft-sec.
WBAR(MX)	SPEC 6	DIVERT	Average crossflow at any axial level, lb/ft-sec.
WERRX	SPEC 2	input	External crossflow convergence criterion for implicit solution. (Group 9)
WERRY	SPEC 2	input	Internal crossflow convergence criterion for implicit solution. (Group 9)

Variable (Dimension)	Comdeck	Subroutine	Definition
WIDTH(MW)	SPEC 2	input	Width of wall connection. (Group 4)
WOLD(M1,ME)	SPEC 4	COBRA	Crossflow from previous time step, lb/ft-sec.
WP(MC)	SPEC 2	DIFFER	Turbulent crossflow, lb/ft-sec.
WPRM(M2)	SPEC 17	DIVERT	Vector storage of the W array.
X(MX)	SPEC 2	SETUP	Axial distance from inlet, ft.
XCROSS(MG,2)	SPEC 6	input	Relative angle/360° of wire wrap gap crossing.
XQUAL(MP)	SPEC 11	input	Tabulated quality for two-phase mixing, paired with BX. (Group 10)
XZERR	SPEC 2	input	Convergence criterion for explicit flow field solution. (Group 9)
Y(MP)	SPEC 2	input	Relative axial location for axial heat flux table. See AXIAL, (Group 3).
Y(MP)	SPEC 22	CURVE	Independent variable array in CURVE.
YG(MP)	SPEC 19	input	Time axis for mass velocity forcing function, paired with FG. (Group 11)
YH(MP)	SPEC 19	input	Time axis for enthalpy forcing function, paired with FP. (Group 11)
YHX(MP)	SPEC 19	input	Time axis for exit enthalpy forcing function. (Group 11)
YP(MP)	SPEC 19	input	Time axis for pressure forcing function paired with FP. (Group 11)
YQ(MP)	SPEC 19	input	Time axis for power forcing function, paired with FQ. (Group 11)
YT(MP)	SPEC 19	input	Time axis for changing maximum time step function, paired with FT. (Group 9)
YZERR	SPEC 2	input	Convergence criterion for explicit energy solution. (Group 9)
Z	SPEC 2	input	Total axial length, in. (Group 9)
ZEND(MT,MY)	SPEC 12	input	Axial location of end of a fuel zone. (Group 8)
ZPT(4)	SPEC 19	input	Minimum plot coordinates for the four types of plots, paired with HIP(4). (Group 12)

APPENDIX G

SAMPLE PROBLEMS

APPENDIX G

SAMPLE PROBLEMS

7-PIN WIRE-WRAPPED BUNDLE

To illustrate the use of GEOM and to provide a benchmark for the forced flow mixing problem, a 7-pin wire-wrapped problem is included. The geometry is shown in Figure G-1. This 7-pin bundle has 0.23-inch diameter fuel pins on a 0.286-inch pitch (0.056-inch gap spacing). The wire wraps are assumed to start at the top and move clockwise with one rotation every 12 inches. The bundle is 36 inches long to allow flow though three pitch lengths. Uniform radial and axial power is assumed with a heat flux of 0.5×10^6 Btu/hr ft^2. The inlet temperature is 800°F and the mass flux is 3.0×10^6 lb/hr ft^2.

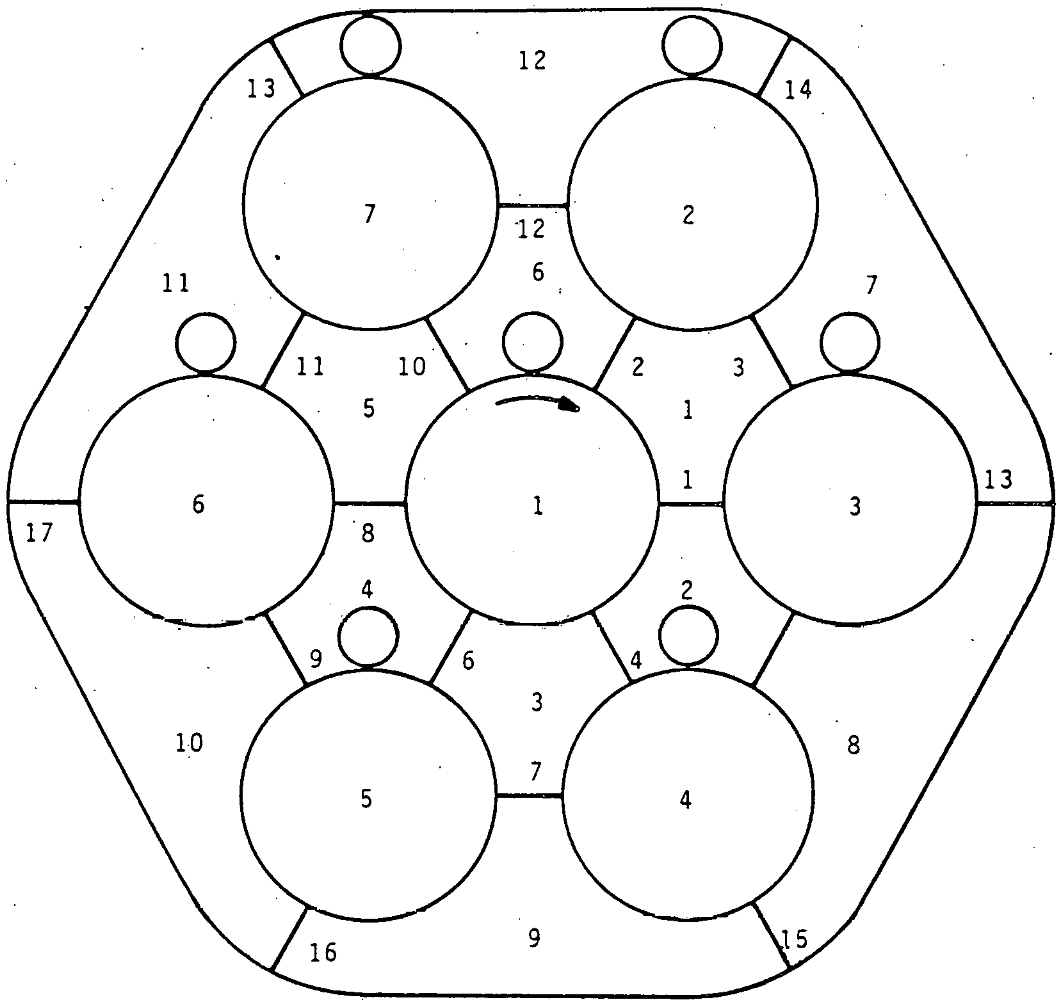


FIGURE G-1. Subchannel Layout and Wire Wrap Positions Looking in the Direction of Flow at the Inlet

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM INPUT

```
    1 GEOM SETUP FOR 7 PIN SAMPLE PROBLEM
.0146.3613.3613
.0222.6759.3613
.0090.2740.120
.056       .056       .056       .056
1 11
    7 .230 1.            1   60 .06




    1      7-PIN WIRE WRAP SAMPLE PROBLEM
    1    30
52E-6 500. .01801   1000000.00  303.76   2204.80     .9235     45.43   .01238
16E-5 550. .01801   1000000.00  319.44   2212.90     .8591     44.60   .01219
40E-5 600. .01828   1000000.00  335.01   2220.50     .8038     43.79   .012
.0012 650. .01842    409870.00  350.49   2227.60     .7558     42.98   .01181
3.E-3 700. .01856    178120.00  365.88   2234.10     .7138     42.18   .01162
.0067 750. .01870     83102.00  381.19   2240.20     .6767     41.39   .01143
.0139 800. .01885     41266.    396.43   2245.80     .6437     40.62   .01124
.0241 840. .01897     24533.    408.58   2249.90     .6198     40.00   .01109
.0404 880. .01909     15060.    420.69   2253.90     .5980     39.39   .01094
.0655 920. .01921      9519.    432.77   2257.60     .5778     38.79   .01078
.0826 940. .01927      7645.    438.80   2259.30     .5683     38.50   .01071
.1035 960. .01933      6180.    444.83   2261.10     .5592     38.20   .01063
.1288 980. .01940      5026.    450.85   2262.80     .5504     37.91   .01056
.15931000. .01946      4111.    456.86   2264.40     .5419     37.61   .01048
.19591020. .01952      3382.    462.87   2266.10     .5338     37.42   .01040
.23951040. .01959      2798.    468.88   2267.60     .5259     37.03   .01033
.29141060. .01965      2326.    474.88   2269.20     .5183     36.74   .01025
.35261080. .01971      1944.    480.88   2270.80     .5110     36.46   .01018
.42451100. .01978      1632.    486.88   2272.30     .5004     36.03   .01006
.50871120. .01985      1376.    492.87   2273.80     .4970     35.89   .01002
.60681140. .01991      1156.    498.87   2275.20     .4904     35.61   .00995
.72061160. .01998       992.    504.86   2276.70     .4840     35.33   .00987
.85211180. .02005       847.5   510.86   2278.20     .4778     35.05   .00979
1.0031200. .02011       726.9   516.85   2279.60     .4717     34.78   .00972
2.1471300. .02046       356.3   546.85   2286.70     .4442     33.42   .00934
4.2281400. .02082       189.1   576.95   2293.90     .4204     32.11   .00896
7.7571500. .02119       107.4   607.21   2301.10     .3999     30.84   .00858
13.401600. .02157        64.63  637.70   2308.50     .3811     29.61   .00819
14.781619. .02165        59.34  643.40   2310.20     .3779     29.38   .00812
124.22145. .02388         8.522 810.92   2351.70     .3094     23.64   .00812
    2    0    0    0
.316 -.25     .316 -.25     .316  -.25     .316 -.25
    3    2
    0    1.    1.    1.
    4    12    12              9
    7    1     18         2         9
         12.        .230      .056
    8    7     7                                9
    9
36.
   36
   10    0     0     0
  .02
   11    1     0
         60.        800.        3.        .5
   12    1     3
  1  7 12
```

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS

INPUT FOR CASE 1 7-PIN WIRE WRAP SAMPLE PROBLEM DATE 04/21/76 0 TIME 12.43.59 1

SUMMARY OF INPUT OPTIONS

GROUP	N1	N2	N3	N4	N5	N6	N7	N8	N9
1	30	-0	-0	-0	-0	-0	-0	-0	-0
2	0	0	0	-0	-0	-0	-0	-0	-0
3	2	-0	-0	-0	-0	-0	-0	-0	-0
4	12	12	-0	-0	9	-0	-0	-0	-0
7	1	18	-0	2	-0	9	-0	-0	-0
8	7	7	-0	-0	-0	-0	-0	-0	9
9	-0	-0	-0	-0	-0	-0	-0	-0	-0
10	0	0	0	-0	-0	-0	-0	-0	-0
11	1	0	-0	-0	-0	-0	-0	-0	-0
12	1	3	-0	-0	-0	-0	-0	-0	-0

FLUID PROPERTY TABLE

P	T	VF	VG	HF	HG	VISC.	KF	SIGMA
.0	500.00	.01801	************	303.76	2204.80	.92350	45.43000	.01238
.0	550.00	.01801	************	319.44	2212.90	.85910	44.60000	.01219
.0	600.00	.01828	************	335.01	2220.50	.80380	43.79000	.01200
.0	650.00	.01842	409870.00000	350.49	2227.60	.75580	42.98000	.01181
.0	700.00	.01856	178120.00000	365.88	2234.10	.71360	42.18000	.01162
.0	750.00	.01870	83102.00000	381.19	2240.20	.67670	41.39000	.01143
.0	800.00	.01885	41266.00000	396.43	2245.80	.64370	40.62000	.01124
.0	840.00	.01897	24533.00000	408.58	2249.90	.61980	40.00000	.01109
.0	880.00	.01909	15060.00000	420.69	2253.90	.59800	39.39000	.01094
.1	920.00	.01921	9519.00000	432.77	2257.60	.57760	38.79000	.01078
.1	940.00	.01927	7645.00000	438.80	2259.30	.56830	38.50000	.01071
.1	960.00	.01933	6180.00000	444.83	2261.10	.55920	38.20000	.01063
.1	980.00	.01940	5026.00000	450.85	2262.80	.55040	37.91000	.01056
.2	1000.00	.01946	4111.00000	456.86	2264.40	.54190	37.61000	.01048
.2	1020.00	.01952	3382.00000	462.87	2266.10	.53380	37.42000	.01040
.2	1040.00	.01959	2798.00000	468.88	2267.60	.52590	37.03000	.01033
.3	1060.00	.01965	2326.00000	474.88	2269.20	.51830	36.74000	.01025
.4	1080.00	.01971	1944.00000	480.88	2270.80	.51100	36.46000	.01018
.4	1100.00	.01978	1632.00000	486.88	2272.30	.50040	36.03000	.01006
.5	1120.00	.01985	1376.00000	492.87	2273.80	.49700	35.89000	.01002
.6	1140.00	.01991	1166.00000	498.87	2275.20	.49040	35.61000	.00995
.7	1160.00	.01998	992.00000	504.86	2276.70	.48400	35.33000	.00987
.9	1180.00	.02005	847.50000	510.86	2278.20	.47780	35.05000	.00979
1.0	1200.00	.02011	726.90000	516.85	2279.60	.47170	34.78000	.00972
2.1	1300.00	.02046	356.30000	546.85	2286.70	.44420	33.42000	.00934
4.2	1400.00	.02082	189.10000	576.95	2293.90	.42040	32.11000	.00896
7.8	1500.00	.02119	107.40000	607.21	2301.10	.39950	30.84000	.00858
13.4	1600.00	.02157	64.63000	637.70	2308.50	.38110	29.61000	.00819
14.8	1619.00	.02165	59.34000	643.40	2310.20	.37790	29.38000	.00812
124.2	2145.00	.02388	8.52200	810.92	2351.70	.30940	23.64000	.00612

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS (Continued)

FRICTION FACTOR CORRELATION
- CHANNEL TYPE 1 FRICT = .316*RE**(-.250) + -.0000
- CHANNEL TYPE 2 FRICT = .316*RE**(-.250) + -.0000
- CHANNEL TYPE 3 FRICT = .316*RE**(-.250) + -.0000
- CHANNEL TYPE 4 FRICT = .316*RE**(-.250) + -.0000
- WALL VISCOCITY CORRECTION TO FRICTION FACTOR IS NOT INCLUDED

SINGLE PHASE HEAT TRANSFER CORRELATION

HFILM = K/D(.023*RE**(.800)*PR**(.400) + 0.000)

TWO-PHASE FLOW CORRELATIONS
- NO SUBCOOLED VOID CORRELATION
- HOMOGENEOUS BULK VOID MODEL
- HOMOGENEOUS MODEL FRICTION MULTIPLIER

HEAT FLUX DISTRIBUTION

X/L	RELATIVE FLUX
0.000	1.000
1.000	1.000

SUBCHANNEL INPUT DATA

CHANNEL NO.	TYPE	AREA (SQ-IN)	WETTED PERIM. (IN)	HEATED PERIM. (IN)	HYDRAULIC DIAMETER (IN)	(ADJACENT CHANNEL NO., SPACING, CENTROID DISTANCE)			
1	1	.014600	.361300	.361300	.161639	(2, .056,-.000)	(6, .056,-.000)	(7, .056,-.000)	(-0,-.000,-.000)
2	1	.014600	.361300	.361300	.161639	(3, .056,-.000)	(8, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
3	1	.014600	.361300	.361300	.161639	(4, .056,-.000)	(9, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
4	1	.014600	.361300	.361300	.161639	(5, .056,-.000)	(10, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
5	1	.014600	.361300	.361300	.161639	(6, .056,-.000)	(11, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
6	1	.014600	.361300	.361300	.161639	(12, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
7	1	.031200	.949900	.481300	.131382	(8, .056,-.000)	(12, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
8	1	.031200	.949900	.481300	.131382	(9, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
9	1	.031200	.949900	.481300	.131382	(10, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
10	1	.031200	.949900	.481300	.131382	(11, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
11	1	.031200	.949900	.481300	.131382	(12, .056,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)
12	1	.031200	.949900	.481300	.131382	(-0,-.000,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)	(-0,-.000,-.000)

WIRE WRAP SPACER DATA FOR FORCED DIVERSION CROSSFLOW MIXING

- WRAP PITCH = 12.0 INCHES
- WRAP THICKNESS = .0560 INCHES
- PIN DIAMETER = .2300 INCHES

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS (Continued)

WRAP CROSSING DATA

GAP NO.	SUBCHANNEL PAIR NO.	MIXING PARAMETER	RELATIVE LOCATION OF WRAP CROSSINGS	
1	(1, 2)	.0600	.2500	-.7500
2	(1, 6)	.0600	.5840	-.0840
3	(1, 7)	.0600	.9170	-.4170
4	(2, 3)	.0600	.4170	-.9170
5	(2, 8)	.0600	.0840	-.5840
6	(3, 4)	.0600	.5840	-.0840
7	(3, 9)	.0600	.2500	-.7500
8	(4, 5)	.0600	.7500	-.2500
9	(4, 10)	.0600	.4170	-.9170
10	(5, 6)	.0600	.9170	-.4170
11	(5, 11)	.0600	.5840	-.0840
12	(6, 12)	.0600	.7500	-.2500
13	(7, 8)	.0600	.2500	-0.0000
14	(7, 12)	.0600	-.0840	-0.0000
15	(8, 9)	.0600	.4170	-0.0000
16	(9, 10)	.0600	.5840	-0.0000
17	(10, 11)	.0600	.7500	-0.0000
18	(11, 12)	.0600	.9170	-0.0000

INITIAL WRAP INVENTORY FOR EACH SUBCHANNEL

0	1	0	1	0	1	1	0	0	0
1	2								

ROD INPUT DATA

ROD NO.	TYPE NO.	DIA (IN)	RADIAL POWER FACTOR	FRACTION OF POWER TO ADJACENT CHANNELS (ADJ. CHANNEL NO.)					
1	1	.2300	1.0000	.1667(1)	.1667(2)	.1667(3)	.1667(4)	.1667(5)	.1667(6)
2	1	.2300	1.0000	.1667(1)	.1667(6)	.3333(7)	.3333(12)	-0.0000(-0)	-0.0000(-0)
3	1	.2300	1.0000	.1667(1)	.1667(2)	.3333(7)	.3333(8)	-0.0000(-0)	-0.0000(-0)
4	1	.2300	1.0000	.1667(2)	.1667(3)	.3333(8)	.3333(9)	-0.0000(-0)	-0.0000(-0)
5	1	.2300	1.0000	.1667(3)	.1667(4)	.3333(9)	.3333(10)	-0.0000(-0)	-0.0000(-0)
6	1	.2300	1.0000	.1667(4)	.1667(5)	.3333(10)	.3333(11)	-0.0000(-0)	-0.0000(-0)
7	1	.2300	1.0000	.1667(5)	.1667(6)	.3333(11)	.3333(12)	-0.0000(-0)	-0.0000(-0)

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS (Continued)

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IMPLICIT SOLUTION WITH INLET FLOWS SPECIFIED

CALCULATION PARAMETERS
  LATERAL RESISTANCE FACTOR        .5000
  (S/L) PARAMETER                  .5000
  TURBULENT MOMENTUM FACTOR      -0.0000
  CHANNEL ORIENTATION            -0.0000 DEGREES
  ROLL OPTION (0 = NO ROLL)            0

DATA FOR IMPLICIT SOLUTION
  EXTERNAL ITERATION LIMIT            20
  INTERNAL ITERATION LIMIT            36
  CONVERGENCE FACTORS
       EXTERNAL (DW/W)             .1000
       INTERNAL (DW/W)             .0010
       FLOW     (DF/F)             .0100

MIXING CORRELATIONS
   SUBCOOLED MIXING,    BETA =   .0200
   BOILING MIXING, BETA IS ASSUMMED SAME AS SUBCOOLED

OPERATING CONDITIONS
  SYSTEM PRESSURE     =      60.0 PSIA
  INLET ENTHALPY      =     396.4 BTU/LB
  AVG. MASS VELOCITY  =     3.000 MILLION LB/(HR-SQFT)
  INLET TEMPERATURE   =     800.0 DEGREES F
  AVG. HEAT FLUX      =   .500000 MILLION BTU/(HR-SQFT)
   UNIFORM INLET TEMPERATURE
   UNIFORM INLET MASS VELOCITY
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CHANNEL LENGTH                      36.0000 INCHES
NUMBER OF AXIAL NODES                    36
AXIAL NODE LENGTH                    1.0000 INCHES
TOTAL TRANSIENT TIME                -0.0000 SECONDS
NUMBER OF TIME STEPS                     -0
NOMINAL TIME STEP                 ********* SECONDS

MINIMUM INTERNAL ITERATIONS               5
FRACTION DONOR CELL USTAR           -0.0000
ACCELERATION FACTORS
     CROSSFLOW SOLUTION              1.6000
     LATERAL DELTA-P                  .8000
     FLOW                            1.0000
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7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS (Continued)

FORCE POINT SUMMARY

JX	*	GAPS FORCED AT JX				
3	*	2	5	6	11	14
5	*	1	7	8	12	13
7	*	3	4	9	10	15
9	*	2	5	6	11	16
11	*	1	7	8	12	17
13	*	3	4	9	10	18
15	*	2	5	6	11	14
17	*	1	7	8	12	13
19	*	3	4	9	10	15
21	*	2	5	6	11	16
23	*	1	7	8	12	17
25	*	3	4	9	10	18
27	*	2	5	6	11	14
29	*	1	7	8	12	13
31	*	3	4	9	10	15
33	*	2	5	6	11	16
35	*	1	7	8	12	17

DATA FROM ITERATIVE SOLUTION

ITERATION NO.	TOTAL INTERNAL ITERATIONS	LAST NODE OUT OF CONVERGENCE W	F	MAXIMUM ERROR INTERNAL	EXTERNAL	FLOW	ENTHALPY
1	1251	37	37	211.6830	.9999	.3360	.0176
2	931	37	37	404.6058	2.9988	.2175	.0232
3	898	37	37	22.0061	.9087	.1323	.0050
4	905	37	37	1119.4201	.4867	.0753	.0012
5	864	37	37	228.0563	.4647	.0453	.0011
6	827	37	37	42.3220	.3015	.0237	.0011
7	752	37	37	.3340	.2143	.0154	.0007
8	651	37	16	.1339	.1119	.0123	.0004
9	576	0	0	.0712	.0664	.0093	.0003
10	429	0	0	.0496	.0477	.0089	.0002

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS (Continued)

CHANNEL EXIT SUMMARY RESULTS DATE 04/21/76 0 TIME 12.44.11 1
CASE 1 7-PIN WIRE WRAP SAMPLE PROBLEM

MASS BALANCE - -
MASS FLOW IN .14905E+01 LB/SEC
MASS FLOW OUT .14905E+01 LB/SEC
MASS FLOW ERROR -.27732E-10 LB/SEC

ENERGY BALANCE - -
FLOW ENERGY IN .59088E+03 BTU/SEC
ENERGY ADDED .17554E+03 BTU/SEC
FLOW ENERGY OUT .76651E+03 BTU/SEC
ENERGY ERROR .86642E-01 BTU/SEC

CHANNEL (NO.)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG.F)	DENSITY (LB/FT3)	EQUIL QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/FR-FT2)
1	517.75	1202.99	49.70	0.000	0.000	.0675	2.3772
2	515.39	1195.11	49.76	0.000	0.000	.0907	3.2222
3	517.64	1202.53	49.70	0.000	0.000	.0673	2.3890
4	519.14	1207.55	49.66	0.000	0.000	.0912	3.2392
5	520.19	1211.15	49.63	0.000	0.000	.0698	2.4786
6	518.57	1205.74	49.68	0.000	0.000	.0907	3.2217
7	511.29	1181.43	49.86	0.000	0.000	.1880	3.1242
8	511.03	1180.57	49.87	0.000	0.000	.1857	3.0862
9	512.26	1184.68	49.84	0.000	0.000	.1807	3.0024
10	514.13	1190.91	49.79	0.000	0.000	.1565	2.5999
11	514.12	1190.89	49.79	0.000	0.000	.1382	2.2959
12	512.71	1186.17	49.83	0.000	0.000	.1641	2.7264

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS DATE 04/21/76 0 TIME. 12.44.11 1
CASE 1 7-PIN WIRE WRAP SAMPLE PROBLEM

BUNDLE AVERAGED RESULTS

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	11.0819	[illegible]	800.00	53.05	0.000	0.000	1.4905	3.0000	15.7083	.25756
1.0	10.7709	399.70	810.78	52.96	0.000	0.000	1.4905	3.0000	15.7353	.25756
2.0	10.4570	402.98	821.55	52.87	0.000	0.000	1.4905	3.0000	15.7622	.25756
3.0	10.1536	406.25	832.33	52.78	0.000	0.000	1.4905	3.0000	15.7891	.25756
4.0	9.8359	409.52	843.11	52.69	0.000	0.000	1.4905	3.0000	15.8161	.25756
5.0	9.5315	412.80	853.92	52.60	0.000	0.000	1.4905	3.0000	15.8431	.25756
6.0	9.2169	416.07	864.74	52.51	0.000	0.000	1.4905	3.0000	15.8701	.25756
7.0	8.9136	419.34	875.55	52.42	0.000	0.000	1.4905	3.0000	15.8971	.25756
8.0	8.5991	422.62	886.38	52.33	0.000	0.000	1.4905	3.0000	15.9242	.25756
9.0	8.2962	425.89	897.22	52.24	0.000	0.000	1.4905	3.0000	15.9512	.25756
10.0	7.9823	429.16	908.06	52.15	0.000	0.000	1.4905	3.0000	15.9784	.25756
11.0	7.6739	432.44	918.90	52.07	0.000	0.000	1.4905	3.0000	16.0054	.25756
12.0	7.3662	435.71	929.75	51.98	0.000	0.000	1.4905	3.0000	16.0326	.25756
13.0	7.0634	438.98	940.61	51.89	0.000	0.000	1.4905	3.0000	16.0596	.25756
14.0	6.7564	442.26	951.46	51.80	0.000	0.000	1.4905	3.0000	16.0874	.25756
15.0	6.4476	445.53	962.32	51.71	0.000	0.000	1.4905	3.0000	16.1156	.25756
16.0	6.1341	448.80	973.19	51.61	0.000	0.000	1.4905	3.0000	16.1459	.25756
17.0	5.8309	452.07	984.07	51.52	0.000	0.000	1.4905	3.0000	16.1758	.25756
18.0	5.5177	455.35	994.96	51.43	0.000	0.000	1.4905	3.0000	16.2039	.25756
19.0	5.2149	458.62	1005.85	51.34	0.000	0.000	1.4905	3.0000	16.2311	.25756
20.0	4.9018	461.89	1016.74	51.25	0.000	0.000	1.4905	3.0000	16.2595	.25756
21.0	4.5987	465.16	1027.63	51.16	0.000	0.000	1.4905	3.0000	16.2885	.25756
22.0	4.2858	468.44	1038.52	51.07	0.000	0.000	1.4905	3.0000	16.3190	.25756
23.0	3.9827	471.71	1049.43	50.97	0.000	0.000	1.4905	3.0000	16.3482	.25756
24.0	3.6712	474.98	1060.34	50.89	0.000	0.000	1.4905	3.0000	16.3756	.25756
25.0	3.3690	478.26	1071.26	50.80	0.000	0.000	1.4905	3.0000	16.4033	.25756
26.0	3.0582	481.53	1082.17	50.71	0.000	0.000	1.4905	3.0000	16.4321	.25756
27.0	2.7564	484.80	1093.08	50.62	0.000	0.000	1.4905	3.0000	16.4627	.25756
28.0	2.4452	488.08	1103.99	50.52	0.000	0.000	1.4905	3.0000	16.4947	.25756
29.0	2.1438	491.35	1114.92	50.43	0.000	0.000	1.4905	3.0000	16.5255	.25756
30.0	1.8320	494.62	1125.84	50.33	0.000	0.000	1.4905	3.0000	16.5558	.25756
31.0	1.5310	497.90	1136.75	50.25	0.000	0.000	1.4905	3.0000	16.5844	.25756
32.0	1.2192	501.17	1147.67	50.16	0.000	0.000	1.4905	3.0000	16.6140	.25756
33.0	.9175	504.44	1158.60	50.06	0.000	0.000	1.4905	3.0000	16.6455	.25756
34.0	.6048	507.71	1169.52	49.97	0.000	0.000	1.4905	3.0000	16.6771	.25756
35.0	.3023	510.99	1180.43	49.88	0.000	0.000	1.4905	3.0000	16.7077	.25756
36.0	0.0000	514.26	1191.36	49.79	0.000	0.000	1.4905	3.0000	16.7373	.25756

CHANNEL RESULTS
CASE 1 7-PIN WIRE WRAP SAMPLE PROBLEM DATE 04/21/76 0 TIME 12.44.11 1

TIME = 0.00000 SECONDS PRESSURE = 60.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	11.0813	396.43	800.00	53.05	0.000	0.000	.0845	3.0000	15.7083	.01460
1.0	10.9024	400.52	813.47	52.94	0.000	0.000	.0835	2.9660	15.5637	.01460
2.0	10.4486	404.57	826.79	52.83	0.000	0.000	.0703	3.0039	15.7957	.01214
3.0	10.0520	408.92	841.13	52.71	0.000	0.000	.0703	3.0045	15.8348	.01214
4.0	9.8299	412.83	854.03	52.60	0.000	0.000	.0850	3.0195	15.9466	.01460
5.0	9.4597	416.21	865.21	52.51	0.000	0.000	.0890	3.1601	16.7181	.01460
6.0	9.2069	419.00	874.41	52.43	0.000	0.000	.0702	2.9989	15.8883	.01214
7.0	8.8170	422.10	884.68	52.34	0.000	0.000	.0693	2.9613	15.7148	.01214
8.0	8.5966	424.45	892.45	52.28	0.000	0.000	.0841	2.9868	15.8692	.01460
9.0	8.3751	427.05	901.07	52.21	0.000	0.000	.0851	3.0211	16.0731	.01460
10.0	7.9798	430.98	914.07	52.10	0.000	0.000	.0703	3.0040	16.0150	.01214
11.0	7.7492	435.09	927.70	51.99	0.000	0.000	.0669	2.8567	15.2620	.01214
12.0	7.3694	439.26	941.53	51.88	0.000	0.000	.0859	3.0511	16.3356	.01460
13.0	7.1646	442.78	953.21	51.79	0.000	0.000	.0856	3.0408	16.3102	.01460
14.0	6.7410	446.61	965.93	51.68	0.000	0.000	.0720	3.0752	16.5297	.01214
15.0	6.3368	450.73	979.59	51.55	0.000	0.000	.0727	3.1036	16.7237	.01214
16.0	6.1284	454.11	990.87	51.46	0.000	0.000	.0876	3.1105	16.7905	.01460
17.0	5.7599	457.09	1000.75	51.38	0.000	0.000	.0913	3.2401	17.5168	.01460
18.0	5.5085	459.46	1006.66	51.32	0.000	0.000	.0720	3.0756	16.6475	.01214
19.0	5.1181	462.20	1017.76	51.25	0.000	0.000	.0707	3.0214	16.3773	.01214
20.0	4.9002	464.24	1024.56	51.19	0.000	0.000	.0852	3.0261	16.4218	.01460
21.0	4.6800	466.70	1032.75	51.11	0.000	0.000	.0858	3.0460	16.5539	.01460
22.0	4.2850	470.56	1045.61	51.00	0.000	0.000	.0710	3.0316	16.5109	.01214
23.0	4.0552	474.60	1059.08	50.90	0.000	0.000	.0676	2.8659	15.7501	.01214
24.0	3.6767	478.71	1072.76	50.79	0.000	0.000	.0868	3.0803	16.8460	.01460
25.0	3.4746	482.18	1084.34	50.70	0.000	0.000	.0865	3.0722	16.8330	.01460
26.0	3.0511	485.98	1097.00	50.58	0.000	0.000	.0728	3.1098	17.0776	.01214
27.0	2.6449	490.05	1110.59	50.46	0.000	0.000	.0735	3.1405	17.2875	.01214
28.0	2.4415	493.41	1121.79	50.36	0.000	0.000	.0885	3.1409	17.3231	.01460
29.0	2.0734	496.36	1131.64	50.29	0.000	0.000	.0919	3.2644	18.0312	.01460
30.0	1.8250	498.75	1139.61	50.23	0.000	0.000	.0724	3.0945	17.1131	.01214
31.0	1.4350	501.50	1148.78	50.15	0.000	0.000	.0710	3.0306	16.7869	.01214
32.0	1.2203	503.56	1155.65	50.09	0.000	0.000	.0852	3.0256	16.7795	.01460
33.0	1.0019	506.02	1163.87	50.02	0.000	0.000	.0856	3.0405	16.8860	.01460
34.0	.6018	509.89	1176.75	49.90	0.000	0.000	.0710	3.0329	16.8822	.01214
35.0	.3020	513.92	1190.21	49.80	0.000	0.000	.0691	2.9495	16.4524	.01214
36.0	0.0000	517.75	1202.99	49.70	0.000	0.000	.0675	2.8836	16.1167	.01214

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 7-PIN WIRE WRAP SAMPLE PROBLEM DATE 04/21/76 0 TIME 12.44.11 1

TIME = 0.00000 SECONDS PRESSURE = 60.0 PSIA DATA FOR CHANNEL 7

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	11.0850	396.43	800.60	53.05	0.000	0.000	.1663	3.0000	15.7083	.02874
1.0	10.9085	399.27	809.36	52.97	0.000	0.000	.1578	2.8472	14.9303	.02874
2.0	10.4492	402.34	819.46	52.89	0.000	0.000	.1458	2.8758	15.1048	.02627
3.0	10.0415	405.66	830.39	52.80	0.000	0.000	.1453	2.8662	15.0801	.02627
4.0	9.6306	409.07	841.63	52.70	0.000	0.000	.1535	2.7699	14.5994	.02874
5.0	9.4268	412.28	852.22	52.61	0.000	0.000	.1596	2.8796	15.2034	.02874
6.0	9.2110	414.98	861.12	52.54	0.000	0.000	.1732	2.8772	15.2117	.03120
7.0	8.8513	417.61	869.82	52.47	0.000	0.000	.1807	3.0029	15.8980	.03120
8.0	8.5950	420.18	878.31	52.40	0.000	0.000	.1835	3.0489	16.1636	.03120
9.0	8.3345	422.92	887.39	52.32	0.000	0.000	.1840	3.0572	16.2306	.03120
10.0	7.9872	426.15	898.08	52.23	0.000	0.000	.1890	3.1402	16.6993	.03120
11.0	7.7748	429.33	908.60	52.15	0.000	0.000	.1847	3.0665	16.3447	.03120
12.0	7.3683	433.02	920.81	52.05	0.000	0.000	.1710	3.0841	16.4590	.02874
13.0	7.1647	436.85	933.52	51.95	0.000	0.000	.1628	2.9363	15.7015	.02874
14.0	6.7421	440.67	946.19	51.84	0.000	0.000	.1476	2.9113	15.5984	.02627
15.0	6.3407	444.71	959.60	51.74	0.000	0.000	.1467	2.8954	15.5457	.02627
16.0	6.1281	448.43	971.96	51.62	0.000	0.000	.1551	2.7979	15.0554	.02874
17.0	5.7236	451.84	983.29	51.52	0.000	0.000	.1608	2.9015	15.6438	.02874
18.0	5.5113	454.51	992.19	51.45	0.000	0.000	.1733	2.8769	15.5434	.03120
19.0	5.1526	457.12	1000.87	51.38	0.000	0.000	.1800	2.9914	16.1722	.03120
20.0	4.8976	459.63	1009.21	51.31	0.000	0.000	.1814	3.0147	16.3195	.03120
21.0	4.6382	462.34	1018.25	51.24	0.000	0.000	.1812	3.0113	16.3237	.03120
22.0	4.2920	465.57	1028.98	51.15	0.000	0.000	.1858	3.0871	16.7661	.03120
23.0	4.0810	468.76	1039.59	51.05	0.000	0.000	.1814	3.0142	16.4011	.03120
24.0	3.6758	472.48	1052.00	50.95	0.000	0.000	.1683	3.0361	16.5518	.02874
25.0	3.4744	476.34	1064.86	50.85	0.000	0.000	.1606	2.8975	15.8274	.02874
26.0	3.0521	480.18	1077.67	50.75	0.000	0.000	.1462	2.8838	15.7830	.02627
27.0	2.6494	484.22	1091.15	50.64	0.000	0.000	.1459	2.8794	15.7959	.02627
28.0	2.4411	487.91	1103.44	50.53	0.000	0.000	.1544	2.7857	15.3153	.02874
29.0	2.0364	491.29	1114.72	50.42	0.000	0.000	.1604	2.8929	15.9362	.02874
30.0	1.8277	493.91	1123.48	50.35	0.000	0.000	.1727	2.8690	15.8276	.03120
31.0	1.4698	496.49	1132.06	50.29	0.000	0.000	.1794	2.9816	16.4702	.03120
32.0	1.2173	498.94	1140.24	50.22	0.000	0.000	.1811	3.0096	16.6457	.03120
33.0	.9587	501.63	1149.20	50.14	0.000	0.000	.1813	3.0119	16.6845	.03120
34.0	.6067	504.82	1159.88	50.05	0.000	0.000	.1867	3.1017	17.2140	.03120
35.0	.3036	508.04	1170.59	49.96	0.000	0.000	.1876	3.1174	17.3338	.03120
36.0	0.0000	511.29	1181.43	49.86	0.000	0.000	.1880	3.1242	17.4036	.03120

CHANNEL RESULTS
CASE 1 7-PIN WIRE WRAP SAMPLE PROBLEM DATE 04/21/76 0 TIME 12.44.11 1

TIME = 0.00000 SECONDS PRESSURE = 60.0 PSIA DATA FOR CHANNEL 12

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	11.0778	396.43	800.00	53.05	0.000	0.000	.1520	3.0000	15.7083	.02627
1.0	10.5192	399.52	810.18	52.96	0.000	0.000	.1523	3.0041	15.7556	.02627
2.0	10.4485	402.63	820.42	52.88	0.000	0.000	.1581	2.8521	14.9823	.02874
3.0	10.0429	405.66	830.38	52.80	0.000	0.000	.1634	2.9477	15.5091	.02874
4.0	9.8283	408.37	839.32	52.72	0.000	0.000	.1769	2.9388	15.4842	.03120
5.0	9.4686	411.03	848.08	52.65	0.000	0.000	.1839	3.0553	16.1202	.03120
6.0	9.2112	413.71	856.94	52.57	0.000	0.000	.1860	3.0912	16.3326	.03120
7.0	8.9503	416.51	866.18	52.50	0.000	0.000	.1859	3.0890	16.3450	.03120
8.0	8.6027	419.76	876.94	52.41	0.000	0.000	.1903	3.1617	16.7578	.03120
9.0	8.3911	422.94	887.46	52.32	0.000	0.000	.1855	3.0819	16.3616	.03120
10.0	7.9839	426.61	899.61	52.22	0.000	0.000	.1714	3.0920	16.4467	.02874
11.0	7.7806	430.42	912.23	52.12	0.000	0.000	.1630	2.9403	15.6706	.02874
12.0	7.3576	434.22	924.82	52.02	0.000	0.000	.1477	2.9137	15.5595	.02627
13.0	6.9565	438.25	938.19	51.91	0.000	0.000	.1468	2.8966	15.5005	.02627
14.0	6.7444	441.96	950.49	51.81	0.000	0.000	.1552	2.7988	15.0060	.02874
15.0	6.3407	445.36	961.76	51.72	0.000	0.000	.1609	2.9022	15.5884	.02874
16.0	6.1278	448.04	970.66	51.63	0.000	0.000	.1732	2.8783	15.4846	.03120
17.0	5.7691	450.64	979.31	51.55	0.000	0.000	.1799	2.9699	16.1102	.03120
18.0	5.5138	453.14	987.61	51.49	0.000	0.000	.1814	3.0143	16.2627	.03120
19.0	5.2543	455.84	996.61	51.41	0.000	0.000	.1813	3.0126	16.2763	.03120
20.0	4.9084	459.05	1007.28	51.33	0.000	0.000	.1862	3.0941	16.7440	.03120
21.0	4.6969	462.22	1017.65	51.25	0.000	0.000	.1821	3.0263	16.4036	.03120
22.0	4.2908	465.93	1030.19	51.14	0.000	0.000	.1692	3.0519	16.5783	.02874
23.0	4.0885	469.78	1042.98	51.02	0.000	0.000	.1616	2.9160	15.8749	.02874
24.0	3.6658	473.61	1055.76	50.92	0.000	0.000	.1471	2.9018	15.8288	.02627
25.0	3.2629	477.64	1069.20	50.82	0.000	0.000	.1468	2.8967	15.8334	.02627
26.0	3.0547	481.32	1081.46	50.72	0.000	0.000	.1553	2.8021	15.3456	.02874
27.0	2.6495	484.69	1092.69	50.62	0.000	0.000	.1612	2.9080	15.9575	.02874
28.0	2.4409	487.31	1101.44	50.54	0.000	0.000	.1736	2.8844	15.8521	.03120
29.0	2.0823	489.89	1110.03	50.47	0.000	0.000	.1804	2.9970	16.4962	.03120
30.0	1.8300	492.35	1118.25	50.39	0.000	0.000	.1823	3.0287	16.6947	.03120
31.0	1.5723	495.03	1127.21	50.32	0.000	0.000	.1826	3.0337	16.7455	.03120
32.0	1.2271	498.23	1137.88	50.24	0.000	0.000	.1879	3.1227	17.2650	.03120
33.0	1.0181	501.40	1148.44	50.15	0.000	0.000	.1841	3.0592	16.9442	.03120
34.0	.6082	505.09	1160.77	50.04	0.000	0.000	.1711	3.0868	17.1340	.02874
35.0	.3066	508.95	1173.63	49.93	0.000	0.000	.1672	3.0163	16.7805	.02874
36.0	0.0000	512.71	1186.17	49.83	0.000	0.000	.1641	2.9600	16.5010	.02874

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 7-PIN WIRE WRAP SAMPLE PROBLEM DATE 04/21/76 0 TIME 12.44.11 1

TIME = 0.00000 SECONDS

AXIAL ZONE	W(1, 2)	W(1, 6)	W(1, 7)	W(2, 3)	W(2, 8)	W(3, 4)	W(3, 9)	W(4, 5)	W(4, 10)	W(5, 6)
0.0 - 1.0	-.00759	.04533	-.02625	.04140	-.00617	.03774	.00160	.01802	.01790	-.04216
1.0 - 2.0	.44709	-.21024	-.07839	-.00063	.21379	-.21126	.38340	-.01786	-.37037	.41955
2.0 - 3.0	.26613	-.20163	-.06467	.04212	.21967	-.18588	.26720	.09015	-.28739	.31042
3.0 - 4.0	.21099	-.46955	.08218	.24681	.13551	-.20241	.21467	-.21232	.18943	.04573
4.0 - 5.0	.21502	-.34789	.08537	.08895	.12284	-.13019	.21873	-.19539	.10685	.13290
5.0 - 6.0	.50215	-.07567	-.20102	.21561	.11377	.19369	.18954	-.25406	.21579	-.21111
6.0 - 7.0	.37058	-.15559	-.20444	.21702	.11144	.04296	.16815	-.17192	.21721	-.19076
7.0 - 8.0	.08587	.20859	-.47190	.51740	-.20050	.21746	.12498	.18445	.19971	-.20066
8.0 - 9.0	.16275	.18524	-.35958	.38216	-.20446	.21888	.12179	.03544	.17699	-.17668
9.0 - 10.0	-.20966	.25598	.13071	.08884	-.47514	.52269	-.20032	.21870	.12732	.18600
10.0 - 11.0	-.18551	.17255	.05435	.16541	-.36125	.38559	-.20343	.22005	.12430	.03752
11.0 - 12.0	-.25523	-.13637	.21304	-.20998	.13224	.08980	-.47448	.52431	-.20002	.21886
12.0 - 13.0	-.17175	-.03685	.21207	-.18628	.05585	.16477	-.35974	.38663	-.20394	.22000
13.0 - 14.0	.18662	-.21811	.19520	-.25464	.21385	-.21069	.13360	.09035	-.47432	.52464
14.0 - 15.0	.03825	-.22015	.17391	-.17049	.21272	-.18798	.05883	.16442	-.35946	.38673
15.0 - 16.0	.21720	-.52375	.12726	.18640	.19550	-.25598	.21432	-.21154	.13278	.04071
16.0 - 17.0	.21872	-.38645	.12393	.03799	.17322	-.17234	.21362	-.19076	.05906	.16398
17.0 - 18.0	.52402	-.09109	-.20196	.21749	.12882	.18564	.19664	-.25867	.21501	-.21157
18.0 - 19.0	.38602	-.16487	-.20594	.21934	.12393	.03773	.17436	-.17518	.21576	-.19170
19.0 - 20.0	.09108	.21165	-.47658	.52459	-.20259	.21793	.12988	.18411	.19921	-.20125
20.0 - 21.0	.16430	.19177	-.36279	.38696	-.20782	.22086	.12380	.03681	.17667	-.17716
21.0 - 22.0	-.21155	.26314	.12613	.09183	-.47861	.52572	-.20267	.21856	.13071	.18228
22.0 - 23.0	-.19135	.17891	.05536	.16596	-.36523	.38775	-.20692	.22138	.12489	.03552
23.0 - 24.0	-.26386	-.18142	.21505	-.21091	.12559	.09081	-.47690	.52588	-.20220	.21954
24.0 - 25.0	-.17931	-.03470	.21675	-.18921	.05132	.16631	-.36353	.38877	-.20625	.22292
25.0 - 26.0	.18101	-.22008	.20364	-.26179	.21470	-.21061	.12779	.09148	-.47639	.52660
26.0 - 27.0	.03472	-.22291	.17958	-.17700	.21544	-.18905	.05362	.16643	-.36302	.38636
27.0 - 28.0	.21933	-.52568	.12737	.18243	.20139	-.25959	.21441	-.21114	.12929	.09136
28.0 - 29.0	.22104	-.38729	.12450	.03483	.17777	-.17571	.21452	-.18929	.05470	.16504
29.0 - 30.0	.52516	-.09098	-.20032	.21896	.12721	.18454	.19845	-.25756	.21430	-.21155
30.0 - 31.0	.38605	-.16394	-.20417	.21967	.12455	.03510	.17648	-.17475	.21410	-.16975
31.0 - 32.0	.09075	.21180	-.47365	.52414	-.20107	.21827	.12691	.18468	.19810	-.25662
32.0 - 33.0	.16367	.19082	-.35950	.38521	-.20507	.21945	.12328	.03692	.17461	-.17357
33.0 - 34.0	-.21234	.25763	.13018	.08831	-.47396	.52112	-.20118	.21721	.12723	.18659
34.0 - 35.0	-.20144	.14981	.07506	.11783	-.35246	.36957	-.21803	.23360	.11144	.09154
35.0 - 36.0	-.15849	.12085	.05616	.09685	-.28805	.31110	-.18528	.19518	.09851	.07440

7-PIN WIRE-WRAPPED BUNDLE SAMPLE PROBLEM RESULTS (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 7-PIN WIRE WRAP SAMPLE PROBLEM DATE 04/21/76 0 TIME 12.44.11 1

TIME = 0.00000 SECONDS

AXIAL ZONE	W(5, 11)	W(6, 12)	W(7, 8)	W(7, 12)	W(8, 9)	W(9, 10)	W(10, 11)	W(11, 12)
0.0 - 1.0	-.00061	-.00902	.01277	.06264	.04830	.05288	-.00026	-.05110
1.0 - 2.0	-.21107	.04760	.26582	-.19931	.60202	.93189	.56839	.22182
2.0 - 3.0	-.21392	.05981	.13272	-.19151	.43703	.75122	.47807	.19532
3.0 - 4.0	-.44277	-.20536	.19355	-.21072	.49998	.87500	1.02927	.57773
4.0 - 5.0	-.34037	-.20802	.19276	-.18042	.32066	.63095	.79971	.47257
5.0 - 6.0	.13928	-.46756	.18199	-.54540	.19368	.55529	.93873	1.03891
6.0 - 7.0	.06219	-.35841	.15192	-.44714	.19035	.36169	.67734	.80399
7.0 - 8.0	.21553	.12929	.52823	-1.03341	.17154	.19382	.56884	.95661
8.0 - 9.0	.21612	.05200	.43432	-.79988	.14151	.19017	.37177	.69021
9.0 - 10.0	.19849	.21412	1.02789	-.95713	.52245	.16855	.19382	.57404
10.0 - 11.0	.17609	.21396	.79616	-.68999	.42882	.13864	.19017	.37510
11.0 - 12.0	.12700	.19653	.95298	-.57535	1.02261	.51981	.16850	.19502
12.0 - 13.0	.12460	.17530	.68747	-.37711	.79217	.42606	.13699	.19142
13.0 - 14.0	-.20068	.12705	.57386	-.19601	.94913	1.01818	.51844	.16906
14.0 - 15.0	-.20463	.12346	.37580	-.19223	.68423	.78919	.42449	.13757
15.0 - 16.0	-.47513	-.20146	.19643	-.16936	.57340	.94649	1.01451	.51899
16.0 - 17.0	-.36118	-.20640	.19279	-.13780	.37529	.68265	.78741	.42481
17.0 - 18.0	.13036	-.47638	.16900	-.52007	.19698	.57443	.94571	1.01405
18.0 - 19.0	.05729	-.36277	.13814	-.42531	.19313	.37603	.68288	.78688
19.0 - 20.0	.21552	.12614	.52097	-1.01442	.16869	.19709	.57509	.94512
20.0 - 21.0	.21665	.05574	.42711	-.78743	.13758	.19310	.37654	.68271
21.0 - 22.0	.20064	.21557	1.01621	-.94482	.52035	.16748	.19655	.57377
22.0 - 23.0	.17711	.21762	.78913	-.68311	.42638	.13740	.19342	.37506
23.0 - 24.0	.12997	.20294	.94591	-.57356	1.01738	.52026	.16807	.19576
24.0 - 25.0	.12524	.17990	.68461	-.37569	.78899	.42549	.13709	.19268
25.0 - 26.0	-.20154	.12859	.57187	-.19465	.94492	1.01701	.51692	.16830
26.0 - 27.0	-.20472	.12434	.37433	-.19210	.68323	.78894	.42452	.13822
27.0 - 28.0	-.47557	-.20051	.19460	-.16909	.57000	.94485	1.01654	.51830
28.0 - 29.0	-.36141	-.20448	.19173	-.13852	.37338	.68290	.78869	.42436
29.0 - 30.0	.13059	-.47421	.16986	-.51785	.19545	.57120	.94621	1.01494
30.0 - 31.0	.05578	-.35931	.13864	-.42414	.19202	.37438	.68361	.78703
31.0 - 32.0	.21469	.13179	.51836	-1.01227	.17009	.19582	.57245	.94462
32.0 - 33.0	.21427	.05817	.42464	-.78579	.13857	.19244	.37477	.68173
33.0 - 34.0	.19558	.21531	1.01049	-.94515	.51523	.16692	.19651	.57376
34.0 - 35.0	.15882	.21447	.76075	-.69706	.37393	.10564	.20776	.43571
35.0 - 36.0	.13341	.17264	.60920	-.55791	.30005	.07216	.16228	.34784

ITERATIONS = 10

SPECIFIED NUMBER OF TIME STEPS COMPLETED

COMMON DUMPED TO TAPE 8

THERMAL MODELING

Since thermal modeling capabilities have been increased substantially over COBRA-IIIC, a separate sample problem is necessary. This problem is intended to illustrate the following features of the COBRA-IV thermal model:

- axial conduction in both the coolant and fuel;
- conducting wall model;
- axially heterogeneous fuel types, including a "blank" zone;
- use of the steady-state equal pressure drop model.

The geometry shown in Figure G-2 consists of a three-rod configuration immersed in flowing liquid sodium surrounded by a thermally conducting can. The can is cooled by an outer annular region of liquid sodium. Each rod consists of a central UO_2 fuel zone with a stainless steel zone on each end. The last 10 inches of the model is a "blank" zone, free of rod material.

After the steady state is calculated, the model is subjected to a short transient which represents an immediate power shutoff, followed 1/2 second later by a linear pressure drop decay to zero assembly Δp at 1-1/2 seconds. The steady state is calculated with the new option to specify the pressure drop, and the transient is computed with a pressure drop boundary condition.

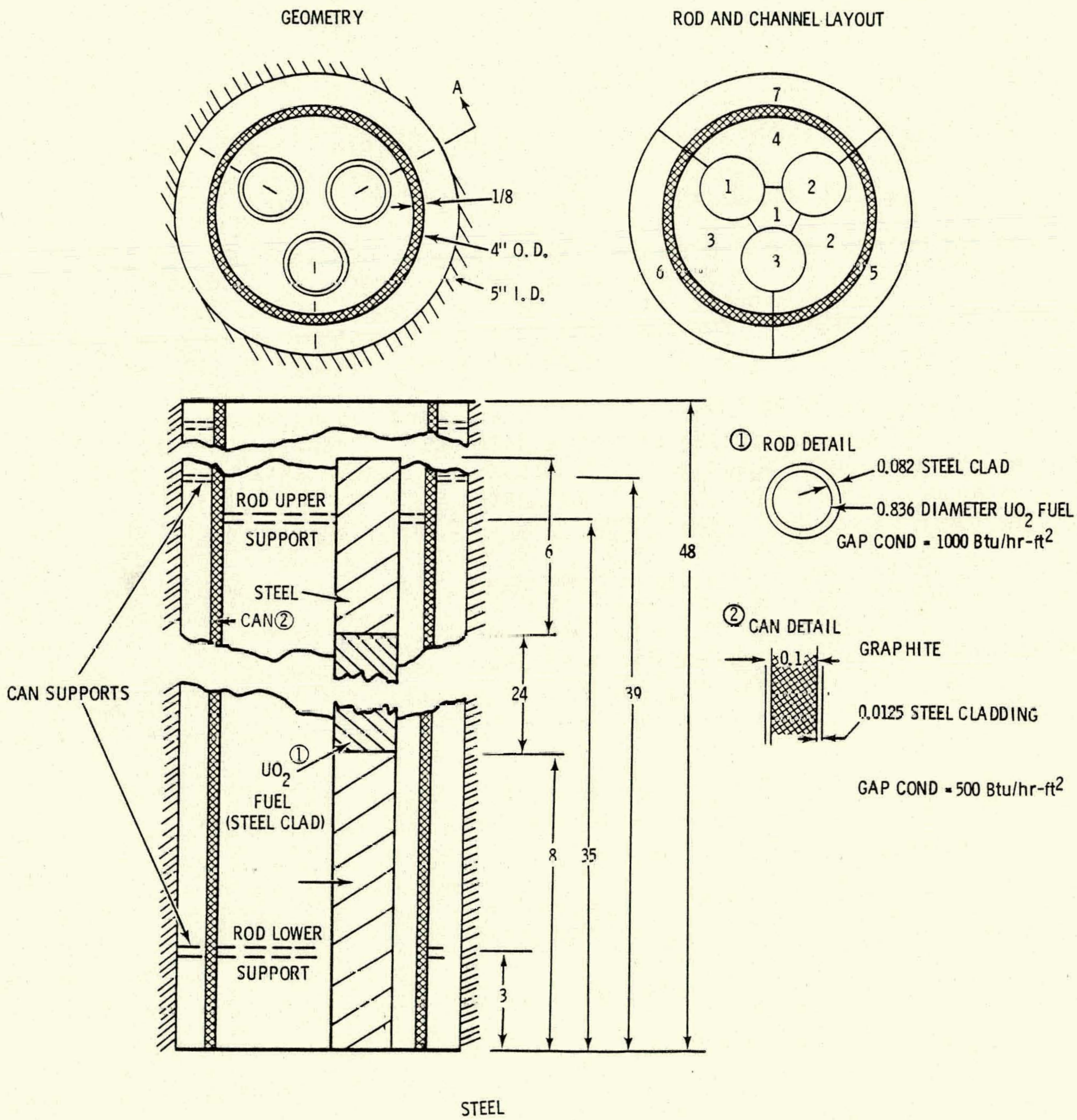

FIGURE G-2. Geometry of Thermal Model Sample Problem

THERMAL MODEL SAMPLE PROBLEM INPUT

```
10000
    1          FUEL THEMAL MODEL TEST
    1   20
52E-4500.0     .01801   999999.     303.76   2204.83     .9235     45.43    .01238
10E+0960.0     .01933     6180.     444.83   2261.09     .5592     38.20    .010632
13E+0980.0     .01940     5026.     450.85   2262.78     .5504     37.91    .010556
16E+01000.     .01946     4111.     456.86   2264.44     .5419     37.61    .010480
20E+01020.     .01952     3382.     462.87   2266.06     .5338     37.42    .010403
24E+01040.     .01959     2798.     468.88   2267.65     .5259     37.03    .010327
29E+01060.     .01965     2326.     474.88   2269.22     .5183     36.74    .010251
35E+01080.     .01971     1944.     460.88   2270.75     .5110     36.46    .010175
47E+01100.     .01978     1632.     486.88   2272.27     .5004     36.03    .010060
54E+01120.     .01985     1376.     492.87   2273.76     .4970     35.89    .010022
61E+01140.     .01991     1166.     498.87   2275.24     .4904     35.61    .009946
72E+01160.     .01996     992.0     504.86   2276.70     .4840     35.33    .009870
85E+01180.     .02005     847.5     510.86   2278.15     .4778     35.05    .009794
10E+11200.     .02011     726.9     516.85   2279.60     .4717     34.78    .009718
21E+11300.     .02046     356.3     546.85   2286.72     .4442     33.42    .009337
42E+11400.     .02082     189.1     576.95   2293.86     .4204     32.11    .008956
74E+11500.     .02119     107.4     607.21   2301.10     .3995     30.84    .008575
14E+21600.     .02157     64.63     637.70   2308.47     .3811     29.61    .008194
15E+21619.     .02165     59.34     643.40   2310.19     .3779     29.38    .008123
12E+32145.     .02388   8.52153     810.92   2351.67     .3094     23.64    .006119
    2                         1
 .316 -.25
  84.  -1.
   3   8
   0.   0..1665   0..1667   .5.3333 1.25   .5 1.25.6666   .5
.6667   0.   1.   0.
   4    7   7    9    3
   1.90371.5711.571     2 .732  1.5    3 .732  1.5    4 .732  1.5
   22.5946.5452.618     3 .375  3.1    4 .375  3.1
   32.5946.5452.618     4 .375  3.1
   42.5946.5452.618
   52.3569.425   1.     6   1. 4.71     7   1. 4.71
   62.3569.425   1.     7   1. 4.71
   72.3569.425   1.
   1 .424 4.06      2 8.14    5 8.14
   2 .424 4.06      3 8.14    6 8.14
   3 .424 4.06      4 8.14    7 8.14
   1   0.    2 120.    3 240.    4 150.    5 210.
   6 270.    7 150.    8 210.    9 270.
   5   4   4
  0.  .79   .8   1.
   1
  1.   1. 1.43 1.43
   2
  1.   1. 1.25 1.25
   3
  1.   1. 1.25 1.25
   4
  1.   1. 1.25 1.25
   6   6   4
  0.  .79   .8   1.
   1
  1.   1. 2.37 2.37
   2
  1.   1. 2.37 2.37
   3
  1.   1. 2.37 2.37
   4
```

```
    1.   1. 2.33 2.33
    5
    1.   1. 2.33 2.33
    6
    1.   1. 2.33 2.33
    7    2         3    3
.0125    1.7292    2.8125    3
    1   .5
    2  .75
    3  .75
    4  .75
    5   2.
    6   2.
    7   2.
    1   .5
    2  .75
    3  .75
    4  .75
    5   0.
    6   0.
    7   0.
    1   0.
    2   0.
    3   0.
    4   0.
    5   1.
    6   1.
    7   1.
    8    3    3    2    3    0    3    0    1
    1   1.  1.5    1.1667    3.4166    4.4167
    2   1.  1.0    1.1667    2.4167    4.4166
    3   1.  0.5    1.1667    2.4166    3.4167
1.958 .0671152. .836  12. .122 489. .0821000.
  12. .122 489. .836  12. .122 489. .082 500.

     1472.   -.5299-3   .2338E-6-.2169E-10
    4
.1667    2.6667    1.7917    2    1.    3
    9    0   20    1
  48.   1.                    .5  .25   0.   0.
   24  400
   .4  .01

   10    0    0    1
  .02
   .5
   11    3    1    0    0    3    3    1
      15.     1200.         .4       .12       516. 1.6
1100.1100.1100.1100.1000.1000.1000.
   0.   1.   .5   1.  1.5   0.
   0.   1. .001   0.   5.   0.
   12    3    3    1    4         40
  1  2  5
  1
   0.   0.   .5  .45
```

THERMAL MODEL SAMPLE PROBLEM RESULTS

INPUT FOR CASE 1 FUEL THERMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.04 1

SUMMARY OF INPUT OPTIONS

GROUP	N1	N2	N3	N4	N5	N6	N7	N8	N9
1	20	-0	-0	-0	-0	-0	-0	-0	-0
2	-0	-0	-0	-0	1	-0	-0	-0	-0
3	8	-0	-0	-0	-0	-0	-0	-0	-0
4	7	7	9	3	-0	-0	-0	-0	-0
5	4	4	-0	-0	-0	-0	-0	-0	-0
6	6	4	-0	-0	-0	-0	-0	-0	-0
7	2	-0	3	3	-0	-0	-0	-0	-0
8	3	3	2	3	0	3	0	1	-0
9	0	20	1	-0	-0	-0	-0	-0	-0
10	0	0	1	-0	-0	-0	-0	-0	-0
11	3	1	0	0	3	3	1	-0	-0
12	3	3	1	4	-0	40	-0	-0	-0

FLUID PROPERTY TABLE

P	T	VF	VG	HF	HG	VISC.	KF	SIGMA
.0	500.00	.01801	999999.00000	303.76	2204.83	.92350	45.43000	.01238
.1	960.00	.01933	6180.00000	444.83	2261.09	.55920	38.20000	.01063
.1	980.00	.01940	5026.00000	450.85	2262.78	.55040	37.91000	.01056
.2	1000.00	.01946	4111.00000	456.86	2264.44	.54190	37.61000	.01048
.2	1020.00	.01952	3382.00000	462.87	2266.06	.53380	37.42000	.01040
.2	1040.00	.01959	2798.00000	468.88	2267.65	.52590	37.03000	.01033
.3	1060.00	.01965	2326.00000	474.88	2269.22	.51830	36.74000	.01025
.4	1080.00	.01971	1944.00000	480.88	2270.75	.51100	36.46000	.01018
.5	1100.00	.01978	1632.00000	486.88	2272.27	.50040	36.03000	.01008
.5	1120.00	.01985	1376.00000	492.87	2273.76	.49700	35.89000	.01002
.6	1140.00	.01991	1166.00000	498.87	2275.24	.49040	35.61000	.00995
.7	1160.00	.01998	992.00000	504.86	2276.70	.48400	35.33000	.00987
.9	1180.00	.02005	847.50000	510.86	2278.15	.47780	35.05000	.00979
1.0	1200.00	.02011	726.90000	516.85	2279.60	.47170	34.78000	.00972
2.1	1300.00	.02046	356.30000	546.85	2286.72	.44420	33.42000	.00934
4.2	1400.00	.02082	189.10000	576.95	2293.86	.42040	32.11000	.00896
7.8	1500.00	.02119	107.40000	607.21	2301.10	.39950	30.84000	.00858
14.0	1600.00	.02157	64.63000	637.70	2308.47	.38110	29.61000	.00819
15.0	1619.00	.02165	59.34000	643.40	2310.19	.37790	29.38000	.00812
120.0	2145.00	.02388	8.52153	810.92	2351.67	.30940	23.64000	.00612

FRICTION FACTOR CORRELATION

CHANNEL TYPE 1 FRICT = MAXIMUM OF (.316*RE**(-.250) + -.0000 OR 84.000*RE**(-1.000) + -.0000)

WALL VISCOSITY CORRECTION TO FRICTION FACTOR IS NOT INCLUDED

SINGLE PHASE HEAT TRANSFER CORRELATION

HFILM = K/D(.023*RE**(.800)*PR**(.400) + 0.000)

TWO-PHASE FLOW CORRELATIONS
NO SUBCOOLED VOID CORRELATION
HOMOGENEOUS BULK VOID MODEL
HOMOGENEOUS MODEL FRICTION MULTIPLIER

HEAT FLUX DISTRIBUTION

X/L	RELATIVE FLUX
0.000	0.000
.167	0.000
.167	.500
.333	1.250
.500	1.250
.667	.500
.667	0.000
1.000	0.000

SUBCHANNEL INPUT DATA

CHANNEL NO.	TYPE	AREA (SQ-IN)	WETTED PERIM. (IN)	HEATED PERIM. (IN)	HYDRAULIC DIAMETER (IN)	(ADJACENT CHANNEL NO., SPACING, CENTROID DISTANCE)
1	1	.903700	1.571000	1.571000	2.300955	(2, .732,1.500)(3, .732,1.500)(4, .732,1.500)(-0,-.000,-.000)
2	1	2.594000	6.545000	2.618000	1.585332	(3, .375,3.100)(4, .375,3.100)(-0,-.000,-.000)(-0,-.000,-.000)
3	1	2.594000	6.545000	2.618000	1.585332	(4, .375,3.100)(-0,-.000,-.000)(-0,-.000,-.000)(-0,-.000,-.000)
4	1	2.594000	6.545000	2.618000	1.585332	(-0,-.000,-.000)(-0,-.000,-.000)(-0,-.000,-.000)(-0,-.000,-.000)
5	1	2.356000	9.425000	1.000000	.999894	(6,1.000,4.710)(7,1.000,4.710)(-0,-.000,-.000)(-0,-.000,-.000)
6	1	2.356000	9.425000	1.000000	.999894	(7,1.000,4.710)(-0,-.000,-.000)(-0,-.000,-.000)(-0,-.000,-.000)
7	1	2.356000	9.425000	1.000000	.999894	(-0,-.000,-.000)(-0,-.000,-.000)(-0,-.000,-.000)(-0,-.000,-.000)

SUBCHANNEL THERMAL CONNECTION DATA

CONNECTION NO.	WALL AVERAGE HEAT CAPACITY (B/FT2-F)	WIDTH OF CONNECTION (FT)	CHANNEL NO.	CONDUCTIVE RESISTANCE (FT2-S-F/B)	CHANNEL NO.	CONDUCTIVE RESISTANCE (FT2-S-F/B)
1	.424	.338	2	8.1400	5	8.1400
2	.424	.338	3	8.1400	6	8.1400
3	.424	.338	4	8.1400	7	8.1400

GAP ORIENTATION (GAP NO. ANGLE)
(1, 0.)(2, 120.)(3, 240.)(4, 150.)(5, 210.)(6, 270.)(7, 150.)(8, 210.)
(9, 270.)(

X/L	AREA VARIATION FACTORS FOR SUBCHANNEL (I) (1)	(2)	(3)	(4)
0.000	1.000	1.000	1.000	1.000
.790	1.000	1.000	1.000	1.000
.800	1.430	1.250	1.250	1.250
1.000	1.430	1.250	1.250	1.250

GAP SPACING VARIATION FACTORS FOR ADJACENT SUBCHANNELS (I,J)

X/L	(1, 2)	(1, 3)	(1, 4)	(2, 3)	(2, 4)	(3, 4)
0.000	1.000	1.000	1.000	1.000	1.000	1.000
.790	1.000	1.000	1.000	1.000	1.000	1.000
.800	2.370	2.370	2.370	2.330	2.330	2.330
1.000	2.370	2.370	2.370	2.330	2.330	2.330

SPACER DATA

SPACER TYPE NO.	1	2	3
LOCATION (X/L)	.013	.729	.813

SPACER TYPE 1

CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.
1	.500	2	.750	3	.750	4	.750
5	2.000	6	2.000	7	2.000		

SPACER TYPE 2

CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.
1	.500	2	.750	3	.750	4	.750
5	0.000	6	0.000	7	0.000		

SPACER TYPE 3

CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.	CHANNEL NO.	DRAG COEFF.
1	0.000	2	0.000	3	0.000	4	0.000
5	1.000	6	1.000	7	1.000		

ROD INPUT DATA

ROD NO.	TYPE NO.	DIA (IN)	RADIAL POWER FACTOR	FRACTION OF POWER TO ADJACENT CHANNELS (ADJ. CHANNEL NO.)					
1	1	1.0000	1.5000	.1667(1)	.4166(3)	.4167(4)	-0.0000(-0)	-0.0000(-0)	-0.0000(-0)
2	1	1.0000	1.0000	.1667(1)	.4167(2)	.4166(4)	-0.0000(-0)	-0.0000(-0)	-0.0000(-0)
3	1	1.0000	.5000	.1667(1)	.4166(2)	.4167(3)	-0.0000(-0)	-0.0000(-0)	-0.0000(-0)

THERMAL PROPERTIES OF FUEL MATERIAL 2 ORDER OF COLLOCATION

	FUEL PROPERTIES				CLAD PROPERTIES				
TYPE NO.	COND. (B/HR-FT-F)	SP. HEAT (B/LB-F)	DENSITY (LB/FT3)	DIA. (IN.)	COND. (B/HR-FT-F)	SP. HEAT (B/LB-F)	DENSITY (LB/FT3)	THICK. (IN.)	GAP COND. (B/HR-FT2-F)
1	1.96	.0670	1152.0	.8360	12.00	.1220	489.0	.0820	1000.00
2	12.00	.1220	489.0	.8360	12.00	.1220	489.0	.0820	500.00
3	0.00	-0.0000	-0.0	0.0000	0.00	-0.0000	-0.0	0.0000	0.00

AXIAL CONDUCTION CONSIDERED

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

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NONUNIFORM FUEL THERMAL CONDUCTIVITY (FUEL TYPE 1)
    REFERENCE TEMP, 1472.0(F)/     K/KO = 1. + -.52990E-03*(T-T0) +  .23380E-06*(T-T0)**2 +  -.21690E-10*(T-T0)**3

AXIAL FUEL TYPE LAYOUT
 ROD  NO.        FUEL ZONE DESCRIPTION
TYPE ZONES     (X/L RANGE) - FUEL TYPE
  1    4    (0.00 - .17)- 2   ( .17 - .67)- 1   ( .67 - .79)- 2   ( .79 -1.00)- 3   (

EXPLICIT SOLUTION WITH PRESSURE DROP SPECIFIED
    RUNNING START FROM IMPLICIT SOLUTION

CALCULATION PARAMETERS
  LATERAL RESISTANCE FACTOR       .5000                            CHANNEL LENGTH                  48.0000 INCHES
  (S/L) PARAMETER                 .2500                            NUMBER OF AXIAL NODES              24
  TURBULENT MOMENTUM FACTOR      0.0000                            AXIAL NODE LENGTH                2.0000 INCHES
  CHANNEL ORIENTATION            0.0000 DEGREES                    TOTAL TRANSIENT TIME             1.0000 SECONDS
  ROLL OPTION (0 = NO ROLL)           0                            NUMBER OF TIME STEPS              400
                                                                   NOMINAL TIME STEP                .0025 SECONDS

DATA FOR IMPLICIT SOLUTION
  EXTERNAL ITERATION LIMIT           20                            MINIMUM INTERNAL ITERATIONS        5
  INTERNAL ITERATION LIMIT           20                            FRACTION DONOR CELL USTAR      -0.0000
  CONVERGENCE FACTORS                                              ACCELERATION FACTORS
       EXTERNAL (DH/H)            .1000                                 CROSSFLOW SOLUTION         1.6000
       INTERNAL (DH/H)            .0010                                 LATERAL DELTA-P             .8000
       FLOW     (DF/F)            .0100                                 FLOW                       1.0000

DATA FOR EXPLICIT SOLUTION
  MAXIMUM TIME STEP               .0100 SECONDS                    ACCELERATION FACTOR            1.0000
  COURANT NUMBER                  .4000                            FRACTION OF LAST CHANGE       -0.0000
  ITERATIVE CONVERGENCE FACTORS                                    ITERATION LIMITS
       VOLUME ERROR (DV/V)        .0100                                 PRESSURE ITERATION           50
       ENTHALPY ERROR (DH/H)      .0001                                 ENERGY EQUATION              20

MIXING CORRELATIONS
   SUBCOOLED MIXING,    BETA =  .0200
   BOILING MIXING, BETA IS ASSUMED SAME AS SUBCOOLED
   CONDUCTION MIXING,  GEOMETRY FACTOR =  .5000

OPERATING CONDITIONS
  SYSTEM PRESSURE     =       15.0 PSIA
  INLET ENTHALPY      =     1200.0 BTU/LB
  AVG. MASS VELOCITY  =       .400 MILLION LB/(HR-SQFT)
  INLET TEMPERATURE   =        0.0 DEGREES F
  AVG. HEAT FLUX      =    .120000 MILLION BTU/(HR-SQFT)
  EXIT ENTHALPY       =      516.0 BTU/LB
   INDIVIDUAL SUBCHANNEL TEMPERATURE SPECIFIED   (CHANNEL-TEMPERATURE)
   ( 1 -1100.0) ( 2 -1100.0) ( 3 -1100.0) ( 4 -1100.0) ( 5 -1000.0) ( 6 -1000.0) ( 7 -1000.0)
   FLOWS SPLIT FOR EQUAL PRESSURE GRADIENT  (CHANNEL-FLOW)
   ( 1 - 8.905E-01) ( 2 - 2.350E+00) ( 3 - 2.350E+00) ( 4 - 2.350E+00) ( 5 - 1.405E+00) ( 6 - 1.405E+00)
   ( 7 - 1.405E+00)
   FORCING FUNCTION FOR PRESSURE DIFFERENCE
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TIME (SEC)	DELTA-P FACTOR
0.0000	1.0000
.5000	1.0000
1.5000	0.0000

FORCING FUNCTION FOR HEAT FLUX

TIME (SEC)	HEAT FLUX FACTOR
0.0000	1.0000
.0010	0.0000
5.0000	0.0000

DATA FROM ITERATIVE SOLUTION

ITERATION NO.	TOTAL INTERNAL ITERATIONS	LAST NODE OUT OF CONVERGENCE		MAXIMUM ERROR			
		W	F	INTERNAL	EXTERNAL	FLOW	ENTHALPY
1	372	25	22	175.3818	.9996	.1103	.0321
2	406	25	25	61.4739	.6510	.1827	.0031
3	434	25	25	3884.8431	.5271	.1276	.0023
4	451	25	25	817.9220	.2259	.0960	.0015
5	452	25	25	120.2114	.1117	.0817	.0011
6	441	0	25	991.3829	.0715	.0447	.0006
7	427	0	25	60.3197	.0677	.0293	.0004
8	396	0	25	473.2161	.0338	.0278	.0003
9	375	0	25	63.7916	.0225	.0120	.0002
10	363	0	0	144.5465	.0155	.0075	.0001
11	313	0	0	41.7837	.0066	.0004	.0000

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DATE 04/21/76 0 TIME 12.28.09 1

CHANNEL EXIT SUMMARY RESULTS
CASE 1 FUEL THEMAL MODEL TEST

MASS BALANCE - -
MASS FLOW IN .22099E+02 LB/SEC
MASS FLOW OUT .22099E+02 LB/SEC
MASS FLOW ERROR -.22920E-06 LB/SEC

ENERGY BALANCE - -
FLOW ENERGY IN .10545E+05 BTU/SEC
ENERGY ADDED .13806E+03 BTU/SEC
FLOW ENERGY OUT .10597E+05 BTU/SEC
ENERGY ERROR -.85668E+02 BTU/SEC

CHANNEL (NO.)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG.F)	DENSITY (LB/FT3)	EQUIL QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/FR-FT2)
1	489.44	1108.53	50.48	0.000	0.000	2.1388	1.2269
2	488.24	1104.55	50.52	0.000	0.000	4.2612	.8516
3	488.70	1106.09	50.50	0.000	0.000	4.2659	.8525
4	489.16	1107.63	50.49	0.000	0.000	4.2707	.8535
5	460.12	1010.86	51.30	0.000	0.000	2.3874	.5253
6	460.15	1010.95	51.30	0.000	0.000	2.3875	.5253
7	460.18	1011.05	51.30	0.000	0.000	2.3876	.5254

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.09 1

BUNDLE AVERAGED RESULTS

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5956	477.15	1067.57	50.93	0.000	0.000	22.0991	.7272	3.9663	15.75370
2.0	1.4426	477.15	1067.57	50.93	0.000	0.000	22.0991	.7272	3.9664	15.75370
4.0	1.3816	477.15	1067.57	50.93	0.000	0.000	22.0991	.7272	3.9664	15.75370
6.0	1.3207	477.15	1067.57	50.93	0.000	0.000	22.0991	.7272	3.9664	15.75370
8.0	1.2597	477.15	1067.57	50.93	0.000	0.000	22.0991	.7272	3.9665	15.75370
10.0	1.1988	477.27	1067.96	50.92	0.000	0.000	22.0991	.7272	3.9667	15.75370
12.0	1.1378	477.42	1068.48	50.92	0.000	0.000	22.0991	.7272	3.9671	15.75370
14.0	1.0769	477.61	1069.11	50.91	0.000	0.000	22.0991	.7272	3.9675	15.75370
16.0	1.0159	477.84	1069.87	50.91	0.000	0.000	22.0991	.7272	3.9680	15.75370
18.0	.9550	478.09	1070.70	50.90	0.000	0.000	22.0991	.7272	3.9685	15.75370
20.0	.8940	478.34	1071.52	50.90	0.000	0.000	22.0991	.7272	3.9690	15.75370
22.0	.8331	478.58	1072.34	50.89	0.000	0.000	22.0991	.7272	3.9695	15.75370
24.0	.7722	478.83	1073.16	50.88	0.000	0.000	22.0991	.7272	3.9700	15.75370
26.0	.7113	479.06	1073.92	50.88	0.000	0.000	22.0991	.7272	3.9705	15.75370
28.0	.6504	479.25	1074.56	50.87	0.000	0.000	22.0991	.7272	3.9709	15.75370
30.0	.5895	479.40	1075.08	50.87	0.000	0.000	22.0991	.7272	3.9712	15.75370
32.0	.5286	479.52	1075.46	50.86	0.000	0.000	22.0991	.7272	3.9715	15.75370
34.0	.4677	479.52	1075.47	50.86	0.000	0.000	22.0991	.7272	3.9715	15.75370
36.0	.3550	479.52	1075.47	50.86	0.000	0.000	22.0991	.7272	3.9715	15.75370
38.0	.2992	479.52	1075.47	50.85	0.000	0.000	22.0991	.7097	3.8766	16.14272
40.0	.2407	479.52	1075.47	50.81	0.000	0.000	22.0991	.6334	3.4624	18.08779
42.0	.1804	479.52	1075.47	50.81	0.000	0.000	22.0991	.6334	3.4624	18.08779
44.0	.1203	479.52	1075.47	50.81	0.000	0.000	22.0991	.6334	3.4624	18.08779
46.0	.0601	479.52	1075.47	50.81	0.000	0.000	22.0991	.6334	3.4624	18.08779
48.0	0.0000	479.52	1075.47	50.81	0.000	0.000	22.0991	.6334	3.4624	18.08779

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.09 1

TIME = 0.00000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5894	486.88	1100.00	50.56	0.000	0.000	1.6824	.9651	5.3028	.90370
2.0	1.4386	486.87	1099.97	50.56	0.000	0.000	1.7310	.9930	5.4559	.90370
4.0	1.3762	486.86	1099.93	50.56	0.000	0.000	1.7412	.9968	5.4678	.90370
6.0	1.3152	486.84	1099.88	50.56	0.000	0.000	1.7447	1.0009	5.4990	.90370
8.0	1.2543	486.83	1099.62	50.56	0.000	0.000	1.7472	1.0023	5.5066	.90370
10.0	1.1935	487.04	1100.53	50.55	0.000	0.000	1.7493	1.0035	5.5142	.90370
12.0	1.1327	487.32	1101.46	50.54	0.000	0.000	1.7515	1.0047	5.5217	.90370
14.0	1.0719	487.66	1102.61	50.53	0.000	0.000	1.7535	1.0059	5.5294	.90370
16.0	1.0111	488.07	1103.98	50.52	0.000	0.000	1.7556	1.0071	5.5372	.90370
18.0	.9503	488.50	1105.42	50.51	0.000	0.000	1.7576	1.0083	5.5451	.90370
20.0	.8895	488.92	1106.82	50.50	0.000	0.000	1.7597	1.0094	5.5530	.90370
22.0	.8287	489.33	1108.18	50.48	0.000	0.000	1.7618	1.0106	5.5608	.90370
24.0	.7680	489.73	1109.50	50.47	0.000	0.000	1.7638	1.0118	5.5687	.90370
26.0	.7072	490.08	1110.67	50.46	0.000	0.000	1.7659	1.0130	5.5764	.90370
28.0	.6464	490.34	1111.56	50.45	0.000	0.000	1.7680	1.0142	5.5840	.90370
30.0	.5857	490.53	1112.18	50.45	0.000	0.000	1.7703	1.0155	5.5917	.90370
32.0	.5248	490.63	1112.53	50.44	0.000	0.000	1.7733	1.0172	5.6014	.90370
34.0	.4631	490.51	1112.11	50.45	0.000	0.000	1.7803	1.0213	5.6233	.90370
36.0	.3074	490.36	1111.63	50.45	0.000	0.000	1.8111	1.0389	5.7199	.90370
38.0	.2557	490.19	1111.05	50.46	0.000	0.000	1.8865	1.0098	5.5591	.96847
40.0	.2443	489.92	1110.17	50.47	0.000	0.000	2.0607	.8347	4.5944	1.29229
42.0	.1799	489.78	1109.67	50.47	0.000	0.000	2.1225	.8514	4.6862	1.29229
44.0	.1194	489.65	1109.25	50.47	0.000	0.000	2.1327	.8555	4.7084	1.29229
46.0	.0596	489.54	1108.88	50.48	0.000	0.000	2.1364	.8570	4.7162	1.29229
48.0	0.0000	489.44	1108.53	50.48	0.000	0.000	2.1388	.8580	4.7212	1.29229

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.26.09 1

TIME = 0.00000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SG-IN)
0.0	1.5917	486.88	1100.00	50.56	0.000	0.000	4.4178	.8829	4.8509	2.59400
2.0	1.4362	486.81	1099.75	50.56	0.000	0.000	4.4016	.8797	4.8330	2.59400
4.0	1.3756	486.73	1099.51	50.56	0.000	0.000	4.3983	.8790	4.8291	2.59400
6.0	1.3148	486.66	1099.27	50.56	0.000	0.000	4.3971	.8787	4.8276	2.59400
8.0	1.2540	486.59	1099.04	50.56	0.000	0.000	4.3963	.8786	4.8265	2.59400
10.0	1.1932	486.65	1099.22	50.56	0.000	0.000	4.3957	.8785	4.8260	2.59400
12.0	1.1324	486.74	1099.54	50.56	0.000	0.000	4.3950	.8783	4.8255	2.59400
14.0	1.0716	486.88	1100.00	50.56	0.000	0.000	4.3944	.8782	4.8252	2.59400
16.0	1.0108	487.06	1100.61	50.55	0.000	0.000	4.3938	.8781	4.8251	2.59400
18.0	.9500	487.27	1101.29	50.54	0.000	0.000	4.3931	.8779	4.8249	2.59400
20.0	.8892	487.48	1101.99	50.54	0.000	0.000	4.3924	.8778	4.8247	2.59400
22.0	.8285	487.69	1102.70	50.53	0.000	0.000	4.3916	.8776	4.8245	2.59400
24.0	.7677	487.90	1103.42	50.53	0.000	0.000	4.3908	.8775	4.8242	2.59400
26.0	.7069	488.10	1104.08	50.52	0.000	0.000	4.3899	.8773	4.8238	2.59400
28.0	.6462	488.26	1104.62	50.51	0.000	0.000	4.3890	.8771	4.8232	2.59400
30.0	.5855	488.39	1105.04	50.51	0.000	0.000	4.3880	.8769	4.8225	2.59400
32.0	.5248	488.47	1105.32	50.51	0.000	0.000	4.3867	.8767	4.8213	2.59400
34.0	.4641	488.44	1105.20	50.51	0.000	0.000	4.3842	.8762	4.8184	2.59400
36.0	.3095	488.40	1105.07	50.51	0.000	0.000	4.3742	.8742	4.8073	2.59400
38.0	.2601	488.36	1104.96	50.51	0.000	0.000	4.3486	.8343	4.5880	2.70208
40.0	.2375	488.35	1104.90	50.51	0.000	0.000	4.2829	.6847	3.7655	3.24250
42.0	.1785	488.32	1104.82	50.51	0.000	0.000	4.2682	.6824	3.7526	3.24250
44.0	.1191	488.30	1104.74	50.51	0.000	0.000	4.2642	.6818	3.7490	3.24250
46.0	.0595	488.27	1104.65	50.51	0.000	0.000	4.2625	.6815	3.7474	3.24250
48.0	0.0000	488.24	1104.55	50.52	0.000	0.000	4.2612	.6813	3.7462	3.24250

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.09 1

TIME = 0.00000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 5

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.6006	456.86	1000.00	51.39	0.000	0.000	2.3875	.5253	2.8397	2.35600
2.0	1.4501	457.00	1000.46	51.38	0.000	0.000	2.3875	.5253	2.8399	2.35600
4.0	1.3890	457.14	1000.92	51.38	0.000	0.000	2.3875	.5253	2.8401	2.35600
6.0	1.3278	457.27	1001.38	51.38	0.000	0.000	2.3875	.5253	2.8403	2.35600
8.0	1.2667	457.41	1001.83	51.37	0.000	0.000	2.3875	.5253	2.8405	2.35600
10.0	1.2055	457.54	1002.28	51.37	0.000	0.000	2.3875	.5253	2.8407	2.35600
12.0	1.1444	457.68	1002.73	51.37	0.000	0.000	2.3875	.5253	2.8409	2.35600
14.0	1.0833	457.82	1003.18	51.36	0.000	0.000	2.3875	.5253	2.8411	2.35600
16.0	1.0222	457.95	1003.63	51.36	0.000	0.000	2.3875	.5253	2.8413	2.35600
18.0	.9610	458.09	1004.08	51.36	0.000	0.000	2.3875	.5253	2.8415	2.35600
20.0	.8999	458.22	1004.54	51.35	0.000	0.000	2.3875	.5253	2.8417	2.35600
22.0	.8388	458.36	1004.99	51.35	0.000	0.000	2.3875	.5253	2.8419	2.35600
24.0	.7777	458.50	1005.45	51.34	0.000	0.000	2.3875	.5253	2.8421	2.35600
26.0	.7166	458.64	1005.91	51.34	0.000	0.000	2.3875	.5253	2.8423	2.35600
28.0	.6555	458.77	1006.37	51.34	0.000	0.000	2.3875	.5253	2.8424	2.35600
30.0	.5944	458.91	1006.83	51.33	0.000	0.000	2.3875	.5253	2.8426	2.35600
32.0	.5333	459.05	1007.29	51.33	0.000	0.000	2.3874	.5253	2.8428	2.35600
34.0	.4722	459.19	1007.74	51.33	0.000	0.000	2.3874	.5253	2.8430	2.35600
36.0	.4111	459.32	1008.20	51.32	0.000	0.000	2.3874	.5253	2.8432	2.35600
38.0	.3501	459.46	1008.65	51.32	0.000	0.000	2.3874	.5253	2.8434	2.35600
40.0	.2443	459.59	1009.10	51.32	0.000	0.000	2.3874	.5253	2.8436	2.35600
42.0	.1832	459.73	1009.54	51.31	0.000	0.000	2.3874	.5253	2.8438	2.35600
44.0	.1221	459.86	1009.99	51.31	0.000	0.000	2.3874	.5253	2.8440	2.35600
46.0	.0611	459.99	1010.43	51.30	0.000	0.000	2.3874	.5253	2.8442	2.35600
48.0	0.0000	460.12	1010.86	51.30	0.000	0.000	2.3874	.5253	2.8443	2.35600

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12,26,09 1

TIME = 0,00000 SECONDS

AXIAL ZONE	W(1, 2)	W(1, 3)	W(1, 4)	W(2, 3)	W(2, 4)	W(3, 4)	W(5, 6)	W(5, 7)	W(6, 7)
0.0 - 2.0	-.09708	-.09729	-.09730	-.00012	-.00024	-.00012	-.00001	-.00001	-.00001
2.0 - 4.0	-.02021	-.02025	-.02029	-.00004	-.00009	-.00004	-.00000	-.00000	-.00000
4.0 - 6.0	-.00712	-.00715	-.00717	-.00002	-.00005	-.00002	-.00000	-.00000	-.00000
6.0 - 8.0	-.00484	-.00488	-.00491	-.00004	-.00007	-.00004	-.00000	-.00000	-.00000
8.0 - 10.0	-.00426	-.00435	-.00443	-.00009	-.00019	-.00009	-.00000	-.00000	-.00000
10.0 - 12.0	-.00411	-.00422	-.00431	-.00010	-.00021	-.00011	.00000	.00000	.00000
12.0 - 14.0	-.00406	-.00416	-.00424	-.00009	-.00020	-.00010	.00000	.00000	.00000
14.0 - 16.0	-.00404	-.00412	-.00417	-.00006	-.00014	-.00008	.00000	.00000	.00000
16.0 - 18.0	-.00408	-.00412	-.00411	-.00001	-.00004	-.00003	.00000	.00001	.00000
18.0 - 20.0	-.00415	-.00413	-.00406	.00006	.00009	.00004	.00000	.00001	.00000
20.0 - 22.0	-.00423	-.00415	-.00400	.00013	.00024	.00011	.00001	.00001	.00001
22.0 - 24.0	-.00431	-.00416	-.00395	.00020	.00037	.00018	.00001	.00002	.00001
24.0 - 26.0	-.00441	-.00420	-.00391	.00028	.00053	.00025	.00001	.00002	.00001
26.0 - 28.0	-.00457	-.00428	-.00391	.00036	.00069	.00033	.00001	.00003	.00001
28.0 - 30.0	-.00488	-.00454	-.00411	.00042	.00081	.00039	.00002	.00003	.00002
30.0 - 32.0	-.00629	-.00595	-.00550	.00044	.00084	.00040	.00002	.00004	.00002
32.0 - 34.0	-.01436	-.01415	-.01380	.00031	.00058	.00028	.00002	.00004	.00002
34.0 - 36.0	-.06116	-.06153	-.06180	-.00036	-.00076	-.00040	.00002	.00004	.00002
36.0 - 38.0	-.15144	-.15087	-.15018	.00065	.00125	.00061	.00001	.00001	.00001
38.0 - 40.0	-.39006	-.38861	-.38702	.00150	.00295	.00146	-.00003	-.00006	-.00003
40.0 - 42.0	-.08450	-.08354	-.08243	.00111	.00216	.00106	.00001	.00002	.00001
42.0 - 44.0	-.02125	-.02048	-.01957	.00092	.00179	.00088	.00003	.00005	.00003
44.0 - 46.0	-.00814	-.00747	-.00664	.00083	.00159	.00078	.00003	.00007	.00003
46.0 - 48.0	-.00546	-.00483	-.00405	.00077	.00149	.00072	.00003	.00007	.00003

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.09 1

TIME = 0.00000 SECONDS TEMPERATURE DATA FOR ROD 1 (FUEL TYPE 1 = CYLINDER)

ROD O.D. = 1.000 (IN.) ZONE=(FUEL DIA.(IN.)) = 1=(.836) 2=(.836) 3=(.836) 4=(0.000)

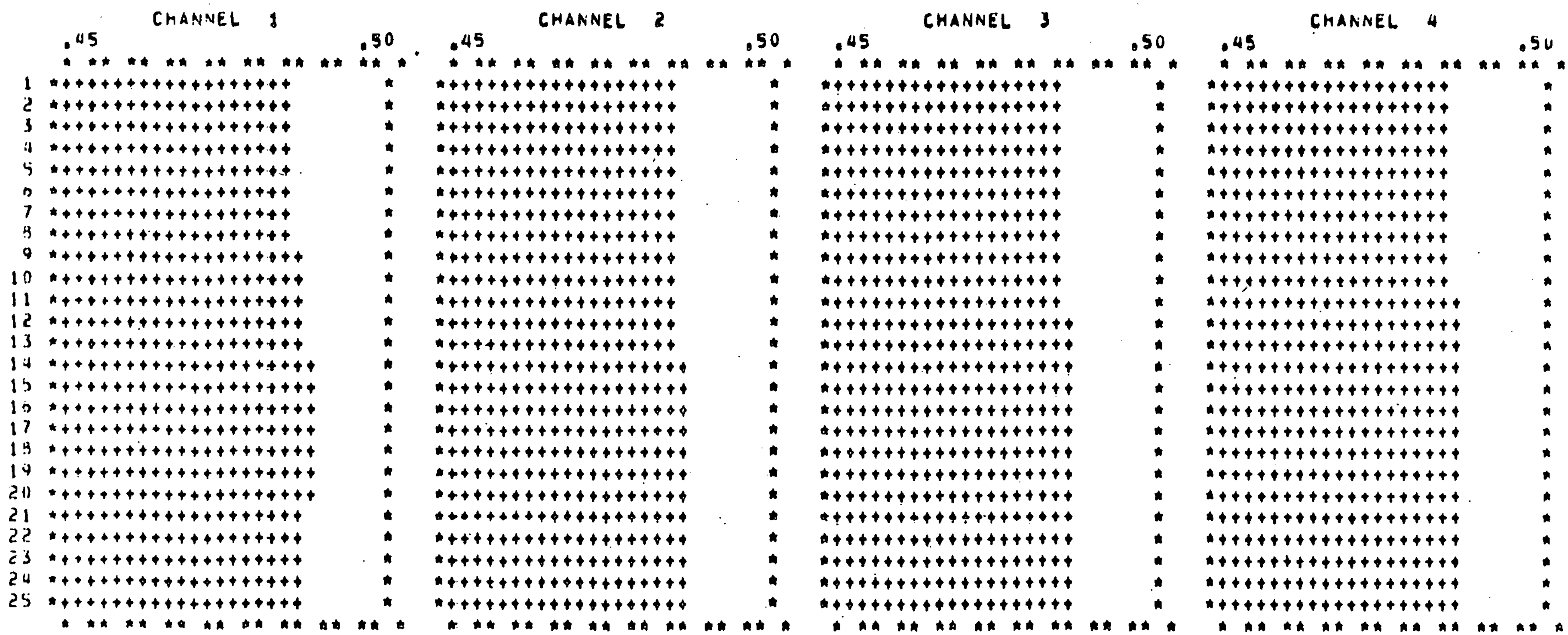
AXIAL ZONE (IN.)	HEAT FLUX (MBTU/HR-FT2)	TYPE	MODE	HSURF (B/H-F-FT2)	FLUID	CLAD	TEMPERATURES(F.) (RELATIVE RADIUS(R/R)) T(1) (1.000)	T(2) (.657)	T(3) (.333)	T(4) (0.000)
0.0 - 2.0	-.0000	2	0	13796.4	1099.8	1099.8	1099.8	1099.8	1099.8	1099.8
2.0 - 4.0	.0000	2	0	13800.1	1099.6	1099.6	1099.6	1099.6	1099.6	1099.6
4.0 - 6.0	.0000	2	0	13801.3	1099.4	1099.4	1099.5	1099.6	1099.6	1099.6
6.0 - 8.0	.0019	2	0	13802.0	1099.2	1099.3	1104.9	1107.1	1108.6	1109.2
8.0 - 10.0	.1059	1	0	13802.3	1099.6	1107.3	1306.2	1983.7	2500.3	2690.9
10.0 - 12.0	.1405	1	0	13802.2	1100.2	1110.5	1374.5	2352.7	3117.8	3402.6
12.0 - 14.0	.1744	1	0	13798.0	1101.1	1113.8	1441.2	2726.3	3691.6	4045.8
14.0 - 16.0	.2080	1	0	13797.1	1102.1	1117.3	1507.9	3099.2	4190.2	4576.6
16.0 - 18.0	.2249	1	0	13798.2	1103.2	1119.6	1541.9	3284.8	4412.3	4801.7
18.0 - 20.0	.2250	1	0	13799.3	1104.4	1120.8	1543.2	3288.0	4415.4	4804.7
20.0 - 22.0	.2250	1	0	13800.5	1105.5	1121.9	1544.4	3289.6	4416.6	4805.6
22.0 - 24.0	.2249	1	0	13801.8	1106.6	1123.0	1545.2	3289.6	4415.7	4804.3
24.0 - 26.0	.2080	1	0	13803.0	1107.6	1122.8	1513.3	3106.9	4196.1	4581.3
26.0 - 28.0	.1743	1	0	13804.3	1108.4	1121.1	1448.5	2736.8	3701.3	4054.8
28.0 - 30.0	.1406	1	0	13805.6	1109.0	1119.2	1383.2	2365.1	3131.4	3416.3
30.0 - 32.0	.1059	1	0	13807.1	1109.3	1117.1	1315.9	1996.8	2515.6	2706.9
32.0 - 34.0	.0018	2	0	13809.9	1109.1	1109.2	1114.8	1116.9	1118.5	1119.1
34.0 - 36.0	.0000	2	0	13821.3	1108.8	1108.8	1107.0	1109.0	1109.1	1109.1
36.0 - 38.0	.0000	2	0	13228.4	1108.5	1108.5	1108.6	1108.6	1108.6	1108.6
38.0 - 40.0	0.0000	0.000	0							
40.0 - 42.0	0.0000	0.000	0							
42.0 - 44.0	0.0000	0.000	0							
44.0 - 46.0	0.0000	0.000	0							
46.0 - 48.0	0.0000	0.000	0							

ITERATIONS = 11

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

TIME 0.0000 SECONDS

ENTHALPY (THOUSAND BTU/LB) AND VOID (TENTHS)



THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

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TIME  0.0000 SECONDS
                                    ENTHALPY (THOUSAND BTU/LB) AND VOID (TENTHS)

           CHANNEL  5                     CHANNEL  6                     CHANNEL  7                     CHANNEL
     .45                     .50   .45                     .50   .45                     .50   .45                     .50
      * ** ** ** ** ** ** ** ** *   * ** ** ** ** ** ** ** ** *   * ** ** ** ** ** ** ** ** *   * ** ** ** ** ** ** ** ** *
  1  *+++                     *    *+++                     *    *+++                     *    *                        *
  2  *+++                     *    *+++                     *    *+++                     *    *                        *
  3  *+++                     *    *+++                     *    *+++                     *    *                        *
  4  *+++                     *    *+++                     *    *+++                     *    *                        *
  5  *+++                     *    *+++                     *    *+++                     *    *                        *
  6  *+++                     *    *+++                     *    *+++                     *    *                        *
  7  *+++                     *    *+++                     *    *+++                     *    *                        *
  8  *+++                     *    *+++                     *    *+++                     *    *                        *
  9  *+++                     *    *+++                     *    *+++                     *    *                        *
 10  *++++                    *    *++++                    *    *++++                    *    *                        *
 11  *++++                    *    *++++                    *    *++++                    *    *                        *
 12  *++++                    *    *++++                    *    *++++                    *    *                        *
 13  *++++                    *    *++++                    *    *++++                    *    *                        *
 14  *++++                    *    *++++                    *    *++++                    *    *                        *
 15  *++++                    *    *++++                    *    *++++                    *    *                        *
 16  *++++                    *    *++++                    *    *++++                    *    *                        *
 17  *++++                    *    *++++                    *    *++++                    *    *                        *
 18  *++++                    *    *++++                    *    *++++                    *    *                        *
 19  *++++                    *    *++++                    *    *++++                    *    *                        *
 20  *++++                    *    *++++                    *    *++++                    *    *                        *
 21  *++++                    *    *++++                    *    *++++                    *    *                        *
 22  *++++                    *    *++++                    *    *++++                    *    *                        *
 23  *++++                    *    *++++                    *    *++++                    *    *                        *
 24  *++++                    *    *+++++                   *    *+++++                   *    *                        *
 25  *+++++                   *    *+++++                   *    *+++++                   *    *                        *
      * ** ** ** ** ** ** ** ** *   * ** ** ** ** ** ** ** ** *   * ** ** ** ** ** ** ** ** *   * ** ** ** ** ** ** ** ** *
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THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
11	.01000	********	34.32	.34	34.3901	0.0000	-R
6	.01000	.344	34.31	.27	34.3982	.0100	.0044
2	.01000	.344	34.28	.24	34.3861	.0200	.0063
2	.01000	.344	34.23	.23	34.3525	.0300	.0074
2	.01000	.343	34.13	.25	34.2661	.0400	.0090
3	.01000	.341	33.95	.26	34.0947	.0500	.0091
2	.01000	.340	33.96	.26	33.9605	.0600	.0088
2	.01000	.342	34.17	.25	34.1736	.0700	.0077
2	.01000	.344	34.36	.24	34.3558	.0800	.0077
2	.01000	.345	34.51	.23	34.5113	.0900	.0076
2	.01000	.346	34.64	.22	34.6449	.1000	.0075
2	.01000	.348	34.76	.22	34.7626	.1100	.0073
2	.01000	.349	34.87	.21	34.8713	.1200	.0070
2	.01000	.350	34.98	.20	34.9766	.1300	.0068
2	.01000	.351	35.08	.20	35.0805	.1400	.0066
2	.01000	.352	35.18	.19	35.1817	.1500	.0064
2	.01000	.353	35.28	.19	35.2753	.1600	.0063
2	.01000	.354	35.35	.19	35.3549	.1700	.0062
2	.01000	.354	35.41	.19	35.4128	.1800	.0061
2	.01000	.354	35.44	.19	35.4410	.1900	.0060
2	.01000	.354	35.43	.19	35.4312	.2000	.0059

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.20.14 1

TIME = .20000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5952	486.88	1100.00	50.56	0.000	0.000	1.8736	1.0748	5.9052	.90370
2.0	1.4403	486.87	1099.96	50.56	0.000	0.000	1.8689	1.0721	5.8905	.90370
4.0	1.3823	486.84	1099.88	50.56	0.000	0.000	1.8614	1.0678	5.8667	.90370
6.0	1.3256	486.81	1099.78	50.56	0.000	0.000	1.8506	1.0616	5.8326	.90370
8.0	1.2702	486.78	1099.66	50.56	0.000	0.000	1.8360	1.0532	5.7865	.90370
10.0	1.2159	486.96	1100.27	50.55	0.000	0.000	1.8171	1.0424	5.7275	.90370
12.0	1.1623	487.20	1101.08	50.55	0.000	0.000	1.7943	1.0293	5.6563	.90370
14.0	1.1090	487.51	1102.09	50.54	0.000	0.000	1.7694	1.0150	5.5789	.90370
16.0	1.0554	487.87	1103.30	50.53	0.000	0.000	1.7458	1.0015	5.5057	.90370
18.0	1.0008	488.26	1104.59	50.52	0.000	0.000	1.7270	.9907	5.4477	.90370
20.0	.9450	488.63	1105.83	50.50	0.000	0.000	1.7150	.9838	5.4111	.90370
22.0	.8878	488.99	1107.03	50.49	0.000	0.000	1.7096	.9807	5.3950	.90370
24.0	.8291	489.33	1108.19	50.48	0.000	0.000	1.7089	.9803	5.3941	.90370
26.0	.7693	489.64	1109.21	50.47	0.000	0.000	1.7109	.9815	5.4014	.90370
28.0	.7087	489.87	1109.97	50.47	0.000	0.000	1.7141	.9833	5.4119	.90370
30.0	.6476	490.02	1110.50	50.46	0.000	0.000	1.7173	.9851	5.4228	.90370
32.0	.5861	490.11	1110.78	50.46	0.000	0.000	1.7206	.9870	5.4336	.90370
34.0	.5244	489.97	1110.33	50.46	0.000	0.000	1.7263	.9903	5.4508	.90370
36.0	.4616	489.84	1109.69	50.47	0.000	0.000	1.7603	1.0098	5.5576	.90370
38.0	.3174	489.70	1109.43	50.47	0.000	0.000	1.8521	.9914	5.4563	.96647
40.0	.2846	489.62	1109.15	50.47	0.000	0.000	1.9366	.7777	4.2801	1.29229
42.0	.2423	489.57	1108.98	50.48	0.000	0.000	1.9571	.7851	4.3205	1.29229
44.0	.1802	489.51	1108.79	50.48	0.000	0.000	1.9640	.7879	4.3356	1.29224
46.0	.1199	489.45	1108.58	50.48	0.000	0.000	1.9688	.7898	4.3461	1.29229
48.0	.0599	489.37	1108.32	50.48	0.000	0.000	1.9785	.7937	4.3673	1.29229

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.14 1

TIME = .20000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5952	486.88	1100.00	50.56	0.000	0.000	4.4022	.8795	4.8338	2.59400
2.0	1.4405	486.81	1099.76	50.56	0.000	0.000	4.3937	.8781	4.8242	2.59400
4.0	1.3827	486.74	1099.52	50.56	0.000	0.000	4.3801	.8753	4.8091	2.59400
6.0	1.3261	486.67	1099.28	50.56	0.000	0.000	4.3618	.8717	4.7889	2.59400
8.0	1.2706	486.60	1099.06	50.56	0.000	0.000	4.3402	.8674	4.7650	2.59400
10.0	1.2162	486.66	1099.27	50.56	0.000	0.000	4.3171	.8627	4.7397	2.59400
12.0	1.1625	486.77	1099.63	50.56	0.000	0.000	4.2944	.8582	4.7151	2.59400
14.0	1.1090	486.92	1100.15	50.55	0.000	0.000	4.2736	.8541	4.6928	2.59400
16.0	1.0551	487.12	1100.82	50.55	0.000	0.000	4.2558	.8505	4.6737	2.59400
18.0	1.0004	487.35	1101.58	50.54	0.000	0.000	4.2409	.8475	4.6580	2.59400
20.0	.9444	487.59	1102.36	50.54	0.000	0.000	4.2292	.8452	4.6457	2.59400
22.0	.8872	487.82	1103.15	50.53	0.000	0.000	4.2204	.8434	4.6367	2.59400
24.0	.8287	488.07	1103.97	50.52	0.000	0.000	4.2145	.8423	4.6310	2.59400
26.0	.7690	488.29	1104.72	50.51	0.000	0.000	4.2113	.8416	4.6281	2.59400
28.0	.7085	488.48	1105.34	50.51	0.000	0.000	4.2101	.8414	4.6273	2.59400
30.0	.6474	488.62	1105.82	50.50	0.000	0.000	4.2102	.8414	4.6277	2.59400
32.0	.5861	488.73	1106.16	50.50	0.000	0.000	4.2108	.8415	4.6286	2.59400
34.0	.5246	488.70	1106.06	50.50	0.000	0.000	4.2105	.8414	4.6282	2.59400
36.0	.4632	488.66	1105.94	50.50	0.000	0.000	4.2002	.8394	4.6168	2.59400
38.0	.3203	488.62	1105.80	50.50	0.000	0.000	4.1713	.8003	4.4016	2.70208
40.0	.2834	488.54	1105.53	50.51	0.000	0.000	4.1441	.6626	3.6439	3.24250
42.0	.2395	488.46	1105.26	50.51	0.000	0.000	4.1393	.6618	3.6394	3.24250
44.0	.1797	488.38	1105.02	50.51	0.000	0.000	4.1376	.6615	3.6378	3.24250
46.0	.1198	488.32	1104.80	50.51	0.000	0.000	4.1359	.6612	3.6362	3.24250
48.0	.0599	488.26	1104.61	50.51	0.000	0.000	4.1318	.6606	3.6324	3.24250

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.14 1

TIME = .20000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 5

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5952	456.86	1000.00	51.39	0.000	0.000	2.3159	.5096	2.7546	2.35600
2.0	1.4549	457.00	1000.47	51.38	0.000	0.000	2.3040	.5070	2.7406	2.35600
4.0	1.4005	457.14	1000.93	51.38	0.000	0.000	2.2890	.5036	2.7229	2.35600
6.0	1.3463	457.28	1001.39	51.38	0.000	0.000	2.2724	.5000	2.7034	2.35600
8.0	1.2918	457.41	1001.84	51.37	0.000	0.000	2.2560	.4964	2.6840	2.35600
10.0	1.2368	457.55	1002.30	51.37	0.000	0.000	2.2410	.4931	2.6664	2.35600
12.0	1.1809	457.69	1002.75	51.37	0.000	0.000	2.2284	.4903	2.6516	2.35600
14.0	1.1240	457.82	1003.20	51.36	0.000	0.000	2.2185	.4881	2.6400	2.35600
16.0	1.0661	457.96	1003.66	51.36	0.000	0.000	2.2114	.4866	2.6317	2.35600
18.0	1.0072	458.10	1004.12	51.35	0.000	0.000	2.2066	.4855	2.6262	2.35600
20.0	.9476	458.23	1004.57	51.35	0.000	0.000	2.2037	.4849	2.6230	2.35600
22.0	.8873	458.37	1005.03	51.35	0.000	0.000	2.2022	.4845	2.6213	2.35600
24.0	.8267	458.51	1005.49	51.34	0.000	0.000	2.2014	.4844	2.6206	2.35600
26.0	.7658	458.65	1005.96	51.34	0.000	0.000	2.2010	.4843	2.6203	2.35600
28.0	.7049	458.79	1006.42	51.34	0.000	0.000	2.2008	.4842	2.6202	2.35600
30.0	.6440	458.93	1006.88	51.33	0.000	0.000	2.2005	.4842	2.6201	2.35600
32.0	.5831	459.07	1007.35	51.33	0.000	0.000	2.2002	.4841	2.6199	2.35600
34.0	.5223	459.21	1007.81	51.33	0.000	0.000	2.1999	.4840	2.6197	2.35600
36.0	.4616	459.34	1008.26	51.32	0.000	0.000	2.1994	.4839	2.6193	2.35600
38.0	.4010	459.48	1008.72	51.32	0.000	0.000	2.1989	.4838	2.6189	2.35600
40.0	.3404	459.62	1009.17	51.31	0.000	0.000	2.1978	.4836	2.6178	2.35600
42.0	.2420	459.75	1009.62	51.31	0.000	0.000	2.1974	.4835	2.6175	2.35600
44.0	.1815	459.89	1010.07	51.31	0.000	0.000	2.1974	.4835	2.6177	2.35600
46.0	.1210	460.02	1010.51	51.30	0.000	0.000	2.1975	.4835	2.6180	2.35600
48.0	.0605	460.15	1010.95	51.30	0.000	0.000	2.1976	.4836	2.6183	2.35600

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT).

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.14 1

TIME = .20000 SECONDS

AXIAL ZONE	W(1, 2)	W(1, 3)	W(1, 4)	W(2, 3)	W(2, 4)	W(3, 4)	W(5, 6)	W(5, 7)	W(6, 7)
0.0 - 2.0	-.00124	-.00340	-.00556	-.00222	-.00446	-.00223	-.00564	-.01114	-.00550
2.0 - 4.0	-.00333	-.00763	-.01192	-.00439	-.00878	-.00439	-.00855	-.01690	-.00835
4.0 - 6.0	-.00448	-.01085	-.01717	-.00648	-.01292	-.00644	-.01008	-.01994	-.00986
6.0 - 8.0	-.00339	-.01157	-.01968	-.00834	-.01660	-.00827	-.01056	-.02090	-.01034
8.0 - 10.0	.00057	-.00897	-.01840	-.00972	-.01934	-.00962	-.01014	-.02008	-.00995
10.0 - 12.0	.00637	-.00386	-.01396	-.01042	-.02071	-.01030	-.00901	-.01788	-.00887
12.0 - 14.0	.01126	.00110	-.00895	-.01032	-.02055	-.01024	-.00745	-.01482	-.00737
14.0 - 16.0	.01221	.00282	-.00650	-.00951	-.01897	-.00948	-.00573	-.01145	-.00571
16.0 - 18.0	.00827	.00019	-.00782	-.00815	-.01627	-.00813	-.00410	-.00822	-.00412
18.0 - 20.0	.00142	-.00496	-.01127	-.00642	-.01281	-.00641	-.00271	-.00547	-.00276
20.0 - 22.0	-.00480	-.00935	-.01385	-.00459	-.00911	-.00457	-.00164	-.00336	-.00171
22.0 - 24.0	-.00816	-.01098	-.01377	-.00279	-.00561	-.00284	-.00091	-.00189	-.00098
24.0 - 26.0	-.00855	-.00992	-.01127	-.00129	-.00264	-.00136	-.00047	-.00099	-.00052
26.0 - 28.0	-.00720	-.00747	-.00770	-.00013	-.00033	-.00021	-.00023	-.00049	-.00026
28.0 - 30.0	-.00548	-.00497	-.00443	.00067	.00128	.00059	-.00011	-.00025	-.00014
30.0 - 32.0	-.00465	-.00364	-.00257	.00119	.00232	.00112	-.00008	-.00018	-.00010
32.0 - 34.0	-.00940	-.00803	-.00659	.00155	.00304	.00147	-.00010	-.00020	-.00011
34.0 - 36.0	-.06673	-.06466	-.06249	.00230	.00456	.00224	-.00009	-.00020	-.00010
36.0 - 38.0	-.18141	-.18064	-.17976	.00086	.00168	.00080	.00012	.00024	.00012
38.0 - 40.0	-.17116	-.17103	-.17073	.00024	.00045	.00018	.00109	.00218	.00109
40.0 - 42.0	-.03510	-.03513	-.03496	.00027	.00051	.00023	-.00024	-.00046	-.00023
42.0 - 44.0	-.01279	-.01273	-.01247	.00055	.00108	.00052	-.00073	-.00144	-.00071
44.0 - 46.0	-.00954	-.00903	-.00834	.00108	.00212	.00104	-.00070	-.00136	-.00066
46.0 - 48.0	-.02046	-.01916	-.01773	.00183	.00363	.00179	-.00037	-.00068	-.00032

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.14 1

TIME = .20000 SECONDS TEMPERATURE DATA FOR ROD 1 (FUEL TYPE 1 = CYLINDER)

ROD O.D. = 1.000 (IN.) ZONE=(FUEL DIA.(IN.)) = 1=(.836) 2=(.836) 3=(.836) 4=(0.000)

AXIAL ZONE (IN.)	HEAT FLUX (MBTU/HR-FT2)	TYPE	MODE	HSURF (B/H-F-FT2)	*	FLUID	CLAD	T(1) (1.000)	T(2) (.667)	T(3) (.333)	T(4) (0.000)
					*			TEMPERATURES(F.) (RELATIVE RADIUS(R/R))			
0.0 - 2.0	-.0000	2	0	13947.5		1099.8	1099.8	1099.8	1099.8	1099.8	1099.8
2.0 - 4.0	.0000	2	0	13916.6		1099.6	1099.6	1099.6	1099.6	1099.6	1099.6
4.0 - 6.0	.0001	2	0	13872.4		1099.4	1099.4	1099.5	1099.6	1099.6	1099.6
6.0 - 8.0	.0019	2	0	13815.3		1099.2	1099.3	1104.9	1107.1	1108.6	1109.2
8.0 - 10.0	.1059	1	0	13747.7		1099.6	1107.3	1304.3	1977.8	2495.3	2686.6
10.0 - 12.0	.1397	1	0	13671.9		1100.2	1110.4	1372.2	2344.9	3111.2	3397.1
12.0 - 14.0	.1723	1	0	13591.2		1101.0	1113.7	1438.6	2716.6	3683.5	4039.1
14.0 - 16.0	.2047	1	0	13519.2		1102.0	1117.1	1505.0	3087.5	4180.5	4568.7
16.0 - 18.0	.2208	1	0	13458.9		1103.1	1119.5	1538.9	3272.2	4401.6	4793.3
18.0 - 20.0	.2208	1	0	13412.0		1104.2	1120.7	1540.3	3275.3	4404.9	4796.3
20.0 - 22.0	.2207	1	0	13379.2		1105.3	1121.8	1541.4	3276.9	4406.1	4797.1
22.0 - 24.0	.2209	1	0	13359.2		1106.4	1122.9	1542.3	3277.0	4405.2	4795.9
24.0 - 26.0	.2048	1	0	13349.6		1107.4	1122.7	1510.5	3095.2	4186.3	4573.4
26.0 - 28.0	.1718	1	0	13347.5		1108.1	1121.0	1445.9	2727.1	3693.2	4048.1
28.0 - 30.0	.1395	1	0	13350.3		1108.7	1119.1	1380.9	2357.3	3124.7	3410.8
30.0 - 32.0	.1064	1	0	13355.5		1109.0	1117.0	1314.0	1990.9	2510.5	2702.7
32.0 - 34.0	.0037	2	0	13362.6		1108.7	1109.0	1114.8	1116.9	1118.5	1119.1
34.0 - 36.0	.0020	2	0	13381.4		1108.5	1108.6	1109.0	1109.0	1109.1	1109.1
36.0 - 38.0	.0019	2	0	12816.8		1108.2	1108.3	1108.5	1108.6	1108.6	1108.6
38.0 - 40.0	0.0000	0.000	0								
40.0 - 42.0	0.0000	0.000	0								
42.0 - 44.0	0.0000	0.000	0								
44.0 - 46.0	0.0000	0.000	0								
46.0 - 48.0	0.0000	0.000	0								

ITERATIONS = 2

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
2	.01000	.354	35.38	.19	35.3757	.2100	.0057
2	.01000	.353	35.27	.19	35.2700	.2200	.0052
2	.01000	.351	35.11	.19	35.1131	.2300	.0046
2	.01000	.349	34.91	.19	34.9083	.2400	.0038
2	.01000	.347	34.66	.19	34.6630	.2500	.0029
2	.01000	.344	34.39	.19	34.3981	.2600	.0021
2	.01000	.342	34.15	.19	34.1576	.2700	.0015
2	.01000	.341	34.03	.19	34.0719	.2800	.0017
2	.01000	.340	33.94	.19	34.0112	.2900	.0023
2	.01000	.339	33.85	.19	33.9413	.3000	.0028
2	.01000	.339	33.77	.19	33.8586	.3100	.0032
2	.01000	.338	33.68	.19	33.7752	.3200	.0033
2	.01000	.337	33.58	.19	33.6739	.3300	.0033
2	.01000	.336	33.48	.18	33.5781	.3400	.0032
2	.01000	.335	33.39	.18	33.4718	.3500	.0031
2	.01000	.334	33.35	.18	33.3993	.3600	.0030
2	.01000	.333	33.30	.17	33.3455	.3700	.0030
2	.01000	.333	33.24	.17	33.2848	.3800	.0029
2	.01000	.332	33.18	.17	33.2192	.3900	.0029
2	.01000	.332	33.11	.17	33.1507	.4000	.0028

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.20 1

TIME = .40000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5952	485.88	1100.00	50.56	0.000	0.000	1.7054	.9783	5.3752	.90370
2.0	1.4562	485.87	1099.95	50.56	0.000	0.000	1.7078	.9796	5.3826	.90370
4.0	1.3954	485.84	1099.87	50.56	0.000	0.000	1.7108	.9814	5.3920	.90370
6.0	1.3345	485.81	1099.77	50.56	0.000	0.000	1.7141	.9833	5.4024	.90370
8.0	1.2737	485.78	1099.65	50.56	0.000	0.000	1.7175	.9852	5.4130	.90370
10.0	1.2131	485.96	1100.26	50.55	0.000	0.000	1.7208	.9871	5.4240	.90370
12.0	1.1526	487.20	1101.06	50.55	0.000	0.000	1.7240	.9890	5.4349	.90370
14.0	1.0923	487.49	1102.05	50.54	0.000	0.000	1.7272	.9908	5.4458	.90370
16.0	1.0322	487.85	1103.23	50.53	0.000	0.000	1.7302	.9925	5.4566	.90370
18.0	.9723	488.22	1104.47	50.52	0.000	0.000	1.7332	.9942	5.4670	.90370
20.0	.9126	488.58	1105.67	50.51	0.000	0.000	1.7358	.9957	5.4764	.90370
22.0	.8530	488.93	1106.84	50.50	0.000	0.000	1.7378	.9968	5.4838	.90370
24.0	.7937	489.27	1107.97	50.48	0.000	0.000	1.7386	.9973	5.4876	.90370
26.0	.7345	489.57	1108.97	50.48	0.000	0.000	1.7379	.9969	5.4863	.90370
28.0	.6755	489.79	1109.72	50.47	0.000	0.000	1.7353	.9954	5.4787	.90370
30.0	.6166	489.95	1110.23	50.46	0.000	0.000	1.7310	.9929	5.4656	.90370
32.0	.5578	490.03	1110.50	50.46	0.000	0.000	1.7257	.9900	5.4494	.90370
34.0	.4991	489.89	1110.04	50.47	0.000	0.000	1.7234	.9886	5.4414	.90370
36.0	.4395	489.75	1109.57	50.47	0.000	0.000	1.7481	1.0028	5.5190	.90370
38.0	.3003	489.60	1109.09	50.47	0.000	0.000	1.8351	.9823	5.4058	.96647
40.0	.2703	489.51	1108.77	50.48	0.000	0.000	1.9169	.7689	4.2315	1.29229
42.0	.2304	489.44	1108.54	50.48	0.000	0.000	1.9322	.7751	4.2652	1.29229
44.0	.1711	489.37	1108.32	50.48	0.000	0.000	1.9377	.7773	4.2771	1.29229
46.0	.1137	489.31	1108.11	50.48	0.000	0.000	1.9418	.7790	4.2860	1.29229
48.0	.0567	489.25	1107.91	50.49	0.000	0.000	1.9460	.7806	4.2952	1.29229

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.20 1

TIME = .40000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5952	486.88	1100.00	50.56	0.000	0.000	3.9805	.7953	4.3708	2.59400
2.0	1.4563	486.80	1099.73	50.56	0.000	0.000	3.9813	.7956	4.3714	2.59400
4.0	1.3954	486.72	1099.48	50.56	0.000	0.000	3.9826	.7959	4.3727	2.59400
6.0	1.3345	486.65	1099.23	50.56	0.000	0.000	3.9845	.7963	4.3746	2.59400
8.0	1.2738	486.58	1099.01	50.57	0.000	0.000	3.9871	.7968	4.3773	2.59400
10.0	1.2131	486.65	1099.22	50.56	0.000	0.000	3.9907	.7975	4.3813	2.59400
12.0	1.1526	486.76	1099.60	50.56	0.000	0.000	3.9952	.7984	4.3866	2.59400
14.0	1.0923	486.92	1100.14	50.55	0.000	0.000	4.0009	.7996	4.3932	2.59400
16.0	1.0322	487.13	1100.64	50.55	0.000	0.000	4.0078	.8009	4.4014	2.59400
18.0	.9723	487.37	1101.63	50.54	0.000	0.000	4.0160	.8026	4.4110	2.59400
20.0	.9127	487.61	1102.44	50.53	0.000	0.000	4.0257	.8045	4.4223	2.59400
22.0	.8531	487.86	1103.27	50.53	0.000	0.000	4.0368	.8067	4.4351	2.59400
24.0	.7938	488.11	1104.11	50.52	0.000	0.000	4.0494	.8092	4.4496	2.59400
26.0	.7346	488.35	1104.90	50.51	0.000	0.000	4.0635	.8121	4.4657	2.59400
28.0	.6756	488.54	1105.55	50.51	0.000	0.000	4.0790	.8152	4.4833	2.59400
30.0	.6167	488.70	1106.06	50.50	0.000	0.000	4.0954	.8185	4.5018	2.59400
32.0	.5579	488.81	1106.43	50.50	0.000	0.000	4.1123	.8218	4.5206	2.59400
34.0	.4992	488.78	1106.36	50.50	0.000	0.000	4.1275	.8249	4.5373	2.59400
36.0	.4408	488.75	1106.26	50.50	0.000	0.000	4.1306	.8255	4.5406	2.59400
38.0	.3033	488.72	1106.14	50.50	0.000	0.000	4.1126	.7890	4.3398	2.70208
40.0	.2691	488.66	1105.93	50.50	0.000	0.000	4.0956	.6548	3.6015	3.24250
42.0	.2276	488.59	1105.70	50.51	0.000	0.000	4.0992	.6554	3.6045	3.24250
44.0	.1706	488.52	1105.47	50.51	0.000	0.000	4.1037	.6561	3.6083	3.24250
46.0	.1136	488.45	1105.23	50.51	0.000	0.000	4.1059	.6564	3.6101	3.24250
48.0	.0567	488.38	1104.99	50.51	0.000	0.000	4.1052	.6563	3.6094	3.24250

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.20 1

TIME = .40000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 5

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5952	456.86	1000.60	51.39	0.000	0.000	2.0689	.4552	2.4606	2.35600
2.0	1.4675	457.02	1000.52	51.38	0.000	0.000	2.0688	.4552	2.4608	2.35600
4.0	1.4069	457.17	1001.03	51.38	0.000	0.000	2.0687	.4552	2.4609	2.35600
6.0	1.3463	457.31	1001.51	51.38	0.000	0.000	2.0687	.4552	2.4611	2.35600
8.0	1.2856	457.46	1001.98	51.37	0.000	0.000	2.0689	.4552	2.4615	2.35600
10.0	1.2250	457.59	1002.44	51.37	0.000	0.000	2.0692	.4553	2.4621	2.35600
12.0	1.1644	457.73	1002.90	51.36	0.000	0.000	2.0698	.4554	2.4629	2.35600
14.0	1.1038	457.87	1003.35	51.36	0.000	0.000	2.0706	.4556	2.4640	2.35600
16.0	1.0433	458.00	1003.80	51.36	0.000	0.000	2.0717	.4558	2.4655	2.35600
18.0	.9827	458.14	1004.26	51.35	0.000	0.000	2.0732	.4562	2.4675	2.35600
20.0	.9222	458.28	1004.71	51.35	0.000	0.000	2.0751	.4566	2.4699	2.35600
22.0	.8618	458.41	1005.17	51.35	0.000	0.000	2.0775	.4571	2.4730	2.35600
24.0	.8015	458.55	1005.63	51.34	0.000	0.000	2.0804	.4578	2.4766	2.35600
26.0	.7413	458.69	1006.09	51.34	0.000	0.000	2.0838	.4585	2.4808	2.35600
28.0	.6812	458.83	1006.55	51.34	0.000	0.000	2.0875	.4593	2.4854	2.35600
30.0	.6214	458.97	1007.01	51.33	0.000	0.000	2.0916	.4602	2.4905	2.35600
32.0	.5617	459.11	1007.47	51.33	0.000	0.000	2.0959	.4612	2.4956	2.35600
34.0	.5023	459.24	1007.93	51.32	0.000	0.000	2.1002	.4621	2.5011	2.35600
36.0	.4431	459.38	1008.39	51.32	0.000	0.000	2.1045	.4631	2.5063	2.35600
38.0	.3841	459.52	1008.84	51.32	0.000	0.000	2.1082	.4639	2.5109	2.35600
40.0	.3254	459.65	1009.29	51.31	0.000	0.000	2.1103	.4643	2.5137	2.35600
42.0	.2319	459.79	1009.74	51.31	0.000	0.000	2.1121	.4647	2.5160	2.35600
44.0	.1737	459.92	1010.18	51.31	0.000	0.000	2.1135	.4650	2.5178	2.35600
46.0	.1157	460.05	1010.62	51.30	0.000	0.000	2.1144	.4652	2.5189	2.35600
48.0	.0578	460.18	1011.06	51.30	0.000	0.000	2.1147	.4653	2.5195	2.35600

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT).

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.20.20 1

TIME = .40000 SECONDS

AXIAL ZONE	W(1, 2)	W(1, 3)	W(1, 4)	W(2, 3)	W(2, 4)	W(3, 4)	W(5, 6)	W(5, 7)	W(6, 7)
0.0 - 2.0	-.00297	-.00262	-.00226	.00039	.00080	.00040	-.00004	-.00008	-.00003
2.0 - 4.0	-.00333	-.00266	-.00197	.00075	.00151	.00077	-.00008	-.00015	-.00006
4.0 - 6.0	-.00305	-.00203	-.00100	.00109	.00218	.00110	-.00016	-.00031	-.00015
6.0 - 8.0	-.00225	-.00091	.00042	.00137	.00273	.00136	-.00023	-.00045	-.00022
8.0 - 10.0	-.00107	.00055	.00217	.00160	.00318	.00158	-.00020	-.00040	-.00020
10.0 - 12.0	.00032	.00219	.00407	.00181	.00361	.00180	-.00007	-.00014	-.00007
12.0 - 14.0	.00189	.00398	.00608	.00202	.00402	.00200	.00014	.00028	.00014
14.0 - 16.0	.00361	.00590	.00822	.00223	.00446	.00222	.00039	.00077	.00039
16.0 - 18.0	.00554	.00804	.01059	.00247	.00495	.00247	.00065	.00130	.00065
18.0 - 20.0	.00785	.01059	.01339	.00274	.00550	.00275	.00091	.00183	.00091
20.0 - 22.0	.01080	.01360	.01688	.00304	.00611	.00306	.00118	.00236	.00118
22.0 - 24.0	.01456	.01786	.02123	.00336	.00674	.00337	.00143	.00287	.00144
24.0 - 26.0	.01907	.02267	.02634	.00368	.00735	.00367	.00168	.00336	.00168
26.0 - 28.0	.02390	.02777	.03169	.00395	.00788	.00392	.00189	.00378	.00189
28.0 - 30.0	.02806	.03213	.03623	.00414	.00826	.00411	.00207	.00413	.00206
30.0 - 32.0	.02986	.03401	.03818	.00423	.00841	.00417	.00218	.00436	.00217
32.0 - 34.0	.02433	.02845	.03261	.00422	.00840	.00417	.00225	.00449	.00224
34.0 - 36.0	-.03342	-.02954	-.02568	.00403	.00798	.00393	.00225	.00447	.00222
36.0 - 38.0	-.15960	-.15656	-.15350	.00313	.00622	.00308	.00233	.00466	.00233
38.0 - 40.0	-.15009	-.14734	-.14450	.00275	.00546	.00270	.00265	.00525	.00260
40.0 - 42.0	-.01907	-.01675	-.01432	.00237	.00469	.00231	.00152	.00302	.00150
42.0 - 44.0	-.00226	-.00034	.00170	.00198	.00391	.00191	.00083	.00165	.00082
44.0 - 46.0	-.00293	-.00146	.00010	.00151	.00297	.00144	.00035	.00070	.00034
46.0 - 48.0	-.00668	-.00565	-.00447	.00114	.00222	.00107	.00006	.00012	.00006

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.20 1

TIME = .40000 SECONDS TEMPERATURE DATA FOR ROD 1 (FUEL TYPE 1 = CYLINDER)

ROD O.D. = 1.000 (IN.) ZONE=(FUEL DIA.(IN.)) = 1=(.836) 2=(.836) 3=(.836) 4=(0.000)

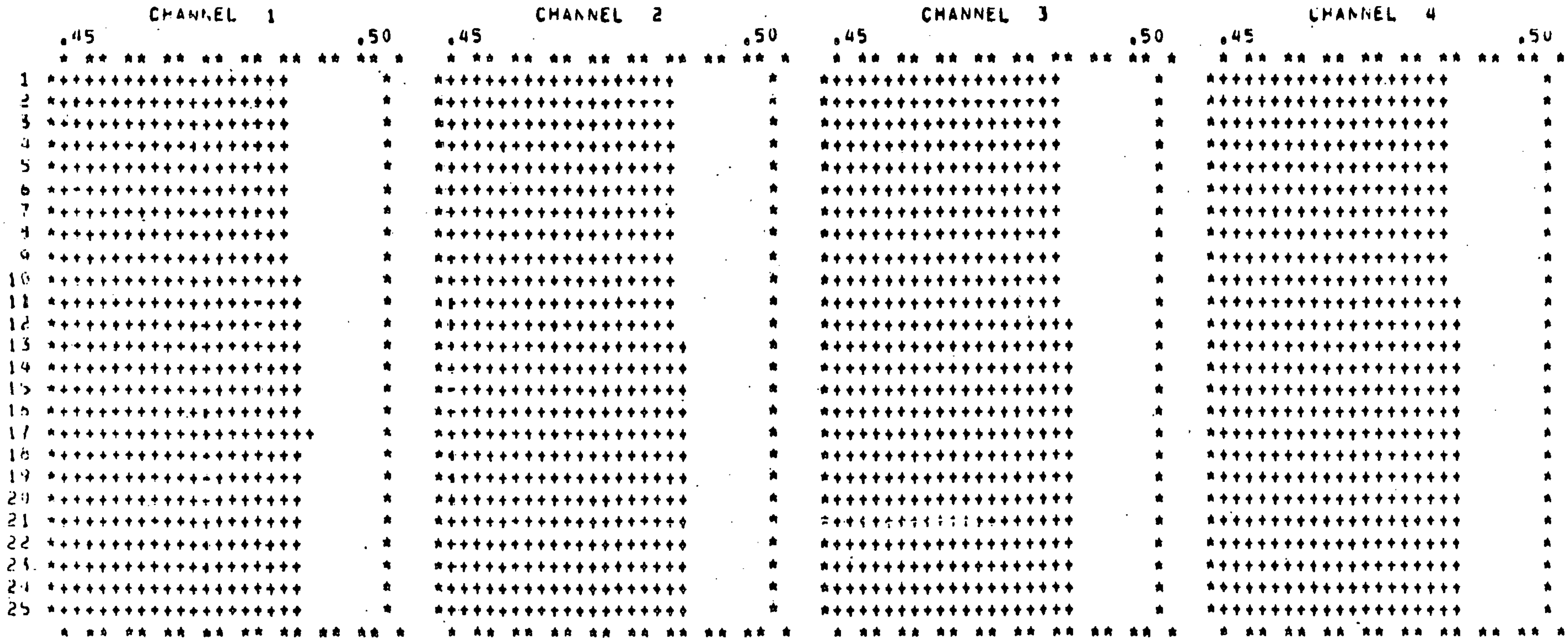
AXIAL ZONE (IN.)	HEAT FLUX (MBTU/HR-FT2)	TYPE	MODE	HSURF (B/H-F-FT2)	FLUID	CLAD	T(1) (1.000)	T(2) (.667)	T(3) (.333)	T(4) (0.000)
							TEMPERATURES(F.) (RELATIVE RADIUS(R/R))			
0.0 - 2.0	.0001	2	0	12885.5	1079.8	1099.8	1099.8	1099.8	1099.8	1099.8
2.0 - 4.0	.0002	2	0	12893.5	1079.5	1099.6	1099.6	1099.6	1099.6	1099.6
4.0 - 6.0	.0003	2	0	12903.9	1099.3	1099.4	1099.5	1099.6	1099.6	1099.6
6.0 - 8.0	.0021	2	0	12916.6	1099.1	1099.3	1104.9	1107.1	1108.6	1109.2
8.0 - 10.0	.1018	1	0	12931.6	1099.6	1107.4	1302.5	1971.9	2490.2	2682.4
10.0 - 12.0	.1353	1	0	12947.5	1100.2	1110.6	1370.0	2337.1	3104.6	3391.6
12.0 - 14.0	.1631	1	0	12962.2	1101.0	1114.0	1436.2	2706.9	3675.3	4032.4
14.0 - 16.0	.2008	1	0	12982.9	1102.1	1117.5	1502.5	3075.9	4170.8	4560.9
16.0 - 18.0	.2175	1	0	13007.3	1103.2	1119.9	1536.3	3259.6	4391.3	4784.9
18.0 - 20.0	.2177	1	0	13033.8	1104.3	1120.9	1537.6	3262.7	4394.5	4787.8
20.0 - 22.0	.2180	1	0	13062.1	1105.4	1122.0	1538.7	3264.3	4395.6	4788.7
22.0 - 24.0	.2184	1	0	13091.9	1106.4	1123.1	1539.5	3264.4	4394.7	4787.4
24.0 - 26.0	.2024	1	0	13122.4	1107.4	1122.8	1507.8	3083.6	4176.6	4565.5
26.0 - 28.0	.1700	1	0	13153.2	1108.1	1121.0	1443.3	2717.4	3685.0	4041.3
28.0 - 30.0	.1380	1	0	13183.3	1108.7	1119.1	1378.6	2349.6	3118.1	3405.3
30.0 - 32.0	.1044	1	0	13214.3	1109.0	1116.9	1312.0	1985.1	2505.5	2696.3
32.0 - 34.0	.0025	2	0	13243.1	1108.7	1108.9	1114.8	1116.9	1118.5	1119.1
34.0 - 36.0	.0009	2	0	13277.5	1108.4	1108.4	1108.9	1109.0	1109.1	1109.1
36.0 - 38.0	.0010	2	0	12733.8	1108.1	1108.2	1108.5	1108.6	1108.6	1108.6
38.0 - 40.0	0.0000	0.000	0							
40.0 - 42.0	0.0000	0.000	0							
42.0 - 44.0	0.0000	0.000	0							
44.0 - 46.0	0.0000	0.000	0							
46.0 - 48.0	0.0000	0.000	0							

ITERATIONS = 2

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

TIME .4000 SECONDS

ENTHALPY (THOUSAND BTU/LB) AND VOID (TENTHS)



THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

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TIME   4000 SECONDS
                                   ENTHALPY (THOUSAND BTU/LB) AND VOID (TENTHS)

          CHANNEL  5                   CHANNEL  6                   CHANNEL  7                   CHANNEL
    .45                    .50   .45                    .50   .45                    .50   .45                    .50
    * ** ** ** ** ** ** ** ** *  * ** ** ** ** ** ** ** ** *  * ** ** ** ** ** ** ** ** *  * ** ** ** ** ** ** ** ** *
 1  ****                     *   ****                     *   ****                     *   *                        *
 2  ****                     *   ****                     *   ****                     *   *                        *
 3  ****                     *   ****                     *   ****                     *   *                        *
 4  ****                     *   ****                     *   ****                     *   *                        *
 5  ****                     *   ****                     *   ****                     *   *                        *
 6  ****                     *   ****                     *   ****                     *   *                        *
 7  ****                     *   ****                     *   ****                     *   *                        *
 8  ****                     *   ****                     *   ****                     *   *                        *
 9  *****                    *   *****                    *   *****                    *   *                        *
10  *****                    *   *****                    *   *****                    *   *                        *
11  *****                    *   *****                    *   *****                    *   *                        *
12  *****                    *   *****                    *   *****                    *   *                        *
13  *****                    *   *****                    *   *****                    *   *                        *
14  *****                    *   *****                    *   *****                    *   *                        *
15  *****                    *   *****                    *   *****                    *   *                        *
16  *****                    *   *****                    *   *****                    *   *                        *
17  *****                    *   *****                    *   *****                    *   *                        *
18  *****                    *   *****                    *   *****                    *   *                        *
19  *****                    *   *****                    *   *****                    *   *                        *
20  *****                    *   *****                    *   *****                    *   *                        *
21  *****                    *   *****                    *   *****                    *   *                        *
22  *****                    *   *****                    *   *****                    *   *                        *
23  *****                    *   *****                    *   *****                    *   *                        *
24  ******                   *   ******                   *   ******                   *   *                        *
25  ******                   *   ******                   *   ******                   *   *                        *
    * ** ** ** ** ** ** ** ** *  * ** ** ** ** ** ** ** ** *  * ** ** ** ** ** ** ** ** *  * ** ** ** ** ** ** ** ** *
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DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
2	.01000	.331	33.05	.17	33.0812	.4100	.0026
2	.01000	.330	32.98	.17	33.0128	.4200	.0023
2	.01000	.329	32.91	.17	32.9469	.4300	.0019
2	.01000	.329	32.85	.17	32.8847	.4400	.0015
2	.01000	.328	32.79	.17	32.8271	.4500	.0010
2	.01000	.328	32.74	.18	32.7761	.4600	.0006
2	.01000	.327	32.69	.18	32.7308	.4700	.0007
2	.01000	.327	32.66	.18	32.6908	.4800	.0011
2	.01000	.327	32.65	.19	32.6569	.4900	.0014
2	.01000	.327	32.65	.19	32.6554	.5000	.0017
2	.01000	.327	32.64	.19	32.6506	.5100	.0066
2	.01000	.326	32.63	.19	32.6408	.5200	.0092
4	.01000	.326	32.60	.20	32.6100	.5300	.0063
2	.01000	.326	32.55	.20	32.5600	.5400	.0082
3	.01000	.326	32.51	.20	32.5506	.5500	.0077
2	.01000	.325	32.50	.19	32.5427	.5600	.0092
4	.01000	.325	32.49	.19	32.5294	.5700	.0080
2	.01000	.325	32.47	.19	32.4988	.5800	.0086
4	.01000	.324	32.41	.19	32.4326	.5900	.0074
2	.01000	.323	32.31	.19	32.3301	.6000	.0084

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.26 1

TIME = .60000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.4357	486.88	1100.00	50.56	0.000	0.000	1.4834	.8509	4.6754	.90370
2.0	1.3297	486.87	1099.95	50.56	0.000	0.000	1.4965	.8584	4.7166	.90370
4.0	1.2794	486.84	1099.87	50.56	0.000	0.000	1.5082	.8651	4.7555	.90370
6.0	1.2283	486.81	1099.75	50.56	0.000	0.000	1.5201	.8720	4.7909	.90370
8.0	1.1773	486.77	1099.63	50.56	0.000	0.000	1.5332	.8795	4.8322	.90370
10.0	1.1267	486.96	1100.26	50.55	0.000	0.000	1.5476	.8878	4.8782	.90370
12.0	1.0763	487.21	1101.10	50.55	0.000	0.000	1.5628	.8965	4.9268	.90370
14.0	1.0262	487.51	1102.12	50.54	0.000	0.000	1.5783	.9054	4.9764	.90370
16.0	.9762	487.88	1103.33	50.53	0.000	0.000	1.5936	.9141	5.0256	.90370
18.0	.9261	488.26	1104.60	50.51	0.000	0.000	1.6084	.9226	5.0735	.90370
20.0	.8757	488.62	1105.82	50.50	0.000	0.000	1.6225	.9308	5.1192	.90370
22.0	.8249	488.97	1106.99	50.49	0.000	0.000	1.6358	.9383	5.1620	.90370
24.0	.7735	489.31	1108.13	50.48	0.000	0.000	1.6479	.9453	5.2013	.90370
26.0	.7212	489.61	1109.11	50.47	0.000	0.000	1.6587	.9515	5.2365	.90370
28.0	.6680	489.82	1109.83	50.47	0.000	0.000	1.6682	.9570	5.2671	.90370
30.0	.6139	489.97	1110.31	50.46	0.000	0.000	1.6763	.9616	5.2930	.90370
32.0	.5587	490.04	1110.54	50.46	0.000	0.000	1.6829	.9654	5.3142	.90370
34.0	.5025	489.89	1110.05	50.47	0.000	0.000	1.6892	.9690	5.3334	.90370
36.0	.4449	489.75	1109.59	50.47	0.000	0.000	1.7056	.9784	5.3848	.90370
38.0	.3137	489.60	1109.09	50.47	0.000	0.000	1.7983	.9626	5.2974	.96047
40.0	.2810	489.50	1108.76	50.48	0.000	0.000	1.8855	.7564	4.1623	1.29229
42.0	.2345	489.43	1108.51	50.48	0.000	0.000	1.8972	.7611	4.1880	1.29229
44.0	.1777	489.36	1108.27	50.48	0.000	0.000	1.8942	.7599	4.1812	1.29229
46.0	.1183	489.28	1108.03	50.48	0.000	0.000	1.8867	.7568	4.1643	1.29229
48.0	.0593	489.21	1107.79	50.49	0.000	0.000	1.8757	.7524	4.1398	1.29229

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.26 1

TIME = .60000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.4357	486.88	1100.00	50.56	0.000	0.000	3.4544	.6904	3.7931	2.59400
2.0	1.3289	486.79	1099.71	50.56	0.000	0.000	3.4857	.6966	3.8272	2.59400
4.0	1.2790	486.71	1099.44	50.56	0.000	0.000	3.5188	.7032	3.8634	2.59400
6.0	1.2282	486.64	1099.19	50.56	0.000	0.000	3.5520	.7098	3.8997	2.59400
8.0	1.1773	486.57	1098.95	50.57	0.000	0.000	3.5848	.7164	3.9355	2.59400
10.0	1.1267	486.63	1099.17	50.56	0.000	0.000	3.6168	.7228	3.9709	2.59400
12.0	1.0764	486.75	1099.56	50.56	0.000	0.000	3.6477	.7290	4.0050	2.59400
14.0	1.0263	486.91	1100.12	50.56	0.000	0.000	3.6772	.7349	4.0378	2.59400
16.0	.9762	487.13	1100.63	50.55	0.000	0.000	3.7052	.7405	4.0691	2.59400
18.0	.9261	487.37	1101.65	50.54	0.000	0.000	3.7315	.7457	4.0985	2.59400
20.0	.8756	487.62	1102.48	50.53	0.000	0.000	3.7559	.7506	4.1259	2.59400
22.0	.8248	487.88	1103.33	50.53	0.000	0.000	3.7783	.7551	4.1512	2.59400
24.0	.7733	488.14	1104.19	50.52	0.000	0.000	3.7986	.7591	4.1742	2.59400
26.0	.7210	488.38	1105.00	50.51	0.000	0.000	3.8169	.7628	4.1948	2.59400
28.0	.6678	488.57	1105.66	50.51	0.000	0.000	3.8331	.7660	4.2131	2.59400
30.0	.6136	488.73	1106.18	50.50	0.000	0.000	3.8472	.7689	4.2290	2.59400
32.0	.5584	488.84	1106.54	50.50	0.000	0.000	3.8595	.7713	4.2428	2.59400
34.0	.5023	488.82	1106.47	50.50	0.000	0.000	3.8699	.7734	4.2541	2.59400
36.0	.4452	488.79	1106.36	50.50	0.000	0.000	3.8737	.7741	4.2585	2.59400
38.0	.3173	488.75	1106.25	50.50	0.000	0.000	3.8502	.7387	4.0630	2.70208
40.0	.2799	488.69	1106.05	50.50	0.000	0.000	3.8272	.6119	3.3656	3.24250
42.0	.2356	488.63	1105.84	50.50	0.000	0.000	3.8282	.6120	3.3663	3.24250
44.0	.1771	488.57	1105.64	50.51	0.000	0.000	3.8327	.6128	3.3701	3.24250
46.0	.1182	488.51	1105.43	50.51	0.000	0.000	3.8373	.6135	3.3740	3.24250
48.0	.0591	488.44	1105.21	50.51	0.000	0.000	3.8417	.6142	3.3778	3.24250

THERMAL MODEL SAMPLE PROBLEM RESULTS (Contirued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.26.26 1

TIME = .60000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 5

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.4357	456.86	1000.00	51.39	0.000	0.000	1.6049	.3531	1.9088	2.35600
2.0	1.3461	457.04	1000.59	51.38	0.000	0.000	1.6289	.3584	1.9376	2.35600
4.0	1.2964	457.20	1001.12	51.38	0.000	0.000	1.6541	.3640	1.9678	2.35600
6.0	1.2459	457.35	1001.64	51.37	0.000	0.000	1.6800	.3697	1.9987	2.35600
8.0	1.1951	457.50	1002.13	51.37	0.000	0.000	1.7063	.3755	2.0302	2.35600
10.0	1.1443	457.65	1002.61	51.37	0.000	0.000	1.7328	.3813	2.0619	2.35600
12.0	1.0935	457.79	1003.09	51.36	0.000	0.000	1.7592	.3871	2.0933	2.35600
14.0	1.0425	457.93	1003.55	51.36	0.000	0.000	1.7850	.3928	2.1243	2.35600
16.0	.9912	458.06	1004.01	51.36	0.000	0.000	1.8102	.3983	2.1544	2.35600
18.0	.9395	458.20	1004.47	51.35	0.000	0.000	1.8344	.4036	2.1834	2.35600
20.0	.8874	458.34	1004.92	51.35	0.000	0.000	1.8573	.4087	2.2108	2.35600
22.0	.8346	458.48	1005.38	51.34	0.000	0.000	1.8787	.4134	2.2364	2.35600
24.0	.7813	458.61	1005.84	51.34	0.000	0.000	1.8984	.4177	2.2600	2.35600
26.0	.7272	458.75	1006.30	51.34	0.000	0.000	1.9162	.4216	2.2814	2.35600
28.0	.6723	458.89	1006.76	51.33	0.000	0.000	1.9321	.4251	2.3004	2.35600
30.0	.6167	459.03	1007.22	51.33	0.000	0.000	1.9459	.4282	2.3171	2.35600
32.0	.5604	459.17	1007.68	51.33	0.000	0.000	1.9579	.4308	2.3315	2.35600
34.0	.5034	459.31	1008.14	51.32	0.000	0.000	1.9680	.4330	2.3437	2.35600
36.0	.4457	459.44	1008.59	51.32	0.000	0.000	1.9765	.4349	2.3540	2.35600
38.0	.3875	459.58	1009.05	51.32	0.000	0.000	1.9834	.4364	2.3624	2.35600
40.0	.3287	459.71	1009.49	51.31	0.000	0.000	1.9881	.4375	2.3682	2.35600
42.0	.2384	459.85	1009.94	51.31	0.000	0.000	1.9920	.4383	2.3729	2.35600
44.0	.1790	459.98	1010.38	51.31	0.000	0.000	1.9947	.4389	2.3763	2.35600
46.0	.1194	460.11	1010.82	51.30	0.000	0.000	1.9962	.4392	2.3783	2.35600
48.0	.0597	460.24	1011.26	51.30	0.000	0.000	1.9966	.4393	2.3789	2.35600

<u>THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)</u>

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.26 1

TIME = .60006 SECONDS

AXIAL ZONE	W(1, 2)	W(1, 3)	W(1, 4)	W(2, 3)	W(2, 4)	W(3, 4)	W(5, 6)	W(5, 7)	W(6, 7)
0.0 - 2.0	.01955	.02863	.03743	.00994	.01954	.00961	.01258	.02473	.01214
2.0 - 4.0	.02512	.03656	.04789	.01259	.02460	.01222	.01564	.03100	.01537
4.0 - 6.0	.02468	.03607	.04751	.01203	.02404	.01203	.01555	.03104	.01549
6.0 - 8.0	.02225	.03297	.04380	.01102	.02208	.01108	.01507	.03014	.01506
8.0 - 10.0	.01929	.02935	.03951	.01012	.02029	.01019	.01476	.02954	.01478
10.0 - 12.0	.01661	.02615	.03579	.00949	.01901	.00953	.01455	.02910	.01455
12.0 - 14.0	.01451	.02367	.03287	.00904	.01808	.00906	.01431	.02860	.01430
14.0 - 16.0	.01283	.02165	.03051	.00867	.01734	.00868	.01398	.02793	.01395
16.0 - 18.0	.01138	.01984	.02840	.00832	.01664	.00832	.01354	.02705	.01350
18.0 - 20.0	.01009	.01825	.02643	.00796	.01591	.00796	.01299	.02593	.01294
20.0 - 22.0	.00898	.01676	.02456	.00756	.01511	.00755	.01231	.02458	.01227
22.0 - 24.0	.00805	.01546	.02275	.00711	.01420	.00709	.01151	.02299	.01146
24.0 - 26.0	.00731	.01415	.02099	.00660	.01319	.00658	.01061	.02119	.01056
26.0 - 28.0	.00679	.01306	.01933	.00605	.01209	.00603	.00962	.01923	.00960
28.0 - 30.0	.00644	.01204	.01766	.00543	.01085	.00541	.00858	.01716	.00858
30.0 - 32.0	.00602	.01089	.01579	.00475	.00950	.00474	.00754	.01508	.00754
32.0 - 34.0	.00463	.00877	.01299	.00407	.00816	.00409	.00650	.01301	.00650
34.0 - 36.0	-.01942	-.01652	-.01358	.00281	.00559	.00277	.00553	.01107	.00554
36.0 - 38.0	-.17545	-.17286	-.17024	.00255	.00510	.00254	.00477	.00957	.00480
38.0 - 40.0	-.16614	-.16416	-.16210	.00209	.00419	.00208	.00428	.00857	.00429
40.0 - 42.0	-.01671	-.01540	-.01400	.00154	.00307	.00152	.00282	.00567	.00284
42.0 - 44.0	.01092	.01184	.01285	.00113	.00224	.00110	.00199	.00400	.00200
44.0 - 46.0	.01831	.01854	.01946	.00068	.00134	.00064	.00132	.00266	.00134
46.0 - 48.0	.02361	.02360	.02368	.00008	.00013	.00003	.00059	.00120	.00060

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.26.26 1

TIME = .60000 SECONDS TEMPERATURE DATA FOR ROD 1 (FUEL TYPE 1 = CYLINDER)

ROD O.D. = 1.000 (IN.) ZONE=(FUEL DIA.(IN.)) = 1=(.836) 2=(.836) 3=(.836) 4=(0.000)

AXIAL ZONE (IN.)	HEAT FLUX (MBTU/HR-FT2)	TYPE	MODE	HSURF (B/H-F-FT2)	FLUID	CLAD	T(1) (1.000)	T(2) (.667)	T(3) (.333)	T(4) (0.000)
							TEMPERATURES(F.) (RELATIVE RADIUS(R/R))			
0.0 - 2.0	.0001	2	0	11779.2	1099.8	1099.8	1099.8	1099.8	1099.8	1099.8
2.0 - 4.0	.0002	2	0	11861.0	1099.5	1099.5	1099.6	1099.6	1099.6	1099.6
4.0 - 6.0	.0003	2	0	11948.4	1099.3	1099.3	1099.5	1099.6	1099.6	1099.6
6.0 - 8.0	.0021	2	0	12036.1	1099.1	1099.3	1104.9	1107.1	1108.6	1109.2
8.0 - 10.0	.0985	1	0	12121.2	1099.5	1107.5	1300.6	1966.2	2485.1	2678.0
10.0 - 12.0	.1316	1	0	12201.2	1100.2	1110.8	1367.9	2325.4	3097.9	3385.9
12.0 - 14.0	.1643	1	0	12272.5	1101.0	1114.3	1433.9	2697.8	3667.1	4025.6
14.0 - 16.0	.1970	1	0	12341.2	1102.1	1117.9	1500.0	3064.8	4161.1	4553.0
16.0 - 18.0	.2138	1	0	12404.8	1103.2	1120.3	1533.7	3247.0	4380.8	4776.4
18.0 - 20.0	.2144	1	0	12461.4	1104.4	1121.4	1535.0	3250.2	4384.0	4779.4
20.0 - 22.0	.2148	1	0	12510.7	1105.5	1122.5	1536.1	3251.8	4385.1	4780.2
22.0 - 24.0	.2150	1	0	12553.0	1106.6	1123.5	1537.0	3251.9	4384.3	4779.0
24.0 - 26.0	.1989	1	0	12586.5	1107.5	1123.2	1505.3	3072.1	4166.9	4557.6
26.0 - 28.0	.1666	1	0	12617.6	1108.3	1121.4	1441.0	2707.3	3676.8	4034.6
28.0 - 30.0	.1342	1	0	12641.2	1108.8	1119.3	1376.5	2341.9	3111.4	3399.6
30.0 - 32.0	.1009	1	0	12659.8	1109.1	1117.0	1310.2	1979.5	2500.4	2694.0
32.0 - 34.0	.0016	2	0	12673.9	1108.7	1108.9	1114.8	1116.7	1118.5	1119.1
34.0 - 36.0	.0001	2	0	12688.0	1108.4	1108.4	1108.9	1109.0	1109.1	1109.1
36.0 - 38.0	.0003	2	0	12154.3	1108.1	1108.1	1108.5	1108.5	1108.6	1108.6
38.0 - 40.0	0.0000	0.000	0							
40.0 - 42.0	0.0000	0.000	0							
42.0 - 44.0	0.0000	0.000	0							
44.0 - 46.0	0.0000	0.000	0							
46.0 - 48.0	0.0000	0.000	0							

ITERATIONS = 2

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
3	.01000	.322	32.15	.18	32.1689	.6100	.0078
2	.01000	.320	31.94	.18	31.9597	.6200	.0091
4	.01000	.317	31.66	.18	31.6685	.6300	.0077
2	.01000	.313	31.33	.18	31.3433	.6400	.0083
3	.01000	.310	30.94	.18	30.9553	.6500	.0079
2	.01000	.305	30.52	.18	30.5381	.6600	.0092
4	.01000	.300	30.03	.18	30.0419	.6700	.0084
2	.01000	.295	29.53	.18	29.5391	.6800	.0087
4	.01000	.290	28.96	.19	28.9723	.6900	.0090
2	.01000	.284	28.38	.19	28.3982	.7000	.0092
4	.01000	.278	27.74	.20	27.7603	.7100	.0092
2	.01000	.271	27.10	.20	27.1197	.7200	.0092
4	.01000	.264	26.40	.20	26.4216	.7300	.0092
2	.01000	.257	25.70	.20	25.7253	.7400	.0091
4	.01000	.250	24.96	.20	24.9951	.7500	.0090
2	.01000	.243	24.22	.19	24.2634	.7600	.0091
4	.01000	.235	23.46	.18	23.5225	.7700	.0085
2	.01000	.228	22.70	.17	22.7702	.7800	.0090
4	.01000	.220	21.92	.16	22.0164	.7900	.0079
2	.01000	.213	21.15	.16	21.2548	.8000	.0088

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.31 1

TIME = .80000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.1166	486.88	1100.00	50.56	0.000	0.000	.9208	.5282	2.9022	.90370
2.0	1.0496	486.86	1099.94	50.56	0.000	0.000	.9380	.5381	2.9563	.90370
4.0	1.0017	486.83	1099.63	50.56	0.000	0.000	.9533	.5469	3.0046	.90370
6.0	.9529	486.79	1099.70	50.56	0.000	0.000	.9671	.5548	3.0480	.90370
8.0	.9045	486.75	1099.57	50.56	0.000	0.000	.9797	.5620	3.0876	.90370
10.0	.8568	486.99	1100.38	50.55	0.000	0.000	.9913	.5686	3.1245	.90370
12.0	.8097	487.29	1101.38	50.54	0.000	0.000	1.0019	.5747	3.1586	.90370
14.0	.7634	487.65	1102.57	50.53	0.000	0.000	1.0117	.5804	3.1903	.90370
16.0	.7178	488.06	1103.95	50.52	0.000	0.000	1.0210	.5857	3.2202	.90370
18.0	.6731	488.48	1105.35	50.51	0.000	0.000	1.0299	.5908	3.2491	.90370
20.0	.6292	488.87	1106.65	50.50	0.000	0.000	1.0386	.5958	3.2774	.90370
22.0	.5861	489.23	1107.66	50.49	0.000	0.000	1.0474	.6008	3.3059	.90370
24.0	.5438	489.58	1109.02	50.48	0.000	0.000	1.0563	.6060	3.3347	.90370
26.0	.5022	489.87	1109.98	50.47	0.000	0.000	1.0654	.6112	3.3640	.90370
28.0	.4612	490.06	1110.62	50.46	0.000	0.000	1.0748	.6165	3.3939	.90370
30.0	.4207	490.17	1110.99	50.46	0.000	0.000	1.0842	.6219	3.4238	.90370
32.0	.3809	490.20	1111.10	50.46	0.000	0.000	1.0933	.6272	3.4526	.90370
34.0	.3417	489.99	1110.39	50.46	0.000	0.000	1.1037	.6331	3.4851	.90370
36.0	.3023	489.81	1109.78	50.47	0.000	0.000	1.1166	.6405	3.5255	.90370
38.0	.2323	489.63	1109.18	50.47	0.000	0.000	1.1935	.6388	3.5157	.96647
40.0	.2049	489.51	1108.78	50.48	0.000	0.000	1.2681	.5087	2.7993	1.29229
42.0	.1695	489.43	1108.50	50.48	0.000	0.000	1.2893	.5172	2.8460	1.29229
44.0	.1263	489.35	1108.25	50.48	0.000	0.000	1.3010	.5219	2.8717	1.29229
46.0	.0840	489.28	1108.01	50.48	0.000	0.000	1.3102	.5256	2.8918	1.29229
48.0	.0419	489.21	1107.77	50.49	0.000	0.000	1.3176	.5285	2.9080	1.29229

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.26.31 1

TIME = .80000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.1166	486.88	1100.00	50.56	0.000	0.000	2.0918	.4180	2.2968	2.59400
2.0	1.0490	486.75	1099.58	50.56	0.000	0.000	2.1226	.4242	2.3305	2.59400
4.0	1.0013	486.65	1099.22	50.56	0.000	0.000	2.1547	.4306	2.3656	2.59400
6.0	.9529	486.55	1098.91	50.57	0.000	0.000	2.1863	.4369	2.4002	2.59400
8.0	.9047	486.47	1098.65	50.57	0.000	0.000	2.2169	.4430	2.4337	2.59400
10.0	.8570	486.57	1098.96	50.57	0.000	0.000	2.2462	.4489	2.4659	2.59400
12.0	.8100	486.72	1099.46	50.56	0.000	0.000	2.2738	.4544	2.4965	2.59400
14.0	.7636	486.91	1100.11	50.56	0.000	0.000	2.2994	.4595	2.5249	2.59400
16.0	.7191	487.16	1100.93	50.55	0.000	0.000	2.3229	.4642	2.5511	2.59400
18.0	.6734	487.43	1101.63	50.54	0.000	0.000	2.3442	.4665	2.5749	2.59400
20.0	.6295	487.69	1102.72	50.53	0.000	0.000	2.3633	.4723	2.5962	2.59400
22.0	.5863	487.96	1103.60	50.52	0.000	0.000	2.3800	.4756	2.6150	2.59400
24.0	.5440	488.22	1104.49	50.52	0.000	0.000	2.3945	.4785	2.6314	2.59400
26.0	.5024	488.46	1105.29	50.51	0.000	0.000	2.4071	.4811	2.6456	2.59400
28.0	.4614	488.66	1105.93	50.50	0.000	0.000	2.4181	.4832	2.6580	2.59400
30.0	.4209	488.80	1106.41	50.50	0.000	0.000	2.4268	.4850	2.6678	2.59400
32.0	.3811	488.89	1106.72	50.50	0.000	0.000	2.4344	.4865	2.6763	2.59400
34.0	.3417	488.84	1106.54	50.50	0.000	0.000	2.4414	.4879	2.6838	2.59400
36.0	.3023	488.79	1106.36	50.50	0.000	0.000	2.4436	.4884	2.6863	2.59400
38.0	.2343	488.74	1106.20	50.50	0.000	0.000	2.4198	.4642	2.5536	2.70200
40.0	.2042	488.67	1105.97	50.50	0.000	0.000	2.3970	.3832	2.1079	3.24250
42.0	.1681	488.60	1105.76	50.50	0.000	0.000	2.3927	.3825	2.1039	3.24250
44.0	.1261	488.54	1105.55	50.51	0.000	0.000	2.3912	.3823	2.1026	3.24250
46.0	.0840	488.48	1105.34	50.51	0.000	0.000	2.3900	.3821	2.1015	3.24250
48.0	.0420	488.42	1105.14	50.51	0.000	0.000	2.3869	.3819	2.1004	3.24250

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.20.31 1

TIME = .80000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 5

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.1166	456.86	1000.00	51.39	0.000	0.000	.5387	.1295	.7002	2.35600
2.0	1.0649	457.16	1000.99	51.38	0.000	0.000	.6127	.1346	.7289	2.35600
4.0	1.0175	457.37	1001.69	51.37	0.000	0.000	.6363	.1400	.7570	2.35600
6.0	.9697	457.54	1002.27	51.37	0.000	0.000	.6588	.1450	.7838	2.35600
8.0	.9219	457.70	1002.79	51.37	0.000	0.000	.6803	.1497	.8095	2.35600
10.0	.8705	457.84	1003.28	51.36	0.000	0.000	.7009	.1542	.8340	2.35600
12.0	.8276	457.99	1003.75	51.36	0.000	0.000	.7202	.1585	.8571	2.35600
14.0	.7810	458.13	1004.21	51.35	0.000	0.000	.7381	.1624	.8785	2.35600
16.0	.7349	458.26	1004.67	51.35	0.000	0.000	.7546	.1660	.8961	2.35600
18.0	.6893	458.40	1005.12	51.35	0.000	0.000	.7696	.1693	.9161	2.35600
20.0	.6441	458.53	1005.57	51.34	0.000	0.000	.7832	.1723	.9324	2.35600
22.0	.5994	458.67	1006.01	51.34	0.000	0.000	.7955	.1750	.9471	2.35600
24.0	.5550	458.80	1006.46	51.34	0.000	0.000	.8067	.1775	.9604	2.35600
26.0	.5111	458.94	1006.91	51.33	0.000	0.000	.8166	.1797	.9724	2.35600
28.0	.4676	459.07	1007.36	51.33	0.000	0.000	.8256	.1817	.9831	2.35600
30.0	.4245	459.21	1007.81	51.33	0.000	0.000	.8338	.1835	.9929	2.35600
32.0	.3817	459.34	1008.25	51.32	0.000	0.000	.8413	.1851	1.0019	2.35600
34.0	.3391	459.47	1008.70	51.32	0.000	0.000	.8477	.1865	1.0096	2.35600
36.0	.2970	459.61	1009.14	51.32	0.000	0.000	.8537	.1878	1.0169	2.35600
38.0	.2551	459.74	1009.58	51.31	0.000	0.000	.8594	.1891	1.0237	2.35600
40.0	.2132	459.87	1010.02	51.31	0.000	0.000	.8631	.1899	1.0282	2.35600
42.0	.1651	460.00	1010.45	51.30	0.000	0.000	.8651	.1903	1.0306	2.35600
44.0	.1237	460.13	1010.88	51.30	0.000	0.000	.8665	.1907	1.0324	2.35600
46.0	.0824	460.26	1011.32	51.30	0.000	0.000	.8676	.1909	1.0337	2.35600
48.0	.0412	460.39	1011.75	51.29	0.000	0.000	.8681	.1910	1.0344	2.35600

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT).

CASE 1 FUEL THERMAL MODEL TEST DATE 04/21/76 0 TIME 12.20.31 1

TIME = .80000 SECONDS

AXIAL ZONE	W(1, 2)	W(1, 3)	W(1, 4)	W(2, 3)	W(2, 4)	W(3, 4)	W(5, 6)	W(5, 7)	W(6, 7)
0.0 - 2.0	.01264	.02300	.03303	.01168	.02292	.01126	.01413	.02772	.01359
2.0 - 4.0	.01870	.03218	.04553	.01540	.03044	.01509	.01834	.03626	.01794
4.0 - 6.0	.02066	.03460	.04862	.01602	.03180	.01586	.01826	.03639	.01813
6.0 - 8.0	.02139	.03490	.04862	.01550	.03082	.01542	.01675	.03346	.01674
8.0 - 10.0	.02136	.03407	.04707	.01444	.02874	.01441	.01485	.02974	.01491
10.0 - 12.0	.02058	.03229	.04432	.01308	.02606	.01309	.01304	.02612	.01311
12.0 - 14.0	.01917	.02973	.04061	.01155	.02301	.01158	.01143	.02291	.01150
14.0 - 16.0	.01721	.02651	.03612	.00995	.01985	.01000	.01004	.02011	.01009
16.0 - 18.0	.01477	.02278	.03108	.00841	.01677	.00846	.00862	.01766	.00866
18.0 - 20.0	.01197	.01872	.02574	.00699	.01393	.00703	.00774	.01548	.00776
20.0 - 22.0	.00893	.01451	.02033	.00572	.01139	.00575	.00678	.01355	.00679
22.0 - 24.0	.00576	.01029	.01504	.00460	.00915	.00462	.00592	.01183	.00593
24.0 - 26.0	.00274	.00641	.01029	.00369	.00734	.00372	.00513	.01026	.00513
26.0 - 28.0	.00028	.00333	.00655	.00302	.00598	.00302	.00440	.00880	.00441
28.0 - 30.0	-.00223	.00003	.00236	.00216	.00418	.00207	.00381	.00764	.00385
30.0 - 32.0	-.00494	-.00369	-.00232	.00104	.00202	.00102	.00336	.00673	.00336
32.0 - 34.0	-.00520	-.00475	-.00405	.00007	.00024	.00020	.00270	.00531	.00261
34.0 - 36.0	-.01541	-.01897	-.02258	-.00439	-.00899	-.00457	.00189	.00375	.00187
36.0 - 38.0	-.15196	-.15190	-.15176	-.00047	-.00101	-.00051	.00141	.00294	.00153
38.0 - 40.0	-.14715	-.14651	-.14574	-.00001	-.00004	-.00001	-.00027	-.00060	-.00033
40.0 - 42.0	-.03907	-.03955	-.03996	-.00117	-.00238	-.00120	.00030	.00059	.00030
42.0 - 44.0	-.02034	-.02131	-.02220	-.00163	-.00330	-.00167	-.00008	-.00015	-.00006
44.0 - 46.0	-.01577	-.01705	-.01826	-.00180	-.00363	-.00184	-.00047	-.00092	-.00046
46.0 - 48.0	-.01287	-.01426	-.01558	-.00171	-.00344	-.00175	-.00035	-.00070	-.00034

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.31 1

TIME = .80000 SECONDS TEMPERATURE DATA FOR ROD 1 (FUEL TYPE 1 = CYLINDER)

ROD O.D. = 1.000 (IN.) ZONE=(FUEL DIA.(IN.)) = 1=(.836) 2=(.836) 3=(.836) 4=(0.000)

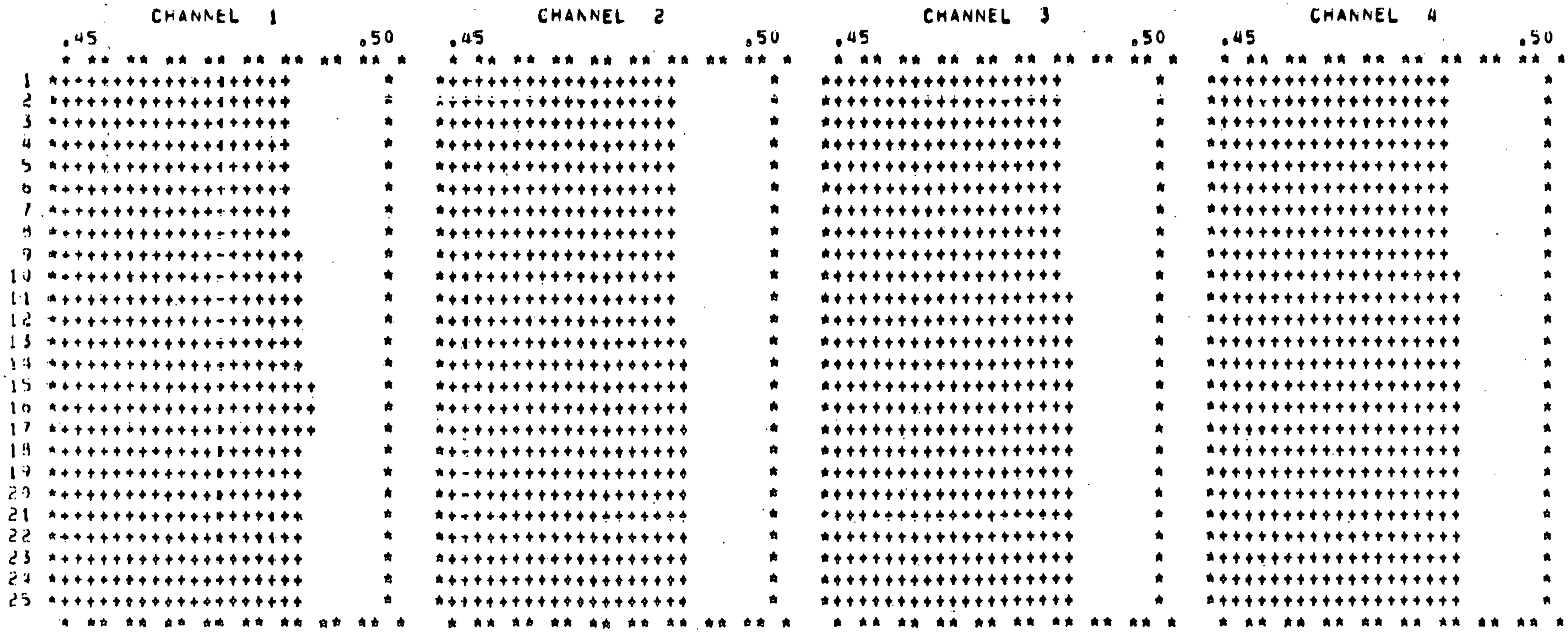
AXIAL ZONE (IN.)	HEAT FLUX (MBTU/HR-FT2)	TYPE	MODE	HSURF (B/H-F-FT2)	*	FLUID	CLAD	TEMPERATURES(F.) (RELATIVE RADIUS(R/R)) T(1) (1.000)	T(2) (.667)	T(3) (.333)	T(4) (0.000)
0.0 - 2.0	.0006	2	0	8052.9		1099.6	1099.7	1099.8	1099.8	1099.8	1099.8
2.0 - 4.0	.0009	2	0	8150.6		1099.3	1099.5	1099.6	1099.6	1099.6	1099.6
4.0 - 6.0	.0012	2	0	8254.5		1099.1	1099.2	1099.5	1099.6	1099.6	1099.6
6.0 - 8.0	.0028	2	0	8357.0		1098.8	1099.2	1104.9	1107.0	1108.6	1109.2
8.0 - 10.0	.0840	1	0	8454.8		1099.4	1109.1	1299.7	1960.3	2480.0	2673.8
10.0 - 12.0	.1114	1	0	8546.0		1100.2	1113.0	1366.9	2321.6	3091.2	3380.6
12.0 - 14.0	.1384	1	0	8627.6		1101.2	1116.9	1432.9	2687.5	3658.9	4019.1
14.0 - 16.0	.1654	1	0	8704.8		1102.4	1120.9	1499.1	3052.6	4151.4	4545.5
16.0 - 18.0	.1789	1	0	8775.5		1103.6	1123.5	1532.8	3234.3	4370.5	4768.4
18.0 - 20.0	.1790	1	0	8839.2		1104.8	1124.5	1534.1	3237.4	4373.6	4771.4
20.0 - 22.0	.1789	1	0	8896.1		1106.0	1125.5	1535.1	3239.1	4374.8	4772.2
22.0 - 24.0	.1788	1	0	8946.4		1107.1	1126.5	1535.9	3239.2	4373.9	4770.9
24.0 - 26.0	.1651	1	0	8990.8		1108.0	1125.8	1504.2	3060.4	4157.3	4550.1
26.0 - 28.0	.1379	1	0	9030.1		1108.7	1123.5	1439.8	2698.1	3668.6	4026.0
28.0 - 30.0	.1107	1	0	9065.1		1109.2	1121.0	1375.2	2334.1	3104.8	3394.2
30.0 - 32.0	.0830	1	0	9093.5		1109.4	1118.2	1309.0	1973.5	2495.3	2689.7
32.0 - 34.0	.0008	2	0	9113.1		1108.9	1109.0	1114.8	1116.9	1118.5	1119.1
34.0 - 36.0	-.0001	2	0	9125.6		1108.4	1108.4	1108.9	1109.0	1109.1	1109.1
36.0 - 38.0	.0003	2	0	8749.0		1108.0	1108.1	1108.5	1108.6	1108.6	1108.6
38.0 - 40.0	0.0000	0.000	0								
40.0 - 42.0	0.0000	0.000	0								
42.0 - 44.0	0.0000	0.000	0								
44.0 - 46.0	0.0000	0.000	0								
46.0 - 48.0	0.0000	0.000	0								

ITERATIONS = 2

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

TIME .8000 SECONDS

ENTHALPY (THOUSAND BTU/LB) AND VOID (TENTHS)



THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

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TIME   .8000 SECONDS
                                             ENTHALPY (THOUSAND BTU/LB) AND VOID (TENTHS)

            CHANNEL  5                      CHANNEL  6                      CHANNEL  7                      CHANNEL
    .45                       .50  .45                       .50  .45                       .50  .45                       .50
    * ** ** ** ** ** ** ** ** *    * ** ** ** ** ** ** ** ** *    * ** ** ** ** ** ** ** ** *    * ** ** ** ** ** ** ** ** *
 1  *+++                      *    *+++                      *    *+++                      *    *                         *
 2  *+++                      *    *+++                      *    *+++                      *    *                         *
 3  *+++                      *    *+++                      *    *+++                      *    *                         *
 4  *+++                      *    *+++                      *    *+++                      *    *                         *
 5  *+++                      *    *+++                      *    *+++                      *    *                         *
 6  *+++                      *    *+++                      *    *+++                      *    *                         *
 7  *+++                      *    *+++                      *    *+++                      *    *                         *
 8  *++++                     *    *++++                     *    *++++                     *    *                         *
 9  *++++                     *    *++++                     *    *++++                     *    *                         *
10  *++++                     *    *++++                     *    *++++                     *    *                         *
11  *++++                     *    *++++                     *    *++++                     *    *                         *
12  *++++                     *    *++++                     *    *++++                     *    *                         *
13  *++++                     *    *++++                     *    *++++                     *    *                         *
14  *++++                     *    *++++                     *    *++++                     *    *                         *
15  *++++                     *    *++++                     *    *++++                     *    *                         *
16  *++++                     *    *++++                     *    *++++                     *    *                         *
17  *++++                     *    *++++                     *    *++++                     *    *                         *
18  *++++                     *    *++++                     *    *++++                     *    *                         *
19  *++++                     *    *++++                     *    *++++                     *    *                         *
20  *++++                     *    *++++                     *    *++++                     *    *                         *
21  *++++                     *    *++++                     *    *++++                     *    *                         *
22  *+++++                    *    *+++++                    *    *+++++                    *    *                         *
23  *+++++                    *    *+++++                    *    *+++++                    *    *                         *
24  *+++++                    *    *+++++                    *    *+++++                    *    *                         *
25  *+++++                    *    *+++++                    *    *+++++                    *    *                         *
    * ** ** ** ** ** ** ** ** *    * ** ** ** ** ** ** ** ** *    * ** ** ** ** ** ** ** ** *    * ** ** ** ** ** ** ** ** *
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THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
4	.01000	.205	20.37	.16	20.4966	.8100	.0071
2	.01000	.197	19.60	.16	19.7342	.8200	.0086
4	.01000	.190	18.83	.15	18.9776	.8300	.0064
2	.01000	.182	18.07	.15	18.2189	.8400	.0083
4	.01000	.175	17.32	.14	17.4678	.8500	.0059
2	.01000	.167	16.57	.14	16.7159	.8600	.0081
4	.01000	.160	15.83	.14	15.9717	.8700	.0057
2	.01000	.152	15.09	.14	15.2266	.8800	.0080
4	.01000	.145	14.36	.13	14.4873	.8900	.0058
2	.01000	.137	13.62	.13	13.7460	.9000	.0082
4	.01000	.130	12.88	.12	13.0060	.9100	.0062
2	.01000	.123	12.14	.12	12.2617	.9200	.0084
4	.01000	.115	11.40	.11	11.5131	.9300	.0067
2	.01000	.108	10.65	.11	10.7570	.9400	.0087
4	.01000	.100	9.89	.12	9.9890	.9500	.0072
2	.01000	.092	9.11	.13	9.2099	.9600	.0090
4	.01000	.084	8.32	.13	8.4109	.9700	.0077
2	.01000	.083	8.32	.14	8.3214	.9800	.0093
4	.01000	.091	9.07	.14	9.0745	.9900	.0082
2	.01000	.099	9.93	.15	9.9346	1.0000	.0096

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.36 1

TIME = 1.00000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.7976	486.88	1100.00	50.56	0.000	0.000	.0382	.0219	.1205	.90370
2.0	.7733	486.85	1099.91	50.56	0.000	0.000	.0624	.0361	.1983	.90370
4.0	.7462	486.82	1099.78	50.56	0.000	0.000	.0850	.0488	.2679	.90370
6.0	.7133	486.77	1099.63	50.56	0.000	0.000	.1047	.0601	.3301	.90370
8.0	.6901	486.73	1099.49	50.56	0.000	0.000	.1231	.0706	.3879	.90370
10.0	.6617	487.06	1100.61	50.55	0.000	0.000	.1404	.0805	.4425	.90370
12.0	.6331	487.45	1101.91	50.54	0.000	0.000	.1568	.0899	.4943	.90370
14.0	.6041	487.89	1103.38	50.53	0.000	0.000	.1723	.0988	.5434	.90370
16.0	.5748	488.39	1105.03	50.51	0.000	0.000	.1869	.1072	.5897	.90370
18.0	.5452	488.88	1106.67	50.50	0.000	0.000	.2008	.1152	.6337	.90370
20.0	.5152	489.31	1108.11	50.48	0.000	0.000	.2140	.1227	.6754	.90370
22.0	.4860	489.70	1109.42	50.47	0.000	0.000	.2265	.1299	.7152	.90370
24.0	.4560	490.07	1110.64	50.46	0.000	0.000	.2386	.1369	.7535	.90370
26.0	.4228	490.35	1111.58	50.45	0.000	0.000	.2503	.1436	.7905	.90370
28.0	.3913	490.51	1112.11	50.45	0.000	0.000	.2616	.1501	.8264	.90370
30.0	.3594	490.57	1112.31	50.45	0.000	0.000	.2727	.1564	.8613	.90370
32.0	.3272	490.54	1112.20	50.45	0.000	0.000	.2831	.1624	.8941	.90370
34.0	.2949	490.19	1111.07	50.46	0.000	0.000	.2913	.1671	.9199	.90370
36.0	.2623	489.94	1110.20	50.47	0.000	0.000	.2831	.1624	.8938	.90370
38.0	.2292	489.67	1109.32	50.47	0.000	0.000	.3294	.1763	.9703	.96047
40.0	.1947	489.52	1108.80	50.48	0.000	0.000	.3716	.1491	.8204	1.29229
42.0	.1560	489.42	1108.49	50.48	0.000	0.000	.3886	.1559	.8578	1.29229
44.0	.1169	489.34	1108.21	50.48	0.000	0.000	.4017	.1611	.8866	1.29229
46.0	.0780	489.26	1107.95	50.49	0.000	0.000	.4137	.1659	.9130	1.29229
48.0	.0390	489.19	1107.70	50.49	0.000	0.000	.4268	.1712	.9419	1.29229

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FULL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.36 1

TIME = 1.00000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.7976	486.88	1100.00	50.56	0.000	0.000	-.2547	-.0509	-.2796	2.59400
2.0	.7727	486.60	1099.06	50.56	0.000	0.000	-.2226	-.0445	-.2444	2.59400
4.0	.7458	486.46	1098.60	50.57	0.000	0.000	-.1878	-.0375	-.2062	2.59400
6.0	.7181	486.36	1098.27	50.57	0.000	0.000	-.1527	-.0305	-.1676	2.59400
8.0	.6900	486.27	1097.96	50.57	0.000	0.000	-.1180	-.0236	-.1295	2.59400
10.0	.6616	486.44	1096.55	50.57	0.000	0.000	-.0840	-.0168	-.0922	2.59400
12.0	.6330	486.65	1099.24	50.56	0.000	0.000	-.0510	-.0102	-.0560	2.59400
14.0	.6040	486.90	1100.08	50.56	0.000	0.000	-.0191	-.0038	-.0210	2.59400
16.0	.5747	487.21	1101.10	50.55	0.000	0.000	.0116	.0023	.0127	2.59400
18.0	.5451	487.52	1102.14	50.54	0.000	0.000	.0410	.0082	.0451	2.59400
20.0	.5153	487.81	1103.11	50.53	0.000	0.000	.0691	.0138	.0760	2.59400
22.0	.4846	488.09	1104.04	50.52	0.000	0.000	.0958	.0191	.1053	2.59400
24.0	.4539	488.37	1104.96	50.51	0.000	0.000	.1209	.0242	.1328	2.59400
26.0	.4227	488.60	1105.74	50.50	0.000	0.000	.1442	.0288	.1585	2.59400
28.0	.3912	488.76	1106.28	50.50	0.000	0.000	.1658	.0331	.1822	2.59400
30.0	.3593	488.86	1106.62	50.50	0.000	0.000	.1851	.0370	.2035	2.59400
32.0	.3272	488.91	1106.79	50.50	0.000	0.000	.2025	.0405	.2227	2.59400
34.0	.2947	488.75	1106.24	50.50	0.000	0.000	.2192	.0438	.2409	2.59400
36.0	.2619	488.65	1105.93	50.50	0.000	0.000	.2403	.0480	.2641	2.59400
38.0	.2283	488.58	1105.67	50.51	0.000	0.000	.2372	.0455	.2503	2.70208
40.0	.1942	488.49	1105.39	50.51	0.000	0.000	.2335	.0373	.2053	3.24250
42.0	.1557	488.43	1105.17	50.51	0.000	0.000	.2370	.0379	.2084	3.24250
44.0	.1169	488.36	1104.96	50.51	0.000	0.000	.2397	.0383	.2107	3.24250
46.0	.0779	488.30	1104.75	50.51	0.000	0.000	.2403	.0384	.2113	3.24250
48.0	.0390	488.24	1104.55	50.52	0.000	0.000	.2383	.0381	.2095	3.24250

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.36 1

TIME = 1.00000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 5

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.7976	456.86	1000.00	51.39	0.000	0.000	-1.3915	-.3062	-1.6558	2.35600
2.0	.7935	457.63	1002.57	51.37	0.000	0.000	-1.3720	-.3019	-1.6327	2.35600
4.0	.7608	457.82	1003.21	51.36	0.000	0.000	-1.3503	-.2971	-1.6070	2.35600
6.0	.7280	457.99	1003.76	51.36	0.000	0.000	-1.3277	-.2921	-1.5802	2.35600
8.0	.6951	458.14	1004.25	51.35	0.000	0.000	-1.3044	-.2870	-1.5526	2.35600
10.0	.6624	458.28	1004.71	51.35	0.000	0.000	-1.2806	-.2818	-1.5244	2.35600
12.0	.6297	458.41	1005.16	51.35	0.000	0.000	-1.2566	-.2765	-1.4959	2.35600
14.0	.5971	458.54	1005.60	51.34	0.000	0.000	-1.2326	-.2712	-1.4674	2.35600
16.0	.5645	458.68	1006.06	51.34	0.000	0.000	-1.2088	-.2660	-1.4392	2.35600
18.0	.5320	458.82	1006.51	51.34	0.000	0.000	-1.1855	-.2608	-1.4115	2.35600
20.0	.4994	458.95	1006.95	51.33	0.000	0.000	-1.1626	-.2558	-1.3844	2.35600
22.0	.4668	459.08	1007.39	51.33	0.000	0.000	-1.1404	-.2509	-1.3580	2.35600
24.0	.4340	459.21	1007.83	51.33	0.000	0.000	-1.1190	-.2462	-1.3326	2.35600
26.0	.4011	459.35	1008.27	51.32	0.000	0.000	-1.0984	-.2417	-1.3082	2.35600
28.0	.3681	459.48	1008.71	51.32	0.000	0.000	-1.0789	-.2374	-1.2851	2.35600
30.0	.3349	459.61	1009.15	51.32	0.000	0.000	-1.0604	-.2333	-1.2632	2.35600
32.0	.3015	459.74	1009.58	51.31	0.000	0.000	-1.0431	-.2295	-1.2426	2.35600
34.0	.2679	459.87	1010.00	51.31	0.000	0.000	-1.0275	-.2261	-1.2241	2.35600
36.0	.2342	460.00	1010.43	51.30	0.000	0.000	-1.0130	-.2229	-1.2069	2.35600
38.0	.2002	460.13	1010.87	51.30	0.000	0.000	-.9997	-.2200	-1.1912	2.35600
40.0	.1659	460.26	1011.31	51.30	0.000	0.000	-.9902	-.2179	-1.1799	2.35600
42.0	.1383	460.43	1011.69	51.29	0.000	0.000	-.9837	-.2165	-1.1725	2.35600
44.0	.1038	460.97	1013.67	51.28	0.000	0.000	-.9782	-.2152	-1.1677	2.35600
46.0	.0693	463.78	1023.04	51.20	0.000	0.000	-.9681	-.2130	-1.1642	2.35600
48.0	.0349	477.29	1069.05	50.83	0.000	0.000	-.9466	-.2083	-1.1630	2.35600

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 FUEL THERMAL MODEL TEST DATE 04/21/76 0 TIME 12.26.36 1

TIME = 1.00000 SECONDS

AXIAL ZONE	W(1, 2)	W(1, 3)	W(1, 4)	W(2, 3)	W(2, 4)	W(3, 4)	W(5, 6)	W(5, 7)	W(6, 7)
0.0 - 2.0	.00263	.01262	.02230	.01200	.02348	.01151	.01567	.03074	.01509
2.0 - 4.0	.01176	.02536	.03896	.01600	.03161	.01570	.01727	.03415	.01692
4.0 - 6.0	.01601	.03049	.04527	.01689	.03358	.01682	.01726	.03435	.01714
6.0 - 8.0	.01750	.03229	.04723	.01710	.03378	.01683	.01662	.03324	.01666
8.0 - 10.0	.01819	.03263	.04739	.01656	.03280	.01641	.01585	.03180	.01599
10.0 - 12.0	.01828	.03228	.04666	.01584	.03141	.01574	.01515	.03038	.01527
12.0 - 14.0	.01808	.03155	.04541	.01496	.02969	.01490	.01455	.02898	.01447
14.0 - 16.0	.01770	.03054	.04377	.01393	.02769	.01392	.01404	.02804	.01403
16.0 - 18.0	.01715	.02926	.04175	.01282	.02551	.01284	.01357	.02711	.01357
18.0 - 20.0	.01642	.02769	.03932	.01165	.02321	.01169	.01311	.02619	.01311
20.0 - 22.0	.01541	.02576	.03645	.01046	.02087	.01052	.01264	.02525	.01263
22.0 - 24.0	.01409	.02344	.03311	.00928	.01854	.00935	.01213	.02424	.01212
24.0 - 26.0	.01251	.02086	.02950	.00818	.01634	.00825	.01156	.02312	.01157
26.0 - 28.0	.01079	.01815	.02577	.00715	.01426	.00719	.01093	.02189	.01096
28.0 - 30.0	.00871	.01499	.02146	.00600	.01193	.00600	.01029	.02060	.01032
30.0 - 32.0	.00696	.01198	.01721	.00465	.00927	.00468	.00958	.01806	.00929
32.0 - 34.0	.00988	.01314	.01661	.00266	.00533	.00272	.00843	.01684	.00842
34.0 - 36.0	.04148	.04056	.03974	-.00226	-.00466	-.00237	.00709	.01416	.00707
36.0 - 38.0	-.07619	-.07274	-.06920	.00299	.00587	.00291	.00596	.01200	.00604
38.0 - 40.0	-.07094	-.06745	-.06385	.00305	.00601	.00299	.00379	.00745	.00367
40.0 - 42.0	-.02152	-.02062	-.01843	.00097	.00187	.00092	.00432	.00862	.00431
42.0 - 44.0	-.01658	-.01600	-.01536	-.00009	-.00025	-.00014	.00284	.00570	.00285
44.0 - 46.0	-.01736	-.01759	-.01775	-.00095	-.00194	-.00100	.00131	.00257	.00126
46.0 - 48.0	-.02248	-.02361	-.02469	-.00183	-.00370	-.00188	.00062	.00125	.00063

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.36 1

TIME = 1.00000 SECONDS TEMPERATURE DATA FOR ROD 1 (FUEL TYPE 1 = CYLINDER)

ROD O.D. = 1.000 (IN.) ZONE=(FUEL DIA.(IN.)) = 1=(.836) 2=(.836) 3=(.836) 4=(0.000)

AXIAL ZONE (IN.)	HEAT FLUX (MBTU/HR-FT2)	TYPE	MODE	HSURF (B/H-F-FT2)	*	FLUID	CLAD	TEMPERATURES(F.) (RELATIVE RADIUS(R/R)) T(1) (1.000)	T(2) (.667)	T(3) (.333)	T(4) (0.000)
0.0 - 2.0	.0003	2	0	583.1		1099.2	1099.6	1099.8	1099.8	1099.8	1099.8
2.0 - 4.0	.0005	2	0	435.7		1098.8	1099.3	1099.6	1099.6	1099.6	1099.6
4.0 - 6.0	.0007	2	0	501.2		1098.5	1099.1	1099.5	1099.6	1099.6	1099.6
6.0 - 8.0	.0012	2	0	730.3		1098.2	1099.1	1104.9	1107.0	1108.6	1109.2
8.0 - 10.0	.0242	1	0	926.7		1099.2	1114.2	1300.8	1954.1	2475.0	2670.1
10.0 - 12.0	.0342	1	0	1102.2		1100.3	1119.7	1368.7	2313.4	3084.8	3375.9
12.0 - 14.0	.0453	1	0	1261.2		1101.6	1125.3	1435.4	2677.2	3651.0	4013.7
14.0 - 16.0	.0565	1	0	1406.7		1103.0	1131.1	1502.4	3040.2	4142.1	4539.3
16.0 - 18.0	.0639	1	0	1540.0		1104.5	1134.5	1536.6	3220.9	4360.5	4761.8
18.0 - 20.0	.0665	1	0	1662.0		1105.8	1135.5	1537.9	3224.0	4363.6	4764.8
20.0 - 22.0	.0683	1	0	1773.6		1107.0	1136.5	1538.9	3225.6	4364.7	4765.6
22.0 - 24.0	.0709	1	0	1875.1		1108.1	1137.4	1539.7	3225.7	4363.9	4764.3
24.0 - 26.0	.0672	1	0	1967.0		1109.0	1135.9	1507.5	3048.0	4147.9	4543.9
26.0 - 28.0	.0575	1	0	2049.8		1109.6	1131.9	1442.3	2667.8	3660.7	4022.6
28.0 - 30.0	.0472	1	0	2123.7		1109.6	1127.8	1377.0	2325.9	3098.3	3369.6
30.0 - 32.0	.0361	1	0	2187.4		1109.8	1123.3	1310.1	1967.3	2490.3	2686.1
32.0 - 34.0	.0007	2	0	2238.7		1108.8	1109.1	1114.8	1116.9	1118.5	1119.1
34.0 - 36.0	.0006	2	0	2270.6		1108.2	1108.4	1108.9	1109.0	1109.1	1109.1
36.0 - 38.0	.0009	2	0	2211.5		1107.6	1108.0	1108.5	1108.5	1108.6	1108.6
38.0 - 40.0	0.0000	0.000	0								
40.0 - 42.0	0.0000	0.000	0								
42.0 - 44.0	0.0000	0.000	0								
44.0 - 46.0	0.0000	0.000	0								
46.0 - 48.0	0.0000	0.000	0								

ITERATIONS = 2

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
4	.01000	.107	10.68	.16	10.6800	1.0100	.0085

NUMBER OF TIME STEPS = 102
TOTAL ITERATIONS = 254
ITERATIONS/TIME STEP = 2

CHANNEL RESULTS
CASE 1 FUEL THERMAL MODEL TEST DATE 04/21/76 0 TIME 12.26.37 1

TIME = 1.01060 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.7816	486.88	1100.00	50.56	0.000	0.000	-.0124	-.0071	-.0390	.90370
2.0	.7521	486.85	1099.91	50.56	0.000	0.000	.0081	.0047	.0256	.90370
4.0	.7246	486.81	1099.78	50.56	0.000	0.000	.0292	.0167	.0919	.90370
6.0	.6976	486.77	1099.63	50.56	0.000	0.000	.0492	.0282	.1550	.90370
8.0	.6704	486.73	1099.49	50.56	0.000	0.000	.0681	.0390	.2145	.90370
10.0	.6428	487.07	1100.62	50.55	0.000	0.000	.0859	.0493	.2708	.90370
12.0	.6149	487.45	1101.91	50.54	0.000	0.000	.1028	.0590	.3243	.90370
14.0	.5866	487.89	1103.38	50.53	0.000	0.000	.1189	.0682	.3749	.90370
16.0	.5580	488.39	1105.04	50.51	0.000	0.000	.1341	.0769	.4230	.90370
18.0	.5291	488.86	1106.68	50.50	0.000	0.000	.1485	.0852	.4687	.90370
20.0	.4998	489.31	1108.13	50.48	0.000	0.000	.1623	.0931	.5122	.90370
22.0	.4702	489.71	1109.45	50.47	0.000	0.000	.1754	.1006	.5538	.90370
24.0	.4403	490.08	1110.67	50.46	0.000	0.000	.1881	.1079	.5939	.90370
26.0	.4100	490.36	1111.62	50.45	0.000	0.000	.2003	.1149	.6320	.90370
28.0	.3795	490.52	1112.15	50.45	0.000	0.000	.2121	.1217	.6701	.90370
30.0	.3487	490.58	1112.35	50.45	0.000	0.000	.2237	.1283	.7066	.90370
32.0	.3175	490.55	1112.24	50.45	0.000	0.000	.2346	.1346	.7411	.90370
34.0	.2861	490.20	1111.09	50.46	0.000	0.000	.2429	.1393	.7671	.90370
36.0	.2548	489.94	1110.22	50.46	0.000	0.000	.2344	.1345	.7402	.90370
38.0	.2225	489.67	1109.31	50.47	0.000	0.000	.2794	.1495	.8230	.96847
40.0	.1899	489.52	1108.80	50.48	0.000	0.000	.3194	[illegible]	.7052	1.29229
42.0	.1520	489.42	1108.49	50.48	0.000	0.000	.3360	.1348	.7418	1.29229
44.0	.1139	489.34	1108.21	50.48	0.000	0.000	.3492	.1401	.7708	1.29229
46.0	.0760	489.26	1107.95	50.49	0.000	0.000	.3613	.1449	.7974	1.29229
48.0	.0379	489.18	1107.70	50.49	0.000	0.000	.3745	.1502	.8265	1.29229

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.37 1

TIME = 1.01000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.7816	486.38	1100.00	50.56	0.000	0.000	-.3995	-.0798	-.4386	2.59400
2.0	.7527	486.58	1098.99	50.57	0.000	0.000	-.3757	-.0751	-.4124	2.59400
4.0	.7249	486.44	1098.54	50.57	0.000	0.000	-.3436	-.0667	-.3772	2.59400
6.0	.6977	486.34	1098.21	50.57	0.000	0.000	-.3082	-.0616	-.3383	2.59400
8.0	.6704	486.26	1097.93	50.57	0.000	0.000	-.2723	-.0544	-.2989	2.59400
10.0	.6427	486.44	1099.53	50.57	0.000	0.000	-.2368	-.0473	-.2600	2.59400
12.0	.6148	486.65	1099.23	50.56	0.000	0.000	-.2023	-.0404	-.2221	2.59400
14.0	.5865	486.91	1100.09	50.56	0.000	0.000	-.1689	-.0338	-.1855	2.59400
16.0	.5579	487.21	1101.11	50.55	0.000	0.000	-.1366	-.0273	-.1500	2.59400
18.0	.5290	487.52	1102.15	50.54	0.000	0.000	-.1055	-.0211	-.1159	2.59400
20.0	.4997	487.81	1103.11	50.53	0.000	0.000	-.0756	-.0151	-.0833	2.59400
22.0	.4701	488.09	1104.04	50.52	0.000	0.000	-.0475	-.0095	-.0522	2.59400
24.0	.4402	488.37	1104.96	50.51	0.000	0.000	-.0209	-.0042	-.0229	2.59400
26.0	.4100	488.60	1105.73	50.50	0.000	0.000	.0040	.0008	.0044	2.59400
28.0	.3794	488.76	1105.27	50.50	0.000	0.000	.0269	.0054	.0296	2.59400
30.0	.3486	488.86	1105.61	50.50	0.000	0.000	.0478	.0096	.0525	2.59400
32.0	.3174	488.91	1105.76	50.50	0.000	0.000	.0665	.0133	.0731	2.59400
34.0	.2860	488.74	1105.20	50.50	0.000	0.000	.0839	.0168	.0923	2.59400
36.0	.2545	488.64	1105.88	50.50	0.000	0.000	.1066	.0213	.1172	2.59400
38.0	.2225	488.57	1105.63	50.51	0.000	0.000	.1054	.0202	.1112	2.70200
40.0	.1893	488.48	1105.35	50.51	0.000	0.000	.1033	.0165	.0909	3.24250
42.0	.1517	488.42	1105.14	50.51	0.000	0.000	.1078	.0172	.0947	3.24250
44.0	.1139	488.35	1104.92	50.51	0.000	0.000	.1109	.0177	.0975	3.24250
46.0	.0759	488.29	1104.71	50.51	0.000	0.000	.1119	.0179	.0983	3.24250
48.0	.0380	488.23	1104.51	50.52	0.000	0.000	.1098	.0176	.0966	3.24250

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CHANNEL RESULTS
CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.37 1

TIME = 1.01000 SECONDS PRESSURE = 15.0 PSIA DATA FOR CHANNEL 5

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.7816	456.86	1000.00	51.39	0.000	0.000	-1.4959	-.3292	-1.7800	2.35600
2.0	.7792	457.67	1002.71	51.37	0.000	0.000	-1.4822	-.3261	-1.7639	2.35600
4.0	.7456	457.86	1003.34	51.36	0.000	0.000	-1.4633	-.3220	-1.7415	2.35600
6.0	.7127	458.03	1003.68	51.36	0.000	0.000	-1.4418	-.3172	-1.7160	2.35600
8.0	.6800	458.17	1004.37	51.35	0.000	0.000	-1.4190	-.3122	-1.6891	2.35600
10.0	.6475	458.31	1004.83	51.35	0.000	0.000	-1.3957	-.3071	-1.6614	2.35600
12.0	.6150	458.45	1005.28	51.35	0.000	0.000	-1.3721	-.3019	-1.6335	2.35600
14.0	.5825	458.58	1005.72	51.34	0.000	0.000	-1.3485	-.2967	-1.6055	2.35600
16.0	.5501	458.71	1006.17	51.34	0.000	0.000	-1.3252	-.2916	-1.5778	2.35600
18.0	.5178	458.85	1006.62	51.34	0.000	0.000	-1.3021	-.2865	-1.5504	2.35600
20.0	.4854	458.98	1007.06	51.33	0.000	0.000	-1.2794	-.2815	-1.5235	2.35600
22.0	.4531	459.12	1007.51	51.33	0.000	0.000	-1.2574	-.2767	-1.4973	2.35600
24.0	.4207	459.25	1007.95	51.32	0.000	0.000	-1.2359	-.2720	-1.4719	2.35600
26.0	.3883	459.38	1008.38	51.32	0.000	0.000	-1.2154	-.2674	-1.4475	2.35600
28.0	.3558	459.51	1008.82	51.32	0.000	0.000	-1.1958	-.2631	-1.4243	2.35600
30.0	.3232	459.64	1009.25	51.31	0.000	0.000	-1.1773	-.2590	-1.4023	2.35600
32.0	.2905	459.77	1009.68	51.31	0.000	0.000	-1.1598	-.2552	-1.3816	2.35600
34.0	.2578	459.90	1010.11	51.31	0.000	0.000	-1.1433	-.2516	-1.3620	2.35600
36.0	.2247	460.03	1010.54	51.30	0.000	0.000	-1.1286	-.2483	-1.3446	2.35600
38.0	.1916	460.16	1010.98	51.30	0.000	0.000	-1.1162	-.2456	-1.3300	2.35600
40.0	.1585	460.30	1011.44	51.30	0.000	0.000	-1.1065	-.2435	-1.3185	2.35600
42.0	.1343	460.52	1012.16	51.29	0.000	0.000	-1.0997	-.2420	-1.3110	2.35600
44.0	.1007	461.29	1014.75	51.27	0.000	0.000	-1.0929	-.2405	-1.3055	2.35600
46.0	.0672	464.88	1026.67	51.17	0.000	0.000	-1.0811	-.2379	-1.3021	2.35600
48.0	.0337	480.32	1078.14	50.75	0.000	0.000	-1.0591	-.2330	-1.3012	2.35600

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 FUEL THERMAL MODEL TEST DATE 04/21/76 0 TIME 12.26.37 1

TIME = 1.01000 SECONDS

AXIAL ZONE	W(1, 2)	W(1, 3)	W(1, 4)	W(2, 3)	W(2, 4)	W(3, 4)	W(5, 6)	W(5, 7)	W(6, 7)
0.0 - 2.0	-.00458	.00349	.01132	.01017	.01985	.00973	.01379	.02696	.01320
2.0 - 4.0	.00803	.02035	.03261	.01478	.02909	.01440	.01548	.03043	.01499
4.0 - 6.0	.01542	.02956	.04388	.01659	.03283	.01637	.01613	.03192	.01583
6.0 - 8.0	.01826	.03323	.04828	.01731	.03409	.01694	.01594	.03175	.01585
8.0 - 10.0	.01950	.03413	.04925	.01698	.03359	.01677	.01539	.03079	.01544
10.0 - 12.0	.01959	.03387	.04871	.01634	.03238	.01622	.01478	.02958	.01484
12.0 - 14.0	.01913	.03315	.04756	.01552	.03080	.01546	.01424	.02834	.01414
14.0 - 16.0	.01877	.03215	.04596	.01448	.02883	.01450	.01378	.02752	.01377
16.0 - 18.0	.01624	.03092	.04400	.01340	.02668	.01343	.01337	.02671	.01337
18.0 - 20.0	.01752	.02939	.04163	.01224	.02440	.01229	.01297	.02591	.01296
20.0 - 22.0	.01654	.02748	.03878	.01106	.02207	.01113	.01255	.02507	.01254
22.0 - 24.0	.01523	.02518	.03546	.00988	.01973	.00995	.01210	.02418	.01210
24.0 - 26.0	.01364	.02256	.03179	.00875	.01748	.00881	.01160	.02320	.01161
26.0 - 28.0	.01180	.01969	.02784	.00766	.01529	.00770	.01102	.02205	.01105
28.0 - 30.0	.00973	.01654	.02357	.00652	.01300	.00654	.01036	.02070	.01035
30.0 - 32.0	.00814	.01372	.01951	.00520	.01035	.00522	.00961	.01893	.00934
32.0 - 34.0	.01572	.01432	.01809	.00298	.00592	.00299	.00872	.01754	.00882
34.0 - 36.0	.04361	.04313	.04274	-.00190	-.00391	-.00198	.00761	.01515	.00755
36.0 - 38.0	-.07145	-.06759	-.06364	.00341	.00671	.00334	.00574	.01136	.00563
38.0 - 40.0	-.06519	-.06136	-.05743	.00338	.00668	.00332	.00388	.00769	.00381
40.0 - 42.0	-.01988	-.01813	-.01629	.00121	.00234	.00115	.00448	.00693	.00445
42.0 - 44.0	-.01598	-.01522	-.01439	.00008	.00010	.00003	.00290	.00584	.00294
44.0 - 46.0	-.01710	-.01720	-.01723	-.00083	-.00171	-.00068	.00155	.00312	.00157
46.0 - 48.0	-.02250	-.02356	-.02455	-.00177	-.00359	-.00182	.00060	.00121	.00061

THERMAL MODEL SAMPLE PROBLEM RESULTS (Continued)

CASE 1 FUEL THEMAL MODEL TEST DATE 04/21/76 0 TIME 12.28.37 1

TIME = 1.01000 SECONDS TEMPERATURE DATA FOR ROD 1 (FUEL TYPE 1 = CYLINDER)

ROD O.D. = 1.000 (IN.) ZONE=(FUEL DIA.(IN.)) = 1=(.836) 2=(.836) 3=(.836) 4=(0.000)

AXIAL ZONE (IN.)	HEAT FLUX (MBTU/HR-FT2)	TYPE	MODE	HSURF (B/H-F-FT2)	*	FLUID	CLAD	TEMPERATURES(F.) (RELATIVE RADIUS(R/R)) T(1) (1.000)	T(2) (.667)	T(3) (.333)	T(4) (0.000)
0.0 - 2.0	.0002	2	0	1157.4		1099.2	1099.6	1099.8	1099.8	1099.8	1099.8
2.0 - 4.0	.0002	2	0	1058.9		1098.8	1099.3	1099.6	1099.6	1099.6	1099.6
4.0 - 6.0	.0003	2	0	942.1		1098.5	1099.1	1099.5	1099.6	1099.6	1099.6
6.0 - 8.0	.0006	2	0	812.8		1098.2	1099.1	1104.9	1107.0	1108.6	1109.2
8.0 - 10.0	.0144	1	0	670.4		1099.2	1114.8	1301.0	1953.8	2474.8	2670.0
10.0 - 12.0	.0223	1	0	505.2		1100.3	1120.5	1369.0	2313.0	3084.4	3375.8
12.0 - 14.0	.0311	1	0	466.4		1101.6	1126.2	1435.8	2676.7	3650.6	4013.5
14.0 - 16.0	.0409	1	0	686.3		1103.0	1132.1	1502.9	3039.5	4141.6	4539.1
16.0 - 18.0	.0479	1	0	862.7		1104.5	1135.6	1537.1	3220.1	4360.0	4761.6
18.0 - 20.0	.0513	1	0	1016.9		1105.8	1136.6	1538.4	3223.3	4363.1	4764.6
20.0 - 22.0	.0543	1	0	1154.2		1107.0	1137.6	1539.4	3224.9	4364.3	4765.4
22.0 - 24.0	.0570	1	0	1277.4		1108.1	1138.5	1540.2	3225.0	4363.4	4764.1
24.0 - 26.0	.0549	1	0	1387.9		1109.0	1136.9	1508.0	3047.3	4147.5	4543.6
26.0 - 28.0	.0475	1	0	1486.8		1109.6	1132.7	1442.7	2687.3	3660.3	4022.4
28.0 - 30.0	.0395	1	0	1573.5		1109.8	1128.4	1377.2	2325.5	3098.0	3389.4
30.0 - 32.0	.0305	1	0	1649.5		1109.8	1123.8	1310.3	1967.0	2490.1	2685.9
32.0 - 34.0	.0007	2	0	1712.0		1108.8	1109.1	1114.8	1116.9	1118.5	1119.1
34.0 - 36.0	.0005	2	0	1751.9		1108.1	1108.4	1108.9	1109.0	1109.1	1109.1
36.0 - 38.0	.0008	2	0	1719.6		1107.6	1108.0	1108.5	1108.5	1108.6	1108.6
38.0 - 40.0	0.0000	0.000	0								
40.0 - 42.0	0.0000	0.000	0								
42.0 - 44.0	0.0000	0.000	0								
44.0 - 46.0	0.0000	0.000	0								
46.0 - 48.0	0.0000	0.000	0								

ITERATIONS = 4

INPUT TRANSIENT TIME COMPLETED

COMMON DUMPED TO TAPE 8

DAMPED U-TUBE MANOMETER OSCILLATION

One of the most important new capabilities of COBRA-IV is that of considering density gradients approaching steam-water interface conditions. The modeling of a U-tube oscillation is an ideal way to demonstrate this capability. The model also employs the code's new ability to arbitrarily block lateral flows in transient calculations.

The geometry chosen for the U-tube is illustrated in Figure G-3. The flow area of 36 square inches, the 6-inch gap and the axial node length of 3 inches were chosen to provide the same area for lateral flow as for axial flow and thus a uniform velocity all the way around the "U". All gaps except the first two are closed via input. The only damping present consists of a drag coefficient of 2.0 placed at the 14.4-inch level in channel 1. One channel is initially filled with saturated liquid and the other with saturated vapor at 60 psia. The calculation is carried out to 4.0 seconds which allows two full oscillations (natural period is 1.92 seconds.)

The intermediate output for this problem shows "surface level" in addition to the normal transient output. This is a post-calculated quantity which is determined by integrating the previously calculated density and is not used elsewhere in the code. Refer to the channel results page for the actual density gradient calculated.

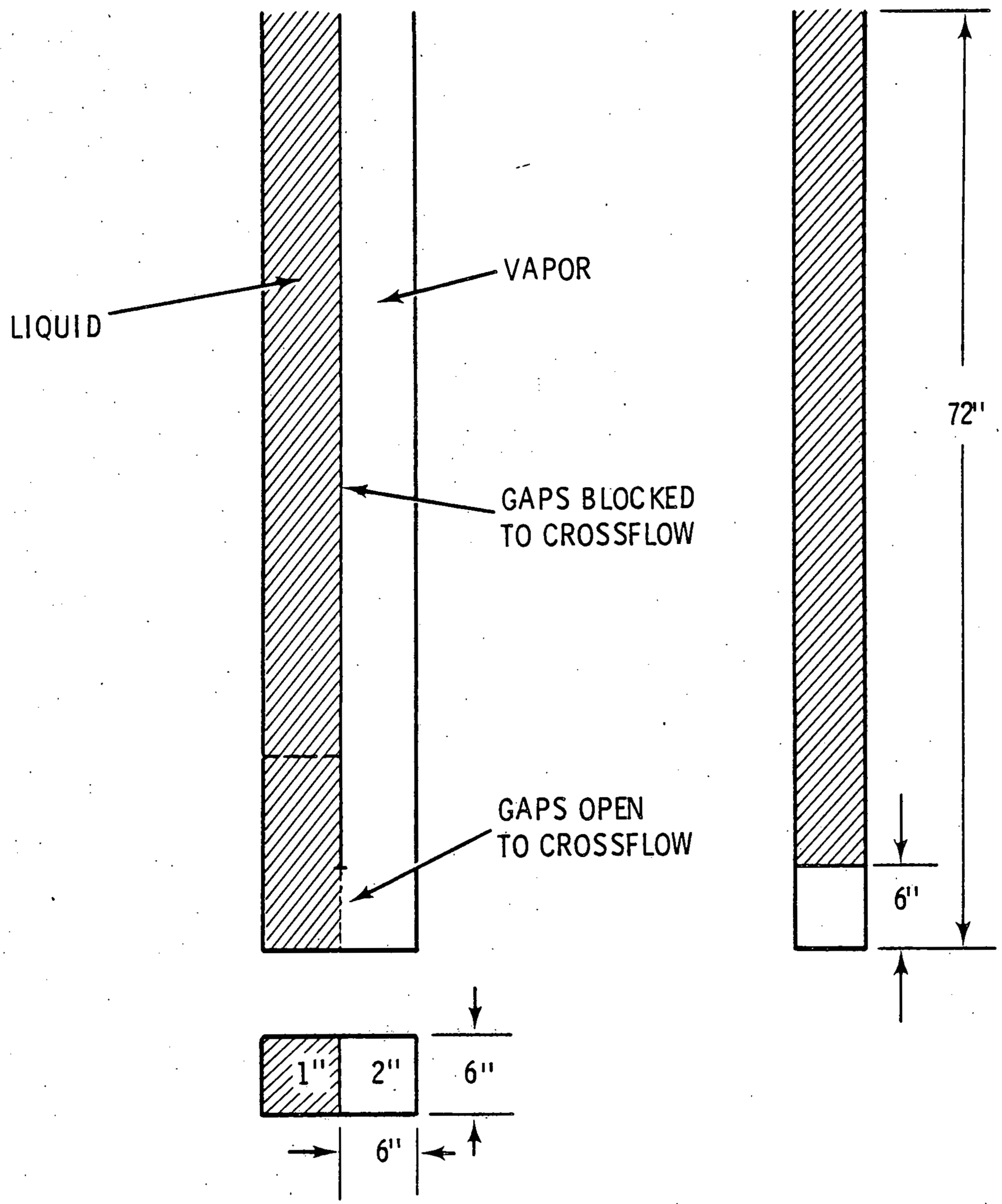

FIGURE G-3. U-Tube Manometer Model

DAMPED U-TUBE MONOMETER OSCILLATION SAMPLE PROBLEM INPUT

```
  500
    1             ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION
    1    20        1
.1780   50.       .01602      1704.8      18.054      1083.4      3.15       .336
.2561   60.       .01603      1207.6      28.060      1087.7      2.68       .342
.3629   70.       .01605       868.4      38.052      1092.1      2.32       .346
.5068   80.       .01607       633.3      48.037      1096.4      2.05       .353
.6981   90.       .01610       468.1      58.018      1100.8      1.851      .358
.9492  100.       .01613       350.4      67.999      1105.1      1.643      .362
1.693  120.       .01620       230.3      87.97       1113.6      1.321      .370
2.889  140.       .01629       123.0     107.95       1122.0      1.110      .378
4.741  160.       .01640        77.29    127.96       1130.2       .949      .383
7.511  180.       .01651        50.22    148.00       1138.2       .770      .388
11.53  200.       .01664        33.64    168.09       1146.0       .720      .391
24.97  240.       .01693        16.32    208.45       1160.6       .579      .396
  50.281.0   0.017274      8.5140       250.2      1174.1      0.491      0.3959    0.003012
 100.327.8   0.017740      4.4310       298.5      1187.2      0.410      0.3936    0.002606
 150.358.4   0.01809       3.0139       330.6      1194.1      0.369      0.3893    0.002350
 200.381.8   0.01839       2.2873       355.5      1198.3      0.345      0.3852    0.00209
 250.401.0   0.01865       1.8432       376.1      1201.1      0.326      0.3806    0.00193
 300.417.4   0.01889       1.5427       394.0      1202.9      0.313      0.3760    0.00180
 350.431.7   0.01912       1.3255       409.8      1204.0      0.301      0.3718    0.00168
 400.444.6   0.01934       1.1610       424.2      1204.6      0.290      0.3682    0.00158
    2

    3    2
   0.    1.    1.    1.
    4    2     2
    1   36.   24.   24.     2     6.
    2   36.   24.   24.
    8    1     1
    1    1.    1.     1    1.
    9    0    30      4           3
  72.    2.    0.    0.    0.1.E-9    1.
   24  400
   .2 .005.0005          .1   20.    1.    0.
  200    0     1      4
   0.  .001   .5   .02  10.  .025
   11    2
         50.      1174.         0.          0.        1174.
250.21174.
   12    1
```

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT

INPUT FOR CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.06 1

SUMMARY OF INPUT OPTIONS

GROUP	N1	N2	N3	N4	N5	N6	N7	N8	N9
1	20	1	-0	-0	-0	-0	-0	-0	-0
2	-0	-0	-0	-0	-0	-0	-0	-0	-0
3	2	-0	-0	-0	-0	-0	-0	-0	-0
4	2	2	-0	-0	-0	-0	-0	-0	-0
8	1	1	-0	-0	-0	-0	-0	-0	-0
9	0	30	4	-0	3	-0	-0	-0	-0
11	2	-0	-0	-0	-0	-0	-0	-0	-0
12	1	-0	-0	-0	-0	-0	-0	-0	-0

FLUID PROPERTY TABLE

P	T	VF	VG	HF	HG	VISC.	KF	SIGMA
.2	50.00	.01602	1704.80000	18.05	1083.40	3.15000	.33600	-0.00000
.3	60.00	.01603	1207.60000	28.06	1087.70	2.68000	.34200	-0.00000
.4	70.00	.01605	868.40000	38.05	1092.10	2.32000	.34600	-0.00000
.5	80.00	.01607	633.30000	48.04	1096.40	2.05000	.35300	-0.00000
.7	90.00	.01610	468.10000	58.02	1100.80	1.85100	.35800	-0.00000
.9	100.00	.01613	350.40000	68.00	1105.10	1.64300	.36200	-0.00000
1.7	120.00	.01620	230.30000	87.97	1113.60	1.32100	.37000	-0.00000
2.9	140.00	.01629	123.00000	107.95	1122.00	1.11000	.37800	-0.00000
4.7	160.00	.01640	77.29000	127.96	1130.20	.94900	.38300	-0.00000
7.5	180.00	.01651	50.22000	148.00	1138.20	.77000	.38800	-0.00000
11.5	200.00	.01664	33.61000	168.09	1146.00	.72000	.39100	-0.00000
25.0	240.00	.01693	16.32000	208.45	1160.60	.57900	.39600	-0.00000
50.0	281.00	.01727	8.51400	250.20	1174.10	.49100	.39570	.00301
100.0	327.80	.01774	4.43100	298.50	1187.20	.41000	.39360	.00261
150.0	355.40	.01809	3.01390	330.60	1194.10	.36900	.38930	.00235
200.0	381.80	.01839	2.28730	355.50	1198.30	.34500	.38520	.00209
250.0	401.00	.01865	1.84320	376.10	1201.10	.32600	.38060	.00193
300.0	417.40	.01889	1.54270	394.00	1202.90	.31300	.37600	.00180
350.0	431.70	.01912	1.32550	409.80	1204.00	.30100	.37180	.00168
400.0	444.60	.01934	1.16100	424.20	1204.60	.29000	.36820	.00158

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

SUPERHEATED STEAM PROPERTIES AT 50.00 PSI

T DEG F	H BTU/LBM	CP BTU/LBM-R	V CU FT/LBM	VISC LBM/FT-HR	K BTU/HR-FT-F	PR
281.0	1174.0	.537	8.5153	.0326	.0166	1.06
304.9	1186.9	.526	8.8380	.0340	.0171	1.04
328.6	1199.3	.509	9.1534	.0353	.0176	1.02
352.7	1211.5	.496	9.4634	.0367	.0183	1.00
424.4	1247.0	.487	10.3719	.0407	.0204	.97
496.1	1282.0	.486	11.2611	.0447	.0227	.96
567.8	1316.8	.487	12.1397	.0487	.0251	.95
639.5	1351.7	.490	13.0117	.0527	.0276	.94
711.2	1386.9	.495	13.8795	.0567	.0303	.93
782.9	1422.4	.500	14.7444	.0606	.0331	.92
854.6	1458.2	.505	15.6073	.0645	.0359	.91
926.4	1494.5	.511	16.4686	.0685	.0388	.90
998.1	1531.1	.517	17.3288	.0724	.0418	.90
1069.8	1566.2	.524	18.1881	.0763	.0449	.89
1141.5	1605.8	.530	19.0467	.0802	.0480	.89
1213.2	1643.8	.536	19.9047	.0841	.0511	.88
1284.9	1682.2	.543	20.7623	.0880	.0543	.88
1356.5	1721.1	.549	21.6195	.0920	.0575	.88
1428.3	1760.5	.556	22.4764	.0959	.0606	.88
1500.0	1800.4	.556	23.3330	.0998	.0638	.87

FRICTION FACTOR CORRELATION
WALL VISCOCITY CORRECTION TO FRICTION FACTOR IS NOT INCLUDED

SINGLE PHASE HEAT TRANSFER CORRELATION
HFILM = K/D(.023*RE**(.800)*PR**(.400) + 0.000)

TWO-PHASE FLOW CORRELATIONS
NO SUBCOOLED VOID CORRELATION
HOMOGENEOUS BULK VOID MODEL
HOMOGENEOUS MODEL FRICTION MULTIPLIER

HEAT FLUX DISTRIBUTION

X/L	RELATIVE FLUX
0.000	1.000
1.000	1.000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

```
SUBCHANNEL INPUT DATA
CHANNEL    TYPE    AREA    WETTED     HEATED     HYDRAULIC     (ADJACENT CHANNEL NO., SPACING, CENTROIC DISTANCE)
  NO.             (SQ-IN) PERIM.      PERIM.     DIAMETER
                           (IN)        (IN)        (IN)
   1        1 36.000000 24.000000 24.000000  6.000000     (  2,6.000,-.000)( -0,-.000,-.000)( -0,-.000,-.000)( -0,-.000,-.000)
   2        1 36.000000 24.000000 24.000000  6.000000     ( -0,-.000,-.000)( -0,-.000,-.000)( -0,-.000,-.000)( -0,-.000,-.000)

ROD INPUT DATA
  ROD  TYPE  DIA  RADIAL POWER      FRACTION OF POWER TO ADJACENT CHANNELS (ADJ. CHANNEL NO.)
 NO.  NO.    (IN)    FACTOR
   1    1  1.0900    1.0000     1.0000(  1) -0.0000( -0) -0.0000( -0) -0.0000( -0) -0.0000( -0) -0.0000( -0)

EXPLICIT SOLUTION WITH INLET FLOWS SPECIFIED
     STANDING START FROM ZERO FOLLOWS

CALCULATION PARAMETERS                                                  CHANNEL LENGTH               72.0000 INCHES
  LATERAL RESISTANCE FACTOR        .0000                                NUMBER OF AXIAL NODES             24
  (S/L) PARAMETER                 1.0000                                AXIAL NODE LENGTH             3.0000 INCHES
  TURBULENT MOMENTUM FACTOR      -0.0000                                TOTAL TRANSIENT TIME          2.0000 SECONDS
  CHANNEL ORIENTATION            -0.0000 DEGREES                        NUMBER OF TIME STEPS             400
  ROLL OPTION (0 = NO ROLL)            0                                NOMINAL TIME STEP          ********* SECONDS

DATA FOR EXPLICIT SOLUTION
  MAXIMUM TIME STEP                .0050 SECONDS                        ACCELERATION FACTOR           1.0000
  COURANT NUMBER                   .2000                                FRACTION OF LAST CHANGE       0.0000
  ITERATIVE CONVERGENCE FACTORS                                         ITERATION LIMITS
       VOLUME ERROR (DV/V)         .0005                                     PRESSURE ITERATION      200
       ENTHALPY ERROR (DH/H)       .0001                                     ENERGY EQUATION          20

  TIME STEP VARIATION TABLE
     TIME        STEP SIZE
    (SEC)          (SEC)
  0.00000          .00100
   .50000          .02000
 10.00000          .02500

OPERATING CONDITIONS
  SYSTEM PRESSURE     =       50.0 PSIA
  INLET ENTHALPY      =     1174.0 BTU/LB
  AVG. MASS VELOCITY  =      0.000 MILLION LB/(HR-SQFT)
  INLET TEMPERATURE   =        0.0 DEGREES F
  AVG. HEAT FLUX      =   0.000000 MILLION BTU/(HR-SQFT)
  EXIT ENTHALPY       =     1174.0 BTU/LB
   INDIVIDUAL SUBCHANNEL ENTHALPY SPECIFIED    (CHANNEL-ENTHALPY)
   ( 1 - 250.2) ( 2 -1174.0)
   UNIFORM INLET MASS VELOCITY
```

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continuec)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.06 1

TIME = 0.00000 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	2.5126	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	2.4121	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
6.0	2.3116	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
9.0	2.2111	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
12.0	2.1106	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
15.0	2.0101	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
18.0	1.9096	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
21.0	1.8091	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
24.0	1.7086	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
27.0	1.6081	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
30.0	1.5076	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
33.0	1.4071	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
36.0	1.3066	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
39.0	1.2061	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
42.0	1.1055	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
45.0	1.0050	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
48.0	.9045	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
51.0	.8040	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
54.0	.7035	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
57.0	.6030	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
60.0	.5025	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
63.0	.4020	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
66.0	.3015	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
69.0	.2010	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
72.0	.1005	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.04.06 1

TIME = 0.00000 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.0051	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	.0049	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
6.0	.0047	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
9.0	.0045	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
12.0	.0043	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
15.0	.0041	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
18.0	.0039	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
21.0	.0037	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
24.0	.0035	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
27.0	.0033	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
30.0	.0031	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
33.0	.0029	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
36.0	.0027	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
39.0	.0024	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
42.0	.0022	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
45.0	.0020	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
48.0	.0018	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
51.0	.0016	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
54.0	.0014	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
57.0	.0012	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
60.0	.0010	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
63.0	.0008	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
66.0	.0006	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
69.0	.0004	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
72.0	.0002	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.06 1

TIME = 0.00000 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	0.00000
3.0 - 6.0	0.00000
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 2

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
5	.00104	.001	.49	.37	.8545	.0010	.0003
SURFACE LEVEL	72.000		.002				
3	.00108	.011	10.19	.61	10.7595	.0020	.0004
SURFACE LEVEL	72.000		.006				
2	.00112	.023	20.49	.79	21.2350	.0031	.0005
SURFACE LEVEL	72.000		.011				
2	.00116	.033	28.38	.93	29.2536	.0042	.0005
SURFACE LEVEL	72.000		.017				
2	.00120	.040	33.52	1.02	34.4872	.0054	.0005
SURFACE LEVEL	72.000		.024				
2	.00125	.045	36.38	1.09	37.4356	.0066	.0005
SURFACE LEVEL	72.000		.031				
2	.00130	.048	37.59	1.13	38.7123	.0079	.0004
SURFACE LEVEL	71.999		.040				
2	.00135	.050	37.65	1.18	38.8341	.0091	.0004
SURFACE LEVEL	71.999		.049				
2	.00140	.051	36.96	1.23	38.1901	.0105	.0004
SURFACE LEVEL	71.998		.059				
2	.00145	.052	35.78	1.28	37.0590	.0119	.0004
SURFACE LEVEL	71.996		.069				
2	.00151	.052	34.30	1.33	35.6364	.0133	.0004
SURFACE LEVEL	71.993		.080				
2	.00156	.051	32.68	1.38	34.0576	.0149	.0004
SURFACE LEVEL	71.989		.092				
2	.00162	.051	30.98	1.43	32.4149	.0164	.0004
SURFACE LEVEL	71.984		.105				
2	.00169	.050	29.29	1.48	30.7709	.0180	.0004
SURFACE LEVEL	71.976		.118				
2	.00175	.049	27.64	1.53	29.1670	.0197	.0004
SURFACE LEVEL	71.966		.132				
3	.00182	.048	26.09	1.58	27.6677	.0215	.0002
SURFACE LEVEL	71.954		.147				
3	.00189	.048	24.58	1.64	26.2162	.0233	.0002
SURFACE LEVEL	71.938		.163				
3	.00196	.047	23.16	1.69	24.8523	.0252	.0002
SURFACE LEVEL	71.919		.180				
3	.00203	.046	21.84	1.75	23.5862	.0271	.0002
SURFACE LEVEL	71.897		.198				
3	.00211	.046	20.62	1.81	22.4249	.0292	.0003
SURFACE LEVEL	71.872		.217				
3	.00219	.045	19.50	1.88	21.3799	.0313	.0004
SURFACE LEVEL	71.643		.237				
3	.00227	.045	18.50	1.96	20.4669	.0335	.0005
SURFACE LEVEL	71.810		.259				
8	.00236	.045	17.67	2.10	19.7706	.0357	.0005
SURFACE LEVEL	71.775		.284				
4	.00245	.046	17.05	2.26	19.3140	.0381	.0005
SURFACE LEVEL	71.737		.311				
4	.00254	.047	16.67	2.46	19.1238	.0405	.0004
SURFACE LEVEL	71.696		.342				
4	.00264	.049	18.90	2.69	19.1917	.0431	.0004
SURFACE LEVEL	71.652		.378				
5	.00274	.051	16.54	2.96	19.5022	.0457	.0003
SURFACE LEVEL	71.605		.419				
6	.00284	.055	16.75	3.25	20.0039	.0485	.0004
SURFACE LEVEL	71.555		.467				
7	.00295	.059	17.06	3.56	20.6201	.0513	.0004

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

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   9    .00306     .063     17.40      3.85     21.2510      .0542      .0005
SURFACE LEVEL    71.443       .583

CHANNEL RESULTS
CASE    1          ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION                    DATE   04/22/76  0 TIME   12.09.13  1

TIME =   .05425 SECONDS     PRESSURE =    50.0 PSIA        DATA FOR CHANNEL   1
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DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.4823	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	.3748	250.20	281.00	57.89	0.000	0.000	-13.8843	-.1994	-.9593	36.00000
6.0	.3305	250.20	281.00	57.89	0.000	0.000	-25.0837	-.3612	-1.7332	36.00000
9.0	.3690	250.20	281.00	57.89	0.000	0.000	-25.0160	-.3602	-1.7285	36.00000
12.0	.4061	250.20	281.00	57.89	0.000	0.000	-24.9357	-.3591	-1.7230	36.00000
15.0	.4379	250.20	281.00	57.89	0.000	0.000	-24.8449	-.3578	-1.7167	36.00000
18.0	.4640	250.20	281.00	57.89	0.000	0.000	-24.7458	-.3563	-1.7098	36.00000
21.0	.4840	250.20	281.00	57.89	0.000	0.000	-24.6410	-.3548	-1.7026	36.00000
24.0	.4979	250.20	281.00	57.89	0.000	0.000	-24.5327	-.3533	-1.6951	36.00000
27.0	.5054	250.20	281.00	57.89	0.000	0.000	-24.4232	-.3517	-1.6875	36.00000
30.0	.5068	250.20	281.00	57.89	0.000	0.000	-24.3144	-.3501	-1.6800	36.00000
33.0	.5022	250.20	281.00	57.89	0.000	0.000	-24.2083	-.3486	-1.6727	36.00000
36.0	.4920	250.20	281.00	57.89	0.000	0.000	-24.1066	-.3471	-1.6657	36.00000
39.0	.4764	250.20	281.00	57.89	0.000	0.000	-24.0106	-.3458	-1.6590	36.00000
42.0	.4559	250.20	281.00	57.89	0.000	0.000	-23.9208	-.3445	-1.6528	36.00000
45.0	.4309	250.20	281.00	57.89	0.000	.000	-23.8383	-.3433	-1.6471	36.00000
48.0	.4018	250.20	281.00	57.89	.000	.000	-23.7650	-.3422	-1.6421	36.00000
51.0	.3693	250.20	281.00	57.89	.000	.000	-23.7025	-.3413	-1.6377	36.00000
54.0	.3341	250.20	281.00	57.89	.000	.000	-23.6515	-.3406	-1.6342	36.00000
57.0	.2964	250.20	281.00	57.89	.000	.000	-23.6118	-.3400	-1.6315	36.00000
60.0	.2567	250.20	281.00	57.89	.000	.000	-23.5826	-.3396	-1.6295	36.00000
63.0	.2154	250.20	281.00	57.89	.000	.000	-23.5539	-.3392	-1.6282	36.00000
66.0	.1732	250.20	281.00	57.86	.000	.000	-23.3245	-.3359	-1.6276	36.00000
69.0	.1322	250.22	281.00	57.32	.000	.010	-19.4377	-.2799	-1.6277	36.00000
72.0	.0846	250.60	281.00	47.77	.000	.175	-.0478	-.0007	-1.6276	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.13 1

TIME = .05425 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.0791	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	.0647	260.16	281.00	9.18	.011	.843	2.2081	.0318	.9620	36.00000
6.0	.0227	298.38	281.00	2.17	.052	.964	.9439	.0136	1.7387	36.00000
9.0	.0090	733.64	281.00	.22	.523	.998	.0967	.0014	1.7275	36.00000
12.0	.0085	1138.12	281.00	.12	.961	1.000	.0522	.0008	1.7080	36.00000
15.0	.0080	1172.53	281.00	.12	.998	1.000	.0497	.0007	1.6898	36.00000
18.0	.0075	1173.95	281.00	.12	1.000	1.000	.0491	.0007	1.6737	36.00000
21.0	.0070	1174.00	281.00	.12	1.000	1.000	.0487	.0007	1.6595	36.00000
24.0	.0065	1174.00	281.00	.12	1.000	1.000	.0484	.0007	1.6471	36.00000
27.0	.0060	1174.00	281.00	.12	1.000	1.000	.0480	.0007	1.6361	36.00000
30.0	.0056	1174.00	281.00	.12	1.000	1.000	.0477	.0007	1.6262	36.00000
33.0	.0051	1174.00	281.00	.12	1.000	1.000	.0475	.0007	1.6173	36.00000
36.0	.0047	1174.00	281.00	.12	1.000	1.000	.0472	.0007	1.6093	36.00000
39.0	.0043	1174.00	281.00	.12	1.000	1.000	.0470	.0007	1.6021	36.00000
42.0	.0039	1174.00	281.00	.12	1.000	1.000	.0468	.0007	1.5956	36.00000
45.0	.0035	1174.00	281.00	.12	1.000	1.000	.0467	.0007	1.5897	36.00000
48.0	.0031	1174.00	281.00	.12	1.000	1.000	.0465	.0007	1.5846	36.00000
51.0	.0028	1174.00	281.00	.12	1.000	1.000	.0464	.0007	1.5802	36.00000
54.0	.0024	1174.00	281.00	.12	1.000	1.000	.0463	.0007	1.5764	36.00000
57.0	.0020	1174.01	281.00	.12	1.000	1.000	.0462	.0007	1.5732	36.00000
60.0	.0017	1174.02	281.00	.12	1.000	1.000	.0461	.0007	1.5707	36.00000
63.0	.0014	1174.02	281.00	.12	1.000	1.000	.0461	.0007	1.5688	36.00000
66.0	.0010	1174.03	281.00	.12	1.000	1.000	.0460	.0007	1.5676	36.00000
69.0	.0007	1174.04	281.00	.12	1.000	1.000	.0460	.0007	1.5669	36.00000
72.0	.0003	1174.04	281.00	.12	1.000	1.000	.0460	.0007	1.5669	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT). DATE 04/22/76 0 TIME 12.09.13 1

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = .05425 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	55.68691
3.0 - 6.0	45.01000
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 9

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
10	.00318	.067	17.69	4.11	21.7998	.0573	.0005
SURFACE LEVEL	71.381	.652					
10	.00330	.071	17.86	4.35	22.2108	.0605	.0004
SURFACE LEVEL	71.313	.727					
9	.00342	.073	17.70	4.56	22.2583	.0638	.0004
SURFACE LEVEL	71.238	.808					
9	.00355	.076	17.51	4.76	22.2654	.0672	.0004
SURFACE LEVEL	71.156	.897					
9	.00369	.079	17.31	4.95	22.2611	.0708	.0004
SURFACE LEVEL	71.065	.992					
8	.00383	.082	17.12	5.14	22.2644	.0745	.0004
SURFACE LEVEL	70.964	1.094					
9	.00397	.085	16.96	5.34	22.3027	.0783	.0004
SURFACE LEVEL	70.853	1.203					
9	.00413	.089	16.82	5.56	22.3870	.0823	.0004
SURFACE LEVEL	70.731	1.322					
9	.00428	.093	16.74	5.80	22.5404	.0864	.0004
SURFACE LEVEL	70.598	1.450					
10	.00445	.098	16.72	6.07	22.7872	.0907	.0004
SURFACE LEVEL	70.452	1.589					
12	.00461	.103	16.85	6.37	23.1431	.0951	.0004
SURFACE LEVEL	70.294	1.741					
13	.00479	.109	17.60	6.70	23.5719	.0997	.0005
SURFACE LEVEL	70.124	1.907					
19	.00497	.115	18.67	7.05	24.0062	.1045	.0005
SURFACE LEVEL	69.939	2.088					
27	.00516	.125	19.49	7.41	25.1519	.1095	.0005
SURFACE LEVEL	69.741	2.287					
36	.00536	.136	20.05	7.76	26.2579	.1146	.0005
SURFACE LEVEL	69.526	2.503					
33	.00556	.146	20.83	8.10	27.3018	.1200	.0005
SURFACE LEVEL	69.292	2.737					
29	.00577	.157	21.58	8.44	28.3224	.1256	.0005
SURFACE LEVEL	69.040	2.990					
28	.00599	.169	22.35	8.79	29.3528	.1313	.0005
SURFACE LEVEL	68.765	3.264					
28	.00622	.182	23.38	9.16	30.4158	.1373	.0005
SURFACE LEVEL	68.469	3.559					
32	.00628	.196	23.97	9.54	31.5320	.1435	.0005
SURFACE LEVEL	68.148	3.878					
36	.00618	.206	25.03	9.94	32.8823	.1498	.0005
SURFACE LEVEL	67.811	4.213					
41	.00599	.213	26.27	10.32	34.3994	.1560	.0005
SURFACE LEVEL	67.468	4.555					
40	.00577	.215	27.58	10.70	35.9612	.1620	.0005
SURFACE LEVEL	67.124	4.898					
38	.00554	.216	28.89	11.05	37.5030	.1678	.0005
SURFACE LEVEL	66.783	5.238					
35	.00536	.214	29.74	11.39	38.5485	.1733	.0005
SURFACE LEVEL	66.446	5.574					
34	.00529	.206	30.17	11.72	38.3567	.1787	.0005
SURFACE LEVEL	66.112	5.907					
35	.00525	.202	30.88	12.04	38.2839	.1839	.0005
SURFACE LEVEL	65.775	6.244					
37	.00524	.201	31.52	12.35	38.2154	.1892	.0005
SURFACE LEVEL	65.431	6.586					
38	.00525	.200	32.16	12.67	38.1076	.1944	.0005
39	.00526	.199	32.81	12.98	37.9499	.1997	.0005
SURFACE LEVEL	64.724	7.291					

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.20 1

TIME = .19969 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.1307	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	1.0176	250.20	281.00	57.89	0.000	0.000	-46.9646	-.6763	-3.2451	36.00000
6.0	.7710	250.20	281.00	57.89	0.000	0.000	-81.9743	-1.1804	-5.6641	36.00000
9.0	.6575	250.20	281.00	57.89	0.000	0.000	-81.9860	-1.1806	-5.6649	36.00000
12.0	.6262	250.20	281.00	57.89	0.000	.000	-81.9983	-1.1808	-5.6658	36.00000
15.0	.5949	250.20	281.00	57.89	0.000	.000	-82.0110	-1.1810	-5.6666	36.00000
18.0	.5636	250.20	281.00	57.89	.000	.000	-82.0239	-1.1811	-5.6675	36.00000
21.0	.5322	250.20	281.00	57.89	.000	.000	-82.0367	-1.1813	-5.6684	36.00000
24.0	.5008	250.20	281.00	57.89	.000	.000	-82.0494	-1.1815	-5.6693	36.00000
27.0	.4693	250.20	281.00	57.89	.000	.000	-82.0618	-1.1817	-5.6701	36.00000
30.0	.4378	250.20	281.00	57.89	.000	.000	-82.0736	-1.1819	-5.6710	36.00000
33.0	.4062	250.20	281.00	57.89	.000	.000	-82.0849	-1.1820	-5.6717	36.00000
36.0	.3746	250.20	281.00	57.89	.000	.000	-82.0955	-1.1822	-5.6725	36.00000
39.0	.3430	250.20	281.00	57.89	.000	.000	-82.1051	-1.1823	-5.6731	36.00000
42.0	.3113	250.20	281.00	57.89	.000	.000	-82.1135	-1.1824	-5.6737	36.00000
45.0	.2796	250.20	281.00	57.89	.000	.000	-82.1190	-1.1825	-5.6743	36.00000
48.0	.2478	250.20	281.00	57.89	.000	.000	-82.1142	-1.1824	-5.6747	36.00000
51.0	.2161	250.20	281.00	57.88	.000	.000	-82.0607	-1.1817	-5.6751	36.00000
54.0	.1847	250.20	281.00	57.84	.000	.001	-81.7622	-1.1774	-5.6753	36.00000
57.0	.1552	250.21	281.00	57.63	.000	.005	-80.2517	-1.1556	-5.6755	36.00000
60.0	.1347	250.24	281.00	56.55	.000	.023	-73.2022	-1.0541	-5.6755	36.00000
63.0	.1411	250.43	281.00	51.59	.000	.109	-48.0374	-.6917	-5.6755	36.00000
66.0	.1084	251.53	281.00	33.86	.001	.416	-10.3842	-.1495	-5.6756	36.00000
69.0	.0133	263.18	281.00	7.32	.014	.875	-.4785	-.0069	-5.6756	36.00000
72.0	.0006	570.69	281.00	.34	.347	.996	-.2666	-.0024	-5.6756	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.20 1

TIME = .19969 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.8706	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	.7108	250.21	281.00	57.65	.000	.004	46.7516	.6732	3.2440	36.00000
6.0	.4104	250.49	281.00	50.06	.000	.136	70.6581	1.0204	5.6621	36.00000
9.0	.0167	253.00	281.00	23.24	.003	.600	32.8942	.4737	5.6619	36.00000
12.0	-.0197	263.36	281.00	7.23	.014	.877	10.2303	.1473	5.6615	36.00000
15.0	-.0006	298.23	281.00	2.18	.052	.964	3.0827	.0444	5.6605	36.00000
18.0	.0043	417.84	281.00	.64	.181	.991	.9071	.0131	5.6578	36.00000
21.0	.0053	743.31	281.00	.22	.534	.998	.3103	.0045	5.6506	36.00000
24.0	.0057	1042.70	281.00	.14	.858	1.000	.1930	.0028	5.6398	36.00000
27.0	.0055	1146.49	281.00	.12	.970	1.000	.1703	.0025	5.6285	36.00000
30.0	.0051	1168.88	281.00	.12	.994	1.000	.1659	.0024	5.6179	36.00000
33.0	.0048	1173.10	281.00	.12	.999	1.000	.1648	.0024	5.6083	36.00000
36.0	.0045	1173.86	281.00	.12	1.000	1.000	.1644	.0024	5.5999	36.00000
39.0	.0041	1174.00	281.00	.12	1.000	1.000	.1642	.0024	5.5926	36.00000
42.0	.0038	1174.03	281.00	.12	1.000	1.000	.1640	.0024	5.5864	36.00000
45.0	.0034	1174.03	281.00	.12	1.000	1.000	.1639	.0024	5.5812	36.00000
48.0	.0031	1174.04	281.00	.12	1.000	1.000	.1637	.0024	5.5769	36.00000
51.0	.0027	1174.04	281.00	.12	1.000	1.000	.1636	.0024	5.5734	36.00000
54.0	.0024	1174.04	281.00	.12	1.000	1.000	.1635	.0024	5.5706	36.00000
57.0	.0021	1174.04	281.00	.12	1.000	1.000	.1635	.0024	5.5684	36.00000
60.0	.0017	1174.04	281.00	.12	1.000	1.000	.1634	.0024	5.5666	36.00000
63.0	.0014	1174.04	281.00	.12	1.000	1.000	.1634	.0024	5.5656	36.00000
66.0	.0010	1174.04	281.00	.12	1.000	1.000	.1634	.0024	5.5648	36.00000
69.0	.0007	1174.04	281.00	.12	1.000	1.000	.1634	.0024	5.5644	36.00000
72.0	.0003	1174.04	281.00	.12	1.000	1.000	.1634	.0024	5.5644	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.20 1

TIME = .19969 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	187.41554
3.0 - 6.0	139.99192
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 39

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
39	.00528	.198	33.55	13.28	37.7501	.2050	.0005
SURFACE LEVEL	64.359	7.656					
41	.00530	.198	34.19	13.59	37.5315	.2102	.0005
SURFACE LEVEL	63.965	8.029					
42	.00533	.198	34.92	13.89	37.3223	.2155	.0005
SURFACE LEVEL	63.603	8.410					
43	.00536	.198	34.70	14.18	37.1535	.2209	.0005
SURFACE LEVEL	63.211	8.801					
44	.00538	.198	35.17	14.47	37.0424	.2262	.0005
SURFACE LEVEL	62.812	9.200					
46	.00539	.199	35.68	14.76	37.0245	.2316	.0005
SURFACE LEVEL	62.403	9.607					
47	.00539	.200	35.62	15.04	37.1127	.2370	.0005
SURFACE LEVEL	61.988	10.022					
48	.00538	.201	36.59	15.32	37.3015	.2424	.0005
SURFACE LEVEL	61.566	10.443					
48	.00535	.202	37.59	15.58	37.5855	.2478	.0005
SURFACE LEVEL	61.140	10.869					
47	.00528	.205	38.34	15.84	38.3432	.2531	.0005
SURFACE LEVEL	60.709	11.298					
47	.00523	.204	38.57	16.09	38.5726	.2584	.0005
SURFACE LEVEL	60.279	11.728					
48	.00517	.205	39.11	16.33	39.1096	.2636	.0005
SURFACE LEVEL	59.847	12.159					
48	.00511	.205	39.68	16.56	39.6794	.2688	.0005
SURFACE LEVEL	59.416	12.590					
47	.00505	.205	40.06	16.78	40.0598	.2739	.0005
SURFACE LEVEL	58.985	13.020					
47	.00498	.205	40.65	17.00	40.6492	.2789	.0005
SURFACE LEVEL	58.555	13.450					
46	.00491	.206	41.30	17.20	41.3014	.2839	.0005
SURFACE LEVEL	58.126	13.878					
45	.00484	.206	42.01	17.39	42.0075	.2888	.0005
SURFACE LEVEL	57.699	14.304					
45	.00480	.203	42.05	17.57	42.0500	.2937	.0005
SURFACE LEVEL	57.276	14.726					
45	.00473	.205	42.85	17.75	42.8488	.2985	.0005
SURFACE LEVEL	56.853	15.149					
45	.00469	.203	43.00	17.91	42.9993	.3032	.0005
SURFACE LEVEL	56.432	15.569					
44	.00466	.202	43.14	18.07	43.1440	.3079	.0005
SURFACE LEVEL	56.012	15.989					
45	.00463	.203	43.54	18.22	43.5427	.3126	.0005
SURFACE LEVEL	55.591	16.409					
44	.00459	.204	44.02	18.37	44.0180	.3172	.0005
SURFACE LEVEL	55.171	16.829					
44	.00456	.202	44.15	18.51	44.1534	.3218	.0005
SURFACE LEVEL	54.752	17.247					
44	.00453	.202	44.35	18.64	44.3478	.3263	.0005
SURFACE LEVEL	54.334	17.665					
44	.00449	.204	45.04	18.76	45.0408	.3309	.0005
SURFACE LEVEL	53.915	18.083					
44	.00445	.204	45.37	18.88	45.3740	.3353	.0005
SURFACE LEVEL	53.499	18.499					
43	.00443	.201	45.27	18.99	45.2651	.3398	.0005
SURFACE LEVEL	53.084	18.913					
43	.00442	.201	45.46	19.10	45.4583	.3442	.0005
44	.00439	.202	45.81	19.20	45.8069	.3486	.0005
SURFACE LEVEL	52.254	19.742					

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.34 1

TIME = .34864 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	2.1209	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	1.8781	250.20	281.00	57.89	.000	.000	-69.4729	-1.0004	-4.8003	36.00000
6.0	1.4156	250.20	281.00	57.89	.000	.000	-113.3241	-1.6319	-7.8302	36.00000
9.0	1.1907	250.20	281.00	57.89	.000	.000	-113.3338	-1.6320	-7.8309	36.00000
12.0	1.1128	250.20	281.00	57.89	.000	.000	-113.3431	-1.6321	-7.8316	36.00000
15.0	1.0350	250.20	281.00	57.89	.000	.000	-113.3519	-1.6323	-7.8322	36.00000
18.0	.9571	250.20	281.00	57.89	.000	.000	-113.3603	-1.6324	-7.8327	36.00000
21.0	.8793	250.20	281.00	57.89	.000	.000	-113.3680	-1.6325	-7.8333	36.00000
24.0	.8015	250.20	281.00	57.89	.000	.000	-113.3749	-1.6326	-7.8338	36.00000
27.0	.7236	250.20	281.00	57.89	.000	.000	-113.3802	-1.6327	-7.8342	36.00000
30.0	.6458	250.20	281.00	57.89	.000	.000	-113.3812	-1.6327	-7.8346	36.00000
33.0	.5680	250.20	281.00	57.89	.000	.000	-113.3674	-1.6325	-7.8350	36.00000
36.0	.4903	250.20	281.00	57.88	.000	.000	-113.2981	-1.6315	-7.8353	36.00000
39.0	.4131	250.20	281.00	57.84	.000	.001	-113.0167	-1.6274	-7.8355	36.00000
42.0	.3380	250.21	281.00	57.69	.000	.003	-111.9283	-1.6118	-7.8356	36.00000
45.0	.2705	250.22	281.00	57.14	.000	.013	-107.8618	-1.5532	-7.8357	36.00000
48.0	.2274	230.30	281.00	55.06	.000	.049	-93.9630	-1.3531	-7.8358	36.00000
51.0	.2248	250.59	281.00	47.97	.000	.172	-58.3018	-.8395	-7.8358	36.00000
54.0	.1590	251.97	281.00	29.76	.002	.487	-15.1284	-.2178	-7.8358	36.00000
57.0	.0272	252.40	281.00	7.72	.013	.868	-1.4973	-.0216	-7.8359	36.00000
60.0	.0024	390.55	281.00	.76	.152	.989	-.2627	-.0038	-7.8361	36.00000
63.0	.0007	1059.07	281.00	.13	.876	1.000	-.2304	-.0033	-7.8363	36.00000
66.0	.0005	1172.49	281.00	.12	.998	1.000	-.2301	-.0033	-7.8364	36.00000
69.0	.0003	1174.02	281.00	.12	1.000	1.000	-.2301	-.0033	-7.8364	36.00000
72.0	.0002	1174.03	281.00	.12	1.000	1.000	-.2301	-.0033	-7.8364	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.34 1

TIME = .34864 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.6990	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	1.5985	250.20	281.00	57.89	.000	.000	69.4514	1.0001	4.7988	36.00000
6.0	1.0157	250.20	281.00	57.89	.000	.000	113.2824	1.6313	7.8274	36.00000
9.0	.5033	250.20	281.00	57.89	.000	.000	113.2754	1.6312	7.8269	36.00000
12.0	.3850	250.20	281.00	57.88	.000	.000	113.2528	1.6308	7.8265	36.00000
15.0	.2620	250.22	281.00	57.37	.000	.009	112.2579	1.6165	7.8263	36.00000
18.0	.1308	250.51	281.00	49.65	.000	.143	97.1507	1.3990	7.8261	36.00000
21.0	-.0491	252.30	281.00	27.31	.002	.529	53.4279	.7694	7.8259	36.00000
24.0	-.0964	259.17	281.00	10.02	.010	.829	19.6028	.2823	7.8255	36.00000
27.0	-.0319	278.14	281.00	3.65	.030	.939	7.1327	.1027	7.8248	36.00000
30.0	-.0094	330.61	281.00	1.32	.087	.979	2.5838	.0372	7.8231	36.00000
33.0	-.0013	478.62	281.00	.47	.247	.994	.9227	.0133	7.8188	36.00000
36.0	.0017	766.92	281.00	.21	.559	.998	.4093	.0059	7.8098	36.00000
39.0	.0026	1018.30	281.00	.14	.831	1.000	.2752	.0040	7.7971	36.00000
42.0	.0027	1128.55	281.00	.12	.951	1.000	.2403	.0035	7.7836	36.00000
45.0	.0025	1162.08	281.00	.12	.987	1.000	.2311	.0033	7.7708	36.00000
48.0	.0022	1171.01	281.00	.12	.997	1.000	.2285	.0033	7.7590	36.00000
51.0	.0020	1173.29	281.00	.12	.999	1.000	.2277	.0033	7.7485	36.00000
54.0	.0018	1173.85	281.00	.12	1.000	1.000	.2273	.0033	7.7395	36.00000
57.0	.0015	1173.99	281.00	.12	1.000	1.000	.2270	.0033	7.7319	36.00000
60.0	.0013	1174.03	281.00	.12	1.000	1.000	.2268	.0033	7.7258	36.00000
63.0	.0010	1174.04	281.00	.12	1.000	1.000	.2267	.0033	7.7212	36.00000
66.0	.0008	1174.04	281.00	.12	1.000	1.000	.2266	.0033	7.7181	36.00000
69.0	.0005	1174.34	281.00	.12	1.000	1.000	.2265	.0033	7.7166	36.00000
72.0	.0003	1174.04	281.00	.12	1.000	1.000	.2265	.0033	7.7166	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DATE 04/22/76 0 TIME 12.09.34 1

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT).

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = .30864 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	277.84172
3.0 - 6.0	175.35542
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 42

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
43	.00438	.201	45.80	19.29	45.8039	.3530	.0005
SURFACE LEVEL	51.839	20.156					
44	.00437	.201	45.89	19.38	45.8887	.3574	.0005
SURFACE LEVEL	51.425	20.570					
43	.00434	.202	46.32	19.46	46.3182	.3618	.0005
SURFACE LEVEL	51.009	20.985					
43	.00430	.204	46.97	19.54	46.9739	.3661	.0005
SURFACE LEVEL	50.595	21.398					
43	.00429	.201	46.76	19.62	46.7635	.3704	.0005
SURFACE LEVEL	50.184	21.809					
42	.00429	.200	46.68	19.68	46.6807	.3747	.0005
SURFACE LEVEL	49.773	22.219					
43	.00427	.201	46.91	19.75	46.9145	.3790	.0005
SURFACE LEVEL	49.361	22.631					
43	.00427	.200	46.81	19.80	46.8144	.3833	.0005
SURFACE LEVEL	48.950	23.042					
43	.00427	.200	46.83	19.86	46.8323	.3875	.0005
SURFACE LEVEL	48.538	23.453					
43	.00427	.201	46.96	19.91	46.9575	.3918	.0005
SURFACE LEVEL	48.125	23.866					
43	.00424	.203	47.53	19.95	47.5306	.3961	.0005
SURFACE LEVEL	47.712	24.278					
43	.00422	.202	47.65	19.99	47.6451	.4003	.0005
SURFACE LEVEL	47.302	24.688					
42	.00422	.200	47.38	20.03	47.3809	.4045	.0005
SURFACE LEVEL	46.893	25.096					
42	.00422	.200	47.46	20.06	47.4569	.4088	.0005
SURFACE LEVEL	46.484	25.505					
43	.00422	.199	47.31	20.08	47.3050	.4130	.0005
SURFACE LEVEL	46.074	25.914					
43	.00423	.200	47.26	20.11	47.2577	.4172	.0005
SURFACE LEVEL	45.664	26.324					
43	.00423	.200	47.21	20.13	47.2065	.4214	.0005
SURFACE LEVEL	45.253	26.734					
43	.00422	.202	47.63	20.14	47.6326	.4257	.0005
SURFACE LEVEL	44.842	27.145					
42	.00419	.202	48.04	20.15	48.0375	.4299	.0005
SURFACE LEVEL	44.432	27.554					
42	.00419	.200	47.67	20.16	47.6708	.4341	.0005
SURFACE LEVEL	44.025	27.961					
42	.00420	.199	47.53	20.16	47.5251	.4382	.0005
SURFACE LEVEL	43.618	28.367					
41	.00421	.199	47.35	20.16	47.3508	.4424	.0005
SURFACE LEVEL	43.211	28.775					
43	.00422	.199	47.24	20.15	47.2372	.4467	.0005
SURFACE LEVEL	42.803	29.182					
42	.00423	.199	47.12	20.14	47.1201	.4509	.0005
SURFACE LEVEL	42.394	29.591					
42	.00423	.200	47.32	20.13	47.3198	.4551	.0005
SURFACE LEVEL	41.984	30.000					
42	.00421	.202	47.76	20.11	47.7579	.4593	.0005
SURFACE LEVEL	41.576	30.408					
41	.00421	.200	47.52	20.09	47.5177	.4636	.0005
SURFACE LEVEL	41.170	30.813					
41	.00423	.198	47.14	20.07	47.1395	.4678	.0005
SURFACE LEVEL	40.765	31.218					
41	.00424	.199	47.03	20.04	47.0286	.4720	.0005
[illegible]	[illegible]	[illegible]					
41	.00426	.199	46.80	20.01	46.8022	.4762	.0005
SURFACE LEVEL	39.953	32.029					

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.44 1

TIME = .47623 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	2.2593	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	2.0021	250.20	281.00	57.89	.000	.000	-72.3972	-1.0425	-5.0024	36.00000
6.0	1.4960	250.20	281.00	57.89	.000	.000	-115.5612	-1.6641	-7.9848	36.00000
9.0	1.2333	250.20	281.00	57.89	.000	.000	-115.5661	-1.6642	-7.9852	36.00000
12.0	1.1201	250.20	281.00	57.89	.000	.000	-115.5702	-1.6642	-7.9855	36.00000
15.0	1.0068	250.20	281.00	57.89	.000	.000	-115.5722	-1.6642	-7.9858	36.00000
18.0	.8936	250.20	281.00	57.89	.000	.000	-115.5685	-1.6642	-7.9860	36.00000
21.0	.7804	250.20	281.00	57.89	.000	.000	-115.5447	-1.6638	-7.9862	36.00000
24.0	.5674	250.20	281.00	57.87	.000	.000	-115.4473	-1.6624	-7.9864	36.00000
27.0	.5552	250.20	281.00	57.82	.000	.001	-115.0784	-1.6571	-7.9865	36.00000
30.0	.4461	250.21	281.00	57.64	.000	.004	-113.7116	-1.6375	-7.9866	36.00000
33.0	.3473	250.23	281.00	56.95	.000	.016	-108.7996	-1.5667	-7.9866	36.00000
36.0	.2792	250.32	281.00	54.49	.000	.059	-92.7855	-1.3361	-7.9867	36.00000
39.0	.2546	250.66	281.00	46.47	.000	.198	-54.7255	-.7880	-7.9867	36.00000
42.0	.1590	252.29	281.00	27.41	.002	.528	-13.3633	-.1924	-7.9867	36.00000
45.0	.0270	264.57	281.00	6.69	.016	.886	-1.3718	-.0198	-7.9866	36.00000
48.0	.0037	406.55	281.00	.69	.169	.990	-.2687	-.0039	-7.9860	36.00000
51.0	.0019	1056.21	281.00	.13	.872	1.000	-.2351	-.0034	-7.9854	36.00000
54.0	.0016	1171.27	281.00	.12	.997	1.000	-.2344	-.0034	-7.9848	36.00000
57.0	.0014	1173.98	281.00	.12	1.000	1.000	-.2344	-.0034	-7.9843	36.00000
60.0	.0011	1174.03	281.00	.12	1.000	1.000	-.2344	-.0034	-7.9839	36.00000
63.0	.0009	1174.03	281.00	.12	1.000	1.000	-.2344	-.0034	-7.9836	36.00000
66.0	.0007	1174.03	281.00	.12	1.000	1.000	-.2344	-.0034	-7.9834	36.00000
69.0	.0005	1174.03	281.00	.12	1.000	1.000	-.2344	-.0034	-7.9833	36.00000
72.0	.0002	1174.03	281.00	.12	1.000	1.000	-.2344	-.0034	-7.9833	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.44 1

TIME = .47623 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.8737	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	1.7731	250.20	281.00	57.89	.000	.000	72.3805	1.0423	5.0012	36.00000
6.0	1.1782	250.20	281.00	57.89	.000	.000	115.5279	1.6636	7.9825	36.00000
9.0	.6981	250.20	281.00	57.89	.000	.000	115.5188	1.6635	7.9819	36.00000
12.0	.6104	250.20	281.00	57.89	.000	.000	115.5097	1.6633	7.9813	36.00000
15.0	.5227	250.20	281.00	57.89	.000	.000	115.5010	1.6632	7.9807	36.00000
18.0	.4350	250.20	281.00	57.89	.000	.000	115.4931	1.6631	7.9801	36.00000
21.0	.3472	250.20	281.00	57.89	.000	.000	115.4858	1.6630	7.9796	36.00000
24.0	.2595	250.20	281.00	57.88	.000	.000	115.4573	1.6626	7.9793	36.00000
27.0	.1719	250.22	281.00	57.43	.000	.008	114.5548	1.6496	7.9790	36.00000
30.0	.0758	250.46	281.00	50.84	.000	.122	101.4130	1.4603	7.9788	36.00000
33.0	-.0767	251.97	281.00	29.81	.002	.486	59.4579	.8562	7.9786	36.00000
36.0	-.1209	258.03	281.00	11.20	.008	.808	22.3360	.3216	7.9782	36.00000
39.0	-.0454	275.18	281.00	4.05	.027	.932	8.0718	.1162	7.9775	36.00000
42.0	-.0156	322.62	281.00	1.46	.078	.977	2.9174	.0420	7.9758	36.00000
45.0	-.0046	455.82	281.00	.52	.223	.993	1.0441	.0150	7.9715	36.00000
48.0	-.0005	728.64	281.00	.23	.518	.998	.4505	.0065	7.9623	36.00000
51.0	.0008	990.13	281.00	.15	.801	.999	.2912	.0042	7.9494	36.00000
54.0	.0011	1116.54	281.00	.13	.938	1.000	.2484	.0036	7.9359	36.00000
57.0	.0010	1157.97	281.00	.12	.983	1.000	.2367	.0034	7.9236	36.00000
60.0	.0009	1169.70	281.00	.12	.995	1.000	.2334	.0034	7.9134	36.00000
63.0	.0007	1172.88	281.00	.12	.999	1.000	.2324	.0033	7.9055	36.00000
66.0	.0005	1173.73	281.00	.12	1.000	1.000	.2320	.0033	7.9002	36.00000
69.0	.0004	1173.96	281.00	.12	1.000	1.000	.2319	.0033	7.8976	36.00000
72.0	.0002	1174.02	281.00	.12	1.000	1.000	.2319	.0033	7.8976	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT), DATE 04/22/76 0 TIME 12.09.44 1

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = .47623 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	289.55515
3.0 - 6.0	172.62496
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 41

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
41	.00427	.198	46.62	19.97	46.6238	.4805	.0005
SURFACE LEVEL	39.546	32.436					
41	.00428	.199	46.62	19.93	46.6164	.4848	.0005
SURFACE LEVEL	39.138	32.843					
40	.00427	.201	47.00	19.89	47.0046	.4890	.0005
SURFACE LEVEL	38.731	33.250					
40	.00426	.200	46.95	19.84	46.9491	.4933	.0005
SURFACE LEVEL	38.326	33.654					
40	.00428	.198	46.48	19.79	46.4782	.4976	.0005
SURFACE LEVEL	37.923	34.057					
39	.00430	.198	46.25	19.74	46.2500	.5019	.0005
SURFACE LEVEL	37.519	34.460					
39	.00433	.198	45.96	19.68	45.9601	.5062	.0005
SURFACE LEVEL	37.115	34.864					
39	.00435	.198	45.72	19.62	45.7180	.5105	.0005
SURFACE LEVEL	36.710	35.268					
39	.00437	.198	45.52	19.56	45.5151	.5148	.0005
SURFACE LEVEL	36.305	35.673					
38	.00437	.201	45.86	19.49	45.8587	.5192	.0005
SURFACE LEVEL	35.899	36.079					
38	.00436	.201	45.97	19.42	45.9718	.5236	.0005
SURFACE LEVEL	35.495	36.482					
37	.00438	.198	45.41	19.34	45.4076	.5279	.0005
SURFACE LEVEL	35.094	36.883					
37	.00442	.197	44.94	19.26	44.9365	.5323	.0005
SURFACE LEVEL	34.693	37.284					
37	.00444	.198	44.81	19.18	44.8082	.5367	.0005
SURFACE LEVEL	34.291	37.686					
37	.00447	.197	44.42	19.10	44.4204	.5412	.0005
SURFACE LEVEL	33.888	38.088					
36	.00450	.197	44.11	19.01	44.1132	.5456	.0005
SURFACE LEVEL	33.485	38.490					
36	.00451	.200	44.32	18.91	44.3184	.5501	.0005
SURFACE LEVEL	33.081	38.894					
35	.00450	.201	44.60	18.82	44.6038	.5547	.0005
SURFACE LEVEL	32.679	39.295					
34	.00452	.198	43.94	18.72	43.9408	.5591	.0005
SURFACE LEVEL	32.281	39.693					
34	.00457	.196	43.36	18.61	43.3599	.5637	.0005
SURFACE LEVEL	31.882	40.091					
34	.00461	.196	42.98	18.51	42.9850	.5682	.0004
SURFACE LEVEL	31.482	40.491					
33	.00464	.197	42.81	18.39	42.8064	.5728	.0005
SURFACE LEVEL	31.082	40.891					
33	.00468	.196	42.34	18.28	42.3415	.5775	.0005
SURFACE LEVEL	30.681	41.291					
33	.00470	.198	42.34	18.16	42.3436	.5822	.0004
SURFACE LEVEL	30.280	41.692					
32	.00470	.200	42.59	18.03	42.5913	.5869	.0004
SURFACE LEVEL	29.880	42.091					
31	.00473	.198	42.05	17.91	42.0464	.5916	.0005
SURFACE LEVEL	29.483	42.487					
31	.00478	.196	41.37	17.78	41.3681	.5963	.0004
SURFACE LEVEL	29.088	42.883					
30	.00484	.195	40.80	17.64	40.8014	.6011	.0005
SURFACE LEVEL	28.691	43.279					
30	.00489	.196	40.43	17.50	40.4275	.6059	.0004
SURFACE LEVEL	[illegible]	[illegible]					
29	.00493	.197	40.19	17.36	40.1861	.6108	.0004
SURFACE LEVEL	27.894	44.075					

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.53 1

TIME = .61081 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.8300	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	1.6100	250.20	281.00	57.89	.000	.000	-62.8039	-.9044	-4.3396	36.00000
6.0	1.1930	250.20	281.00	57.89	.000	.000	-98.3128	-1.4157	-6.7934	36.00000
9.0	.9466	250.20	281.00	57.89	.000	.000	-98.2986	-1.4155	-6.7935	36.00000
12.0	.8064	250.20	281.00	57.88	.000	.000	-98.2382	-1.4146	-6.7936	36.00000
15.0	.6668	250.20	281.00	57.84	.000	.001	-97.9933	-1.4111	-6.7937	36.00000
18.0	.5295	250.21	281.00	57.70	.000	.003	-97.0137	-1.3970	-6.7937	36.00000
21.0	.4006	250.23	281.00	57.12	.000	.013	-93.1821	-1.3418	-6.7938	36.00000
24.0	.2990	250.30	281.00	54.86	.000	.052	-79.5536	-1.1456	-6.7938	36.00000
27.0	.2419	250.64	281.00	46.84	.000	.191	-45.1671	-.6504	-6.7938	36.00000
30.0	.1323	252.41	281.00	26.59	.002	.542	-9.3431	-.1345	-6.7938	36.00000
33.0	.0213	269.08	281.00	5.50	.019	.907	-.9618	-.0138	-6.7935	36.00000
36.0	.0047	440.29	281.00	.57	.206	.992	-.2152	-.0031	-6.7922	36.00000
39.0	.0034	1105.93	281.00	.13	.926	1.000	-.1976	-.0029	-6.7909	36.00000
42.0	.0031	1172.92	281.00	.12	.999	1.000	-.1993	-.0029	-6.7896	36.00000
45.0	.0028	1174.01	281.00	.12	1.000	1.000	-.1993	-.0029	-6.7884	36.00000
48.0	.0026	1174.03	281.00	.12	1.000	1.000	-.1993	-.0029	-6.7873	36.00000
51.0	.0023	1174.03	281.00	.12	1.000	1.000	-.1992	-.0029	-6.7863	36.00000
54.0	.0020	1174.03	281.00	.12	1.000	1.000	-.1992	-.0029	-6.7855	36.00000
57.0	.0017	1174.03	281.00	.12	1.000	1.000	-.1992	-.0029	-6.7848	36.00000
60.0	.0014	1174.03	281.00	.12	1.000	1.000	-.1992	-.0029	-6.7842	36.00000
63.0	.0011	1174.03	281.00	.12	1.000	1.000	-.1992	-.0029	-6.7837	36.00000
66.0	.0009	1174.03	281.00	.12	1.000	1.000	-.1992	-.0029	-6.7835	36.00000
69.0	.0006	1174.03	281.00	.12	1.000	1.000	-.1992	-.0029	-6.7833	36.00000
72.0	.0003	1174.03	281.00	.12	1.000	1.000	-.1992	-.0029	-6.7833	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.09.53 1

TIME = .61081 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5958	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	1.4949	250.20	281.00	57.89	.000	.000	62.8041	.9044	4.3395	36.00000
6.0	1.0429	250.20	281.00	57.89	.000	.000	98.3150	1.4157	6.7932	36.00000
9.0	.7021	250.20	281.00	57.89	.000	.000	98.3121	1.4157	6.7930	36.00000
12.0	.6419	250.20	281.00	57.89	.000	.000	98.3070	1.4156	6.7926	36.00000
15.0	.5807	250.20	281.00	57.89	.000	.000	98.2994	1.4155	6.7921	36.00000
18.0	.5199	250.20	281.00	57.89	.000	.000	98.2894	1.4154	6.7914	36.00000
21.0	.4592	250.20	281.00	57.89	.000	.000	98.2772	1.4152	6.7906	36.00000
24.0	.3985	250.20	281.00	57.89	.000	.000	98.2636	1.4150	6.7896	36.00000
27.0	.3378	250.20	281.00	57.89	.000	.000	98.2494	1.4148	6.7886	36.00000
30.0	.2772	250.20	281.00	57.89	.000	.000	98.2354	1.4146	6.7877	36.00000
33.0	.2166	250.20	281.00	57.89	.000	.000	98.2227	1.4144	6.7868	36.00000
36.0	.1560	250.20	281.00	57.89	.000	.000	98.2044	1.4141	6.7861	36.00000
39.0	.0956	250.21	281.00	57.62	.000	.005	97.7486	1.4076	6.7856	36.00000
42.0	.0327	250.42	281.00	51.91	.000	.103	88.0608	1.2681	6.7852	36.00000
45.0	-.0755	251.95	281.00	29.97	.002	.483	50.8407	.7321	6.7848	36.00000
48.0	-.1064	259.32	281.00	10.88	.009	.814	18.4468	.2656	6.7842	36.00000
51.0	-.0369	276.08	281.00	3.92	.028	.934	6.6402	.0956	6.7831	36.00000
54.0	-.0127	325.65	281.00	1.41	.082	.978	2.3833	.0343	6.7809	36.00000
57.0	-.0041	465.24	281.00	.50	.233	.993	.8490	.0122	6.7761	36.00000
60.0	-.0011	761.89	281.00	.21	.554	.998	.3581	.0052	6.7670	36.00000
63.0	.0001	1021.29	281.00	.14	.835	1.000	.2376	.0034	6.7567	36.00000
66.0	.0003	1130.97	281.00	.12	.953	1.000	.2078	.0030	6.7488	36.00000
69.0	.0002	1163.15	281.00	.12	.988	1.000	.2004	.0029	6.7448	36.00000
72.0	.0001	1171.66	281.00	.12	.997	1.000	.1985	.0029	6.7448	36.00000

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC*FT).   DATE 04/22/76 0 TIME 12.09.53 1

CASE 1   ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = .61081 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	251.21662
3.0 - 6.0	142.04723
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 29

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
28	.00497	.197	39.89	17.21	39.8852	.6157	.0004
SURFACE LEVEL	27.495	44.473					
28	.00498	.199	40.09	17.06	40.0921	.6207	.0004
SURFACE LEVEL	27.097	44.870					
27	.00501	.198	39.67	16.90	39.6742	.6257	.0004
SURFACE LEVEL	26.703	45.264					
27	.00508	.195	38.90	16.74	38.8993	.6307	.0004
SURFACE LEVEL	26.311	45.656					
26	.00515	.194	38.20	16.58	38.2012	.6358	.0004
SURFACE LEVEL	25.917	46.048					
26	.00523	.194	37.67	16.41	37.6664	.6409	.0004
SURFACE LEVEL	25.523	46.443					
25	.00530	.195	37.21	16.23	37.2076	.6462	.0004
SURFACE LEVEL	25.127	46.838					
25	.00536	.196	36.88	16.05	36.8775	.6515	.0004
SURFACE LEVEL	24.730	47.234					
24	.00538	.199	37.03	15.86	37.0262	.6568	.0004
SURFACE LEVEL	24.335	47.629					
23	.00541	.198	36.75	15.67	36.7457	.6622	.0004
SURFACE LEVEL	23.943	48.020					
23	.00549	.194	35.87	15.48	35.8715	.6676	.0004
SURFACE LEVEL	23.554	48.408					
22	.00560	.193	35.07	15.28	35.0678	.6731	.0004
SURFACE LEVEL	23.165	48.796					
22	.00570	.193	34.42	15.07	34.4175	.6787	.0004
SURFACE LEVEL	22.775	49.185					
21	.00581	.193	33.79	14.86	33.7926	.6844	.0004
SURFACE LEVEL	22.384	49.576					
20	.00591	.193	33.20	14.64	33.1958	.6902	.0004
SURFACE LEVEL	21.992	49.967					
20	.00596	.197	33.26	14.41	33.2581	.6961	.0004
SURFACE LEVEL	21.600	50.358					
19	.00600	.198	33.18	14.18	33.1786	.7021	.0004
SURFACE LEVEL	21.212	50.746					
19	.00610	.193	32.17	13.94	32.1712	.7081	.0004
SURFACE LEVEL	20.828	51.128					
18	.00625	.191	31.23	13.70	31.2308	.7142	.0004
SURFACE LEVEL	20.446	51.509					
18	.00640	.190	30.46	13.45	30.4637	.7205	.0004
SURFACE LEVEL	20.063	51.892					
17	.00656	.190	29.71	13.19	29.7132	.7269	.0004
SURFACE LEVEL	19.679	52.275					
17	.00673	.190	28.96	12.91	28.9624	.7334	.0004
SURFACE LEVEL	19.294	52.659					
17	.00687	.192	28.50	12.63	28.5039	.7402	.0003
SURFACE LEVEL	18.910	53.042					
16	.00696	.195	28.39	12.34	28.3862	.7470	.0004
SURFACE LEVEL	18.527	53.423					
15	.00710	.192	27.57	12.05	27.5703	.7540	.0004
SURFACE LEVEL	18.151	53.799					
15	.00732	.188	26.48	11.74	26.4773	.7611	.0003
SURFACE LEVEL	17.778	54.171					
15	.00757	.187	25.50	11.43	25.5017	.7684	.0003
SURFACE LEVEL	17.406	54.542					
15	.00784	.186	24.61	11.10	24.6141	.7760	.0003
SURFACE LEVEL	17.034	54.913					
14	.00813	.186	23.69	10.75	23.6880	.7838	.0004
SURFACE LEVEL	16.663	55.285					
14	.00845	.185	22.74	10.39	22.7358	.7920	.0003
SURFACE LEVEL	16.294	55.652					

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 U TIME 12.10.01 1

TIME = .79195 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.0224	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	.8768	250.20	281.00	57.89	.000	.000	-37.5655	-.5409	-2.5973	36.00000
6.0	.6451	250.20	281.00	57.85	.000	.001	-54.5957	-.7862	-3.7871	36.00000
9.0	.4559	250.21	281.00	57.67	.000	.004	-53.5775	-.7715	-3.7869	36.00000
12.0	.3045	250.24	281.00	56.59	.000	.022	-48.0942	-.6926	-3.7868	36.00000
15.0	.1938	250.46	281.00	50.80	.000	.123	-27.3237	-.3935	-3.7868	36.00000
18.0	.0779	252.09	281.00	28.86	.002	.502	-4.3349	-.0624	-3.7866	36.00000
21.0	.0152	272.06	281.00	4.58	.024	.923	-.4487	-.0065	-3.7853	36.00000
24.0	.0061	477.59	281.00	.47	.246	.994	-.1119	-.0016	-3.7804	36.00000
27.0	.0052	1165.67	281.00	.12	.992	1.000	-.1109	-.0016	-3.7762	36.00000
30.0	.0049	1174.02	281.00	.12	1.000	1.000	-.1108	-.0016	-3.7728	36.00000
33.0	.0046	1174.03	281.00	.12	1.000	1.000	-.1107	-.0016	-3.7702	36.00000
36.0	.0042	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7683	36.00000
39.0	.0039	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7671	36.00000
42.0	.0036	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7664	36.00000
45.0	.0033	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7661	36.00000
48.0	.0029	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7660	36.00000
51.0	.0026	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7662	36.00000
54.0	.0023	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7665	36.00000
57.0	.0020	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7668	36.00000
60.0	.0016	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7671	36.00000
63.0	.0013	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7674	36.00000
66.0	.0010	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7675	36.00000
69.0	.0007	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7676	36.00000
72.0	.0003	1174.03	281.00	.12	1.000	1.000	-.1106	-.0016	-3.7676	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.01 1

TIME = .79195 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.0196	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	.9191	250.20	281.00	57.89	.000	.000	37.6109	.5416	2.5988	36.00000
6.0	.7207	250.20	281.00	57.89	.000	.000	54.8478	.7898	3.7899	36.00000
9.0	.5974	250.20	281.00	57.89	.000	.000	54.8598	.7900	3.7907	36.00000
12.0	.5571	250.20	281.00	57.89	.000	.000	54.8706	.7901	3.7915	36.00000
15.0	.5168	250.20	281.00	57.89	.000	.000	54.8800	.7903	3.7921	36.00000
18.0	.4764	250.20	281.00	57.89	.000	.000	54.8886	.7904	3.7927	36.00000
21.0	.4360	250.20	281.00	57.89	.000	.000	54.8971	.7905	3.7932	36.00000
24.0	.3957	250.20	281.00	57.89	.000	.000	54.9051	.7906	3.7938	36.00000
27.0	.3553	250.20	281.00	57.89	.000	.000	54.9109	.7907	3.7942	36.00000
30.0	.3149	250.20	281.00	57.89	.000	.000	54.9116	.7907	3.7942	36.00000
33.0	.2745	250.20	281.00	57.89	.000	.000	54.9041	.7906	3.7937	36.00000
36.0	.2342	250.20	281.00	57.89	.000	.000	54.8865	.7904	3.7925	36.00000
39.0	.1939	250.20	281.00	57.89	.000	.000	54.8591	.7900	3.7906	36.00000
42.0	.1537	250.20	281.00	57.89	.000	.000	54.8246	.7895	3.7882	36.00000
45.0	.1135	250.20	281.00	57.89	.000	.000	54.7876	.7889	3.7856	36.00000
48.0	.0733	250.20	281.00	57.89	.000	.000	54.7535	.7885	3.7833	36.00000
51.0	.0332	250.20	281.00	57.85	.000	.001	54.6870	.7875	3.7815	36.00000
54.0	-.0019	250.38	281.00	52.79	.000	.088	49.8891	.7184	3.7803	36.00000
57.0	-.0466	252.72	281.00	24.71	.003	.574	23.3469	.3362	3.7789	36.00000
60.0	-.0316	261.15	281.00	8.48	.012	.855	8.0034	.1152	3.7768	36.00000
63.0	-.0112	285.21	281.00	2.95	.038	.951	2.7805	.0400	3.7741	36.00000
66.0	-.0039	353.87	281.00	1.03	.112	.984	.9709	.0140	3.7709	36.00000
69.0	-.0012	556.80	281.00	.35	.332	.996	.3319	.0048	3.7676	36.00000
72.0	-.0003	961.62	281.00	.15	.770	.999	.1435	.0021	3.7668	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT), DATE 04/22/76 0 TIME 12.10.01 1

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = .79195 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	150.38646
3.0 - 6.0	68.86071
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 14

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
14	.00881	.184	21.76	10.01	21.7565	.8004	.0003
SURFACE LEVEL	15.926	56.018					
13	.00917	.189	20.92	9.62	20.9158	.8092	.0004
SURFACE LEVEL	15.562	56.381					
13	.00955	.184	20.06	9.21	20.0624	.8184	.0004
SURFACE LEVEL	15.203	56.739					
12	.01008	.179	18.74	8.77	18.7410	.8279	.0004
SURFACE LEVEL	14.851	57.091					
14	.01065	.179	17.72	8.31	17.7155	.8380	.0005
SURFACE LEVEL	14.504	57.437					
16	.01131	.177	16.59	7.83	16.5914	.8487	.0005
SURFACE LEVEL	14.165	57.776					
15	.01216	.172	15.22	7.31	15.2237	.8600	.0005
SURFACE LEVEL	13.837	58.104					
15	.01321	.168	13.82	6.76	13.8161	.8721	.0005
SURFACE LEVEL	13.521	58.420					
17	.01456	.163	12.31	6.16	12.3280	.8853	.0005
SURFACE LEVEL	13.221	58.720					
18	.01616	.160	10.66	5.51	11.0162	.8999	.0005
SURFACE LEVEL	12.944	58.997					
57	.01822	.155	8.92	4.79	9.5811	.9161	.0005
SURFACE LEVEL	12.702	59.240					
200	.02023	.146	7.01	4.00	7.9929	.9343	.0006
SURFACE LEVEL	12.513	59.428					
200	.02024	.126	5.10	3.12	6.2499	.9545	.0007
SURFACE LEVEL	12.408	59.532					
21	.02025	.092	3.64	2.29	4.5639	.9748	.0005
SURFACE LEVEL	12.409	59.531					
75	.02026	.111	5.50	3.19	5.4965	.9950	.0005
SURFACE LEVEL	12.510	59.419					
47	.02027	.153	7.25	4.13	7.5659	1.0153	.0005
SURFACE LEVEL	12.716	59.202					
100	.01987	.208	8.97	5.09	10.2669	1.0355	.0005
SURFACE LEVEL	13.031	58.885					
59	.01752	.253	10.73	5.94	12.7584	1.0554	.0005
SURFACE LEVEL	13.437	58.477					
46	.01528	.259	12.65	6.56	14.7653	1.0729	.0005
SURFACE LEVEL	13.867	58.044					
54	.01357	.250	14.42	7.02	16.3930	1.0882	.0005
SURFACE LEVEL	14.295	57.611					
63	.01231	.241	15.98	7.36	17.7506	1.1018	.0005
SURFACE LEVEL	14.718	57.186					
55	.01136	.233	17.36	7.62	18.8943	1.1141	.0005
SURFACE LEVEL	15.134	56.768					
47	.01068	.226	18.40	7.81	19.8752	1.1255	.0005
SURFACE LEVEL	15.545	56.355					
45	.01014	.221	19.26	7.95	20.7352	1.1362	.0005
SURFACE LEVEL	15.954	55.944					
46	.00970	.218	20.13	8.06	21.5047	1.1463	.0005
SURFACE LEVEL	16.363	55.534					
49	.00934	.215	20.36	8.14	22.2015	1.1560	.0005
SURFACE LEVEL	16.772	55.124					
48	.00904	.213	20.69	8.21	22.8367	1.1653	.0005
SURFACE LEVEL	17.181	54.713					
46	.00878	.212	21.62	8.25	23.4195	1.1748	.0005
SURFACE LEVEL	17.592	54.301					
46	.00856	.210	22.81	8.29	23.9583	1.1832	.0005
SURFACE LEVEL	[illegible]	[illegible]					
45	.00836	.209	23.49	8.32	24.4597	1.1917	.0005
SURFACE LEVEL	18.419	53.473					

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.20 1

TIME = 1.19171 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.1401	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	1.0396	250.19	280.99	57.89	0.000	0.000	28.2358	.4066	1.9510	36.00000
6.0	.8090	250.19	280.99	57.89	0.000	0.000	58.3421	.8401	4.0312	36.00000
9.0	.5405	249.99	280.80	57.90	0.000	0.000	58.3418	.8401	4.0308	36.00000
12.0	.3971	250.02	280.82	57.90	0.000	0.000	58.3367	.8400	4.0305	36.00000
15.0	.2541	250.21	281.00	57.63	.000	.004	58.0702	.8362	4.0303	36.00000
18.0	.1229	250.54	281.00	43.19	.001	.254	43.5137	.6266	4.0302	36.00000
21.0	-.0032	255.28	281.00	15.62	.006	.732	15.7367	.2266	4.0300	36.00000
24.0	.0030	256.52	281.00	5.38	.020	.909	5.4226	.0781	4.0297	36.00000
27.0	.0040	309.10	281.00	1.79	.064	.971	1.8016	.0259	4.0290	36.00000
30.0	.0040	453.30	281.00	.59	.198	.992	.5917	.0065	4.0272	36.00000
33.0	.0037	737.31	281.00	.20	.581	.999	.2028	.0029	4.0225	36.00000
36.0	.0037	1076.54	281.00	.13	.895	1.000	.1318	.0019	4.0156	36.00000
39.0	.0035	1156.70	281.00	.12	.981	1.000	.1199	.0017	4.0087	36.00000
42.0	.0032	1171.21	281.00	.12	.997	1.000	.1179	.0017	4.0022	36.00000
45.0	.0029	1173.59	281.00	.12	1.000	1.000	.1174	.0017	3.9962	36.00000
48.0	.0026	1173.97	281.00	.12	1.000	1.000	.1172	.0017	3.9910	36.00000
51.0	.0023	1174.03	281.00	.12	1.000	1.000	.1170	.0017	3.9863	36.00000
54.0	.0020	1174.04	281.00	.12	1.000	1.000	.1169	.0017	3.9824	36.00000
57.0	.0017	1174.04	281.00	.12	1.000	1.000	.1168	.0017	3.9791	36.00000
60.0	.0014	1174.04	281.00	.12	1.000	1.000	.1167	.0017	3.9765	36.00000
63.0	.0012	1174.04	281.00	.12	1.000	1.000	.1167	.0017	3.9746	36.00000
66.0	.0009	1174.04	281.00	.12	1.000	1.000	.1167	.0017	3.9733	36.00000
69.0	.0006	1174.04	281.00	.12	1.000	1.000	.1165	.0017	3.9726	36.00000
72.0	.0003	1174.04	281.00	.12	1.000	1.000	.1165	.0017	3.9726	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.20 1

TIME = 1.19171 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.3112	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	1.1695	250.20	281.00	57.89	0.000	0.000	-28.2568	-.4069	-1.9524	36.00000
6.0	1.0334	250.20	281.00	57.89	0.000	0.000	-58.3830	-.8407	-4.0340	36.00000
9.0	.9251	250.20	281.00	57.89	0.000	0.000	-58.3932	-.8409	-4.0347	36.00000
12.0	.8674	250.20	281.00	57.89	0.000	0.000	-58.4031	-.8410	-4.0354	36.00000
15.0	.8098	250.20	281.00	57.89	0.000	0.000	-58.4127	-.8411	-4.0361	36.00000
18.0	.7521	250.19	280.99	57.69	0.000	0.000	-58.4218	-.8413	-4.0367	36.00000
21.0	.6945	250.19	280.99	57.89	0.000	0.000	-58.4302	-.8414	-4.0373	36.00000
24.0	.6368	250.19	280.99	57.89	0.000	0.000	-58.4380	-.8415	-4.0378	36.00000
27.0	.5792	250.20	281.00	57.89	0.000	0.000	-58.4450	-.8416	-4.0383	36.00000
30.0	.5216	250.20	281.00	57.89	0.000	0.000	-58.4511	-.8417	-4.0387	36.00000
33.0	.4639	250.20	281.00	57.89	.000	.000	-58.4561	-.8418	-4.0391	36.00000
36.0	.4063	250.20	281.00	57.89	.000	.000	-58.4582	-.8418	-4.0394	36.00000
39.0	.3486	250.20	281.00	57.89	.000	.000	-58.4474	-.8416	-4.0397	36.00000
42.0	.2911	250.20	281.00	57.87	.000	.000	-58.3637	-.8404	-4.0396	36.00000
45.0	.2340	250.20	281.00	57.79	.000	.002	-57.8525	-.8331	-4.0400	36.00000
48.0	.1800	250.22	281.00	57.28	.000	.011	-54.9212	-.7909	-4.0400	36.00000
51.0	.1404	250.32	281.00	54.38	.000	.061	-40.9586	-.5898	-4.0400	36.00000
54.0	.1043	251.00	281.00	40.55	.001	.300	-10.7718	-.1551	-4.0400	36.00000
57.0	.0198	258.52	281.00	10.67	.009	.817	-.9781	-.0141	-4.0401	36.00000
60.0	.0025	360.58	281.00	.97	.119	.985	-.1507	-.0022	-4.0402	36.00000
63.0	.0005	977.07	281.00	.15	.787	.999	-.1186	-.0017	-4.0403	36.00000
66.0	.0004	1174.04	281.01	.12	1.000	1.000	-.1184	-.0017	-4.0404	36.00000
69.0	.0002	1174.58	282.00	.12	1.000	1.000	-.1184	-.0017	-4.0405	36.00000
72.0	.0001	1174.60	282.04	.12	1.000	1.000	-.1186	-.0017	-4.0405	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT), DATE 04/22/76 0 TIME 12.10.20 1

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = 1.19171 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	-112.98711
3.0 - 6.0	-120.46384
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 45

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
46	.00819	.209	23.68	8.35	24.9286	1.2001	.0005
SURFACE LEVEL	18.834	53.056					
48	.00803	.208	24.23	8.63	25.3692	1.2083	.0005
SURFACE LEVEL	19.252	52.638					
47	.00799	.207	24.79	9.00	25.7837	1.2163	.0005
SURFACE LEVEL	19.670	52.218					
47	.00776	.207	25.38	9.36	26.1741	1.2242	.0005
SURFACE LEVEL	20.091	51.797					
46	.00765	.206	26.48	9.70	26.5429	1.2320	.0005
SURFACE LEVEL	20.513	51.374					
46	.00754	.206	26.76	10.02	26.8915	1.2396	.0005
SURFACE LEVEL	20.936	50.950					
47	.00742	.207	27.39	10.32	27.3878	1.2471	.0005
SURFACE LEVEL	21.360	50.525					
47	.00734	.204	27.42	10.61	27.5332	1.2546	.0005
SURFACE LEVEL	21.785	50.100					
47	.00726	.204	27.73	10.88	27.8281	1.2619	.0005
SURFACE LEVEL	22.211	49.674					
48	.00719	.204	28.09	11.13	28.1068	1.2692	.0005
SURFACE LEVEL	22.638	49.246					
47	.00705	.208	28.88	11.36	28.8793	1.2764	.0005
SURFACE LEVEL	23.066	48.817					
45	.00690	.209	29.66	11.58	29.6554	1.2834	.0005
SURFACE LEVEL	23.491	48.391					
45	.00682	.205	29.67	11.79	29.6695	1.2903	.0005
SURFACE LEVEL	23.911	47.971					
45	.00674	.205	30.01	11.98	30.0058	1.2971	.0005
SURFACE LEVEL	24.330	47.551					
45	.00670	.203	30.06	12.15	30.0571	1.3039	.0005
SURFACE LEVEL	24.749	47.132					
46	.00666	.202	30.21	12.32	30.2078	1.3106	.0005
SURFACE LEVEL	25.168	46.712					
45	.00662	.202	30.41	12.47	30.4054	1.3172	.0005
SURFACE LEVEL	25.588	46.292					
45	.00652	.206	31.10	12.61	31.0978	1.3238	.0005
SURFACE LEVEL	26.008	45.871					
43	.00640	.208	31.84	12.74	31.8402	1.3304	.0005
SURFACE LEVEL	26.425	45.453					
43	.00636	.202	31.62	12.86	31.6218	1.3368	.0005
SURFACE LEVEL	26.837	45.041					
43	.00635	.201	31.60	12.98	31.6007	1.3431	.0005
SURFACE LEVEL	27.248	44.627					
44	.00633	.201	31.62	13.08	31.6249	1.3495	.0005
SURFACE LEVEL	27.660	44.217					
44	.00632	.201	31.70	13.17	31.7008	1.3558	.0005
SURFACE LEVEL	28.074	43.803					
44	.00631	.201	31.77	13.26	31.7736	1.3621	.0005
SURFACE LEVEL	28.468	43.388					
44	.00627	.203	32.11	13.33	32.1055	1.3684	.0005
SURFACE LEVEL	28.902	42.973					
42	.00618	.206	32.83	13.40	32.8327	1.3747	.0005
SURFACE LEVEL	29.315	42.560					
42	.00614	.203	32.82	13.46	32.8178	1.3809	.0005
SURFACE LEVEL	29.723	42.152					
41	.00614	.200	32.54	13.52	32.5365	1.3870	.0005
SURFACE LEVEL	30.129	41.745					
43	.00615	.199	32.43	13.56	32.4304	1.3932	.0005
[illegible]	[illegible]	[illegible]					
43	.00616	.199	32.40	13.60	32.3958	1.3993	.0005
SURFACE LEVEL	30.944	40.929					

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.31 1

TIME = 1.39932 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5361	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	1.4356	250.20	281.00	57.89	0.000	0.000	49.2130	.7087	3.4004	36.00000
6.0	1.0961	250.20	281.00	57.89	0.000	0.000	80.0423	1.1526	5.5306	36.00000
9.0	.8002	250.19	280.99	57.89	0.000	0.000	80.0356	1.1525	5.5301	36.00000
12.0	.6967	250.18	280.98	57.89	0.000	0.000	80.0296	1.1524	5.5297	36.00000
15.0	.5932	250.16	280.96	57.89	0.000	0.000	80.0242	1.1523	5.5292	36.00000
18.0	.4697	250.15	280.95	57.89	0.000	0.000	80.0189	1.1523	5.5289	36.00000
21.0	.3862	250.18	280.98	57.89	0.000	0.000	80.0134	1.1522	5.5285	36.00000
24.0	.2627	250.20	281.00	57.89	.000	.000	80.0064	1.1521	5.5283	36.00000
27.0	.1798	250.22	281.00	57.39	.000	.009	79.3206	1.1422	5.5281	36.00000
30.0	.0769	250.67	281.00	46.37	.001	.199	64.0793	.9227	5.5280	36.00000
33.0	-.0465	253.82	281.00	19.77	.004	.660	27.3258	.3935	5.5279	36.00000
36.0	-.0280	263.60	281.00	7.11	.015	.879	9.8321	.1416	5.5275	36.00000
39.0	-.0094	290.53	281.00	2.56	.044	.957	3.5588	.0512	5.5269	36.00000
42.0	-.0023	364.73	281.00	.93	.124	.986	1.2900	.0186	5.5252	36.00000
45.0	.0003	575.14	281.00	.33	.352	.996	.4591	.0066	5.5210	36.00000
48.0	.0014	915.54	281.00	.16	.720	.999	.2246	.0032	5.5130	36.00000
51.0	.0016	1104.20	281.00	.13	.924	1.000	.1748	.0025	5.5037	36.00000
54.0	.0015	1158.44	281.00	.12	.983	1.000	.1641	.0024	5.4947	36.00000
57.0	.0013	1170.73	281.00	.12	.996	1.000	.1617	.0023	5.4869	36.00000
60.0	.0011	1173.35	281.00	.12	.999	1.000	.1610	.0023	5.4805	36.00000
63.0	.0008	1173.90	281.00	.12	1.000	1.000	.1608	.0023	5.4756	36.00000
66.0	.0006	1174.01	281.00	.12	1.000	1.000	.1607	.0023	5.4723	36.00000
69.0	.0004	1174.03	281.00	.12	1.000	1.000	.1606	.0023	5.4706	36.00000
72.0	.0002	1174.04	281.00	.12	1.000	1.000	.1606	.0023	5.4706	36.00000

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.31 1

TIME = 1.39932 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.7345	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	1.5622	250.20	281.00	57.89	0.000	0.000	-49.2261	-.7089	-3.4013	36.00000
6.0	1.2761	250.20	281.00	57.89	0.000	0.000	-80.0681	-1.1530	-5.5324	36.00000
9.0	1.1049	250.20	281.00	57.89	0.000	0.000	-80.0721	-1.1530	-5.5327	36.00000
12.0	1.0073	250.20	281.00	57.89	0.000	0.000	-80.0756	-1.1531	-5.5329	36.00000
15.0	.9098	250.20	281.00	57.89	.000	.000	-80.0786	-1.1531	-5.5331	36.00000
18.0	.8122	250.20	281.00	57.89	.000	.000	-80.0806	-1.1532	-5.5333	36.00000
21.0	.7146	250.20	281.00	57.89	.000	.000	-80.0798	-1.1531	-5.5335	36.00000
24.0	.6171	250.20	281.00	57.89	.000	.000	-80.0672	-1.1530	-5.5336	36.00000
27.0	.5197	250.20	281.00	57.88	.000	.000	-80.0007	-1.1520	-5.5337	36.00000
30.0	.4228	250.20	281.00	57.83	.000	.001	-79.6812	-1.1474	-5.5337	36.00000
33.0	.3284	250.21	281.00	57.60	.000	.005	-78.1903	-1.1259	-5.5336	36.00000
36.0	.2050	250.25	281.00	56.52	.000	.024	-71.6262	-1.0314	-5.5336	36.00000
39.0	.1936	250.42	281.00	51.77	.000	.106	-48.8263	-.7031	-5.5338	36.00000
42.0	.1339	251.40	281.00	35.29	.001	.391	-12.6717	-.1825	-5.5336	36.00000
45.0	.0240	260.19	281.00	9.16	.011	.843	-1.2393	-.0178	-5.5337	36.00000
48.0	.0033	369.67	281.00	.90	.129	.987	-.1799	-.0026	-5.5332	36.00000
51.0	.0016	1084.08	281.00	.13	.903	1.000	-.1625	-.0023	-5.5326	36.00000
54.0	.0014	1173.87	281.00	.12	1.000	1.000	-.1624	-.0023	-5.5321	36.00000
57.0	.0012	1174.13	281.18	.12	1.000	1.000	-.1623	-.0023	-5.5316	36.00000
60.0	.0010	1174.20	281.31	.12	1.000	1.000	-.1623	-.0023	-5.5313	36.00000
63.0	.0008	1174.20	281.30	.12	1.000	1.000	-.1623	-.0023	-5.5310	36.00000
66.0	.0006	1174.15	281.20	.12	1.000	1.000	-.1624	-.0023	-5.5308	36.00000
69.0	.0004	1174.08	281.07	.12	1.000	1.000	-.1624	-.0023	-5.5307	36.00000
72.0	.0002	1174.03	281.00	.12	1.000	1.000	-.1624	-.0023	-5.5307	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT), DATE 04/22/76 0 TIME 12.10.31 1

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = 1.39932 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	-196.68363
3.0 - 6.0	-123.34929
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 43

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
42	.00617	.199	32.35	13.64	32.3514	1.4055	.0005
SURFACE LEVEL	31.353	40.519					
43	.00618	.199	32.31	13.66	32.3086	1.4117	.0005
SURFACE LEVEL	31.763	40.109					
42	.00613	.203	32.89	13.68	32.8915	1.4178	.0005
SURFACE LEVEL	32.174	39.698					
41	.00607	.204	33.28	13.70	33.2837	1.4240	.0005
SURFACE LEVEL	32.580	39.291					
40	.00608	.199	32.86	13.71	32.8612	1.4300	.0005
SURFACE LEVEL	32.983	38.888					
41	.00611	.198	32.53	13.71	32.5277	1.4361	.0005
SURFACE LEVEL	33.385	38.486					
41	.00614	.198	32.39	13.70	32.3913	1.4422	.0005
SURFACE LEVEL	33.789	38.081					
41	.00617	.198	32.24	13.69	32.2442	1.4484	.0005
SURFACE LEVEL	34.194	37.676					
41	.00620	.196	32.10	13.68	32.0958	1.4545	.0005
SURFACE LEVEL	34.600	37.270					
40	.00620	.200	32.30	13.66	32.3001	1.4607	.0005
SURFACE LEVEL	35.007	36.862					
40	.00614	.203	32.82	13.63	32.8214	1.4669	.0005
SURFACE LEVEL	35.412	36.457					
38	.00614	.200	32.56	13.60	32.5552	1.4731	.0005
SURFACE LEVEL	35.812	36.056					
38	.00619	.197	32.07	13.56	32.0744	1.4792	.0005
SURFACE LEVEL	36.210	35.658					
39	.00624	.197	31.75	13.52	31.7530	1.4854	.0005
SURFACE LEVEL	36.610	35.258					
38	.00629	.197	31.51	13.47	31.5115	1.4917	.0005
SURFACE LEVEL	37.011	34.856					
38	.00635	.197	31.27	13.41	31.2658	1.4980	.0005
SURFACE LEVEL	37.413	34.454					
38	.00639	.197	31.10	13.35	31.0950	1.5043	.0005
SURFACE LEVEL	37.816	34.050					
37	.00637	.201	31.53	13.29	31.5318	1.5107	.0005
SURFACE LEVEL	38.219	33.647					
36	.00634	.201	31.63	13.21	31.6306	1.5171	.0005
SURFACE LEVEL	38.618	33.247					
36	.00640	.197	31.02	13.14	31.0217	1.5234	.0005
SURFACE LEVEL	39.013	32.852					
36	.00648	.195	30.50	13.06	30.4979	1.5298	.0005
SURFACE LEVEL	39.408	32.457					
36	.00655	.195	30.17	12.97	30.1710	1.5363	.0004
SURFACE LEVEL	39.805	32.059					
35	.00663	.195	29.83	12.87	29.8333	1.5428	.0005
SURFACE LEVEL	40.203	31.661					
35	.00670	.195	29.49	12.77	29.4922	1.5495	.0004
SURFACE LEVEL	40.602	31.262					
34	.00673	.199	29.63	12.67	29.6334	1.5562	.0005
SURFACE LEVEL	41.001	30.862					
33	.00670	.202	29.96	12.55	29.9629	1.5629	.0005
SURFACE LEVEL	41.398	30.465					
32	.00676	.197	29.36	12.44	29.3606	1.5696	.0005
SURFACE LEVEL	41.769	30.074					
32	.00685	.195	28.81	12.32	28.8051	1.5763	.0005
SURFACE LEVEL	42.178	29.684					
32	.00697	.193	28.22	12.19	28.2156	1.5832	.0004
[illegible]	[illegible]	[illegible]					
32	.00708	.193	27.77	12.05	27.7726	1.5902	.0004
SURFACE LEVEL	42.960	28.902					

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.40 1

TIME = 1.59015 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.4072	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	1.3067	250.20	281.00	57.89	0.000	0.000	43.6079	.6280	3.0131	36.00000
6.0	1.0406	250.20	281.00	57.89	0.000	0.000	67.8759	.9774	4.6899	36.00000
9.0	.8341	250.20	281.00	57.89	0.000	0.000	67.8738	.9774	4.6898	36.00000
12.0	.7611	250.20	281.00	57.89	0.000	0.000	67.8701	.9773	4.6895	36.00000
15.0	.6881	250.19	280.99	57.89	0.000	0.000	67.8648	.9773	4.6892	36.00000
18.0	.6150	250.19	280.99	57.89	0.000	0.000	67.8582	.9772	4.6887	36.00000
21.0	.5420	250.18	280.98	57.89	0.000	0.000	67.8505	.9770	4.6882	36.00000
24.0	.4690	250.18	280.98	57.89	0.000	0.000	67.8422	.9769	4.6876	36.00000
27.0	.3960	250.18	280.98	57.89	0.000	0.000	67.8338	.9768	4.6870	36.00000
30.0	.3230	250.18	280.98	57.89	0.000	0.000	67.8257	.9767	4.6864	36.00000
33.0	.2500	250.19	280.99	57.89	0.000	0.000	67.8185	.9766	4.6860	36.00000
36.0	.1770	250.20	281.00	57.89	.000	.000	67.8120	.9765	4.6856	36.00000
39.0	.1045	250.21	281.00	57.58	.000	.005	67.4402	.9711	4.6854	36.00000
42.0	.0359	250.62	281.00	47.29	.000	.183	55.3948	.7977	4.6852	36.00000
45.0	-.0519	253.92	281.00	19.42	.004	.666	22.7428	.3275	4.6849	36.00000
48.0	-.0261	264.13	281.00	6.88	.015	.883	8.0531	.1160	4.6845	36.00000
51.0	-.0092	292.62	281.00	2.45	.046	.960	2.8733	.0414	4.6836	36.00000
54.0	-.0029	372.13	281.00	.88	.132	.987	1.0278	.0148	4.6818	36.00000
57.0	-.0006	600.62	281.00	.31	.379	.997	.3608	.0052	4.6774	36.00000
60.0	.0003	953.95	281.00	.15	.762	.999	.1799	.0026	4.6703	36.00000
63.0	.0005	1121.63	281.00	.12	.943	1.000	.1451	.0021	4.6634	36.00000
66.0	.0004	1163.43	281.00	.12	.989	1.000	.1384	.0020	4.6586	36.00000
69.0	.0003	1171.99	281.00	.12	.998	1.000	.1370	.0020	4.6561	36.00000
72.0	.0001	1173.69	281.00	.12	1.000	1.000	.1368	.0020	4.6561	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.40 1

TIME = 1.59015 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.5065	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	1.3481	250.20	281.00	57.89	0.000	0.000	-43.6047	-.6279	-3.0129	36.00000
6.0	1.0915	250.20	281.00	57.89	.000	.000	-67.8706	-.9773	-4.6896	36.00000
9.0	.9129	250.20	281.00	57.89	.000	.000	-67.8673	-.9773	-4.6895	36.00000
12.0	.7849	250.20	281.00	57.89	.000	.000	-67.8576	-.9772	-4.6894	36.00000
15.0	.6570	250.20	281.00	57.88	.000	.000	-67.8145	-.9765	-4.6893	36.00000
18.0	.5295	250.20	281.00	57.85	.000	.001	-67.5990	-.9734	-4.6893	36.00000
21.0	.4041	250.21	281.00	57.66	.000	.004	-66.5067	-.9577	-4.6892	36.00000
24.0	.2883	250.24	281.00	56.73	.000	.020	-61.2167	-.8615	-4.6892	36.00000
27.0	.2035	250.40	281.00	52.22	.000	.098	-41.2226	-.5936	-4.6892	36.00000
30.0	.1220	251.41	281.00	35.16	.001	.393	-9.5102	-.1369	-4.6892	36.00000
33.0	.0217	261.72	281.00	8.11	.012	.862	-.9467	-.0136	-4.6890	36.00000
36.0	.0046	382.94	281.00	.81	.144	.988	-.1467	-.0021	-4.6878	36.00000
39.0	.0031	1116.71	281.00	.13	.938	1.000	-.1376	-.0020	-4.6867	36.00000
42.0	.0029	1173.96	281.00	.12	1.000	1.000	-.1376	-.0020	-4.6856	36.00000
45.0	.0026	1174.07	281.06	.12	1.000	1.000	-.1375	-.0020	-4.6847	36.00000
48.0	.0023	1174.11	281.13	.12	1.000	1.000	-.1375	-.0020	-4.6838	36.00000
51.0	.0021	1174.13	281.16	.12	1.000	1.000	-.1375	-.0020	-4.6831	36.00000
54.0	.0018	1174.12	281.16	.12	1.000	1.000	-.1374	-.0020	-4.6824	36.00000
57.0	.0016	1174.10	281.11	.12	1.000	1.000	-.1374	-.0020	-4.6819	36.00000
60.0	.0013	1174.07	281.05	.12	1.000	1.000	-.1374	-.0020	-4.6815	36.00000
63.0	.0010	1174.04	281.00	.12	1.000	1.000	-.1374	-.0020	-4.6812	36.00000
66.0	.0008	1174.03	281.00	.12	1.000	1.000	-.1374	-.0020	-4.6810	36.00000
69.0	.0005	1174.03	281.00	.12	1.000	1.000	-.1374	-.0020	-4.6809	36.00000
72.0	.0003	1174.03	281.00	.12	1.000	1.000	-.1374	-.0020	-4.6809	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT), DATE 04/22/76 0 TIME 12.10.40 1

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = 1.59015 SECONDS

AXIAL ZONE			W(1, 2)
0.0	-	3.0	-174.42637
3.0	-	6.0	-97.07216
6.0	-	9.0	0.00000
9.0	-	12.0	0.00000
12.0	-	15.0	0.00000
15.0	-	18.0	0.00000
18.0	-	21.0	0.00000
21.0	-	24.0	0.00000
24.0	-	27.0	0.00000
27.0	-	30.0	0.00000
30.0	-	33.0	0.00000
33.0	-	36.0	0.00000
36.0	-	39.0	0.00000
39.0	-	42.0	0.00000
42.0	-	45.0	0.00000
45.0	-	48.0	0.00000
48.0	-	51.0	0.00000
51.0	-	54.0	0.00000
54.0	-	57.0	0.00000
57.0	-	60.0	0.00000
60.0	-	63.0	0.00000
63.0	-	66.0	0.00000
66.0	-	69.0	0.00000
69.0	-	72.0	0.00000

ITERATIONS = 32

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
31	.00720	.193	27.32	11.91	27.3190	1.5972	.0005
SURFACE LEVEL	43.352	28.509					
31	.00730	.194	27.02	11.76	27.0153	1.6044	.0004
SURFACE LEVEL	43.746	28.115					
30	.00732	.199	27.23	11.60	27.2316	1.6117	.0004
SURFACE LEVEL	44.139	27.722					
29	.00736	.198	27.03	11.44	27.0275	1.6191	.0004
SURFACE LEVEL	44.526	27.334					
28	.00750	.193	26.20	11.27	26.1975	1.6264	.0004
SURFACE LEVEL	44.909	26.951					
27	.00765	.192	25.61	11.10	25.6110	1.6339	.0005
SURFACE LEVEL	45.292	26.568					
27	.00783	.191	24.93	10.91	24.9285	1.6416	.0004
SURFACE LEVEL	45.675	26.184					
27	.00802	.191	24.36	10.72	24.3579	1.6494	.0004
SURFACE LEVEL	46.059	25.800					
27	.00821	.191	23.77	10.52	23.7723	1.6574	.0004
SURFACE LEVEL	46.444	25.415					
26	.00834	.194	23.59	10.30	23.5934	1.6656	.0004
SURFACE LEVEL	46.829	25.030					
25	.00840	.197	23.62	10.08	23.6210	1.6740	.0004
SURFACE LEVEL	47.210	24.648					
24	.00857	.192	22.87	9.85	22.8670	1.6824	.0004
SURFACE LEVEL	47.584	24.274					
24	.00884	.188	21.91	9.62	21.9130	1.6909	.0004
SURFACE LEVEL	47.954	23.904					
23	.00915	.187	21.12	9.37	21.1158	1.6998	.0004
SURFACE LEVEL	48.325	23.533					
22	.00945	.187	20.48	9.11	20.4757	1.7089	.0004
SURFACE LEVEL	48.695	23.162					
22	.00980	.185	19.63	8.83	19.6329	1.7184	.0004
SURFACE LEVEL	49.064	22.794					
21	.01019	.185	18.85	8.54	18.8462	1.7282	.0004
SURFACE LEVEL	49.431	22.426					
21	.01052	.188	18.40	8.24	18.4039	1.7384	.0004
SURFACE LEVEL	49.797	22.061					
20	.01078	.190	18.08	7.91	18.0820	1.7489	.0004
SURFACE LEVEL	50.156	21.702					
19	.01121	.185	17.13	7.58	17.1303	1.7597	.0004
SURFACE LEVEL	50.505	21.353					
19	.01185	.179	15.93	7.23	15.9275	1.7709	.0004
SURFACE LEVEL	50.846	21.012					
18	.01263	.175	14.79	6.86	14.7852	1.7827	.0004
SURFACE LEVEL	51.183	20.676					
18	.01354	.173	13.71	6.45	13.7147	1.7954	.0004
SURFACE LEVEL	51.514	20.345					
17	.01462	.170	12.59	6.02	12.5926	1.8089	.0004
SURFACE LEVEL	51.838	20.023					
16	.01595	.167	11.40	5.55	11.3973	1.8235	.0005
SURFACE LEVEL	52.148	19.713					
50	.01746	.161	10.11	5.03	10.1146	1.8395	.0005
SURFACE LEVEL	52.442	19.421					
155	.01974	.158	8.68	4.47	8.9378	1.8571	.0005
SURFACE LEVEL	52.710	19.153					
200	.02072	.152	7.13	3.84	7.6768	1.8768	.0010
SURFACE LEVEL	52.937	18.925					
200	.02074	.132	5.82	3.19	6.3720	1.8976	.0008
SURFACE LEVEL	[illegible]	[illegible]					
165	.02075	.105	4.69	2.54	5.0810	1.9183	.0005
SURFACE LEVEL	53.174	18.688					

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.50 1

TIME = 1.91831 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.9915	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	.8910	250.20	281.00	57.89	0.000	0.000	9.1916	.1324	.6351	36.00000
6.0	.8069	250.20	281.00	57.89	0.000	0.000	4.5406	.0654	.3137	36.00000
9.0	.7573	250.20	281.00	57.89	0.000	0.000	4.5404	.0654	.3137	36.00000
12.0	.7057	250.20	281.00	57.89	0.000	0.000	4.5403	.0654	.3137	36.00000
15.0	.6540	250.20	281.00	57.89	0.000	0.000	4.5401	.0654	.3137	36.00000
18.0	.6024	250.20	281.00	57.89	0.000	0.000	4.5400	.0654	.3137	36.00000
21.0	.5508	250.20	281.00	57.89	0.000	0.000	4.5399	.0654	.3137	36.00000
24.0	.4991	250.19	280.99	57.89	0.000	0.000	4.5397	.0654	.3137	36.00000
27.0	.4475	250.19	280.99	57.89	0.000	0.000	4.5396	.0654	.3137	36.00000
30.0	.3958	250.19	280.99	57.89	0.000	0.000	4.5595	.0654	.3137	36.00000
33.0	.3442	250.18	280.98	57.89	0.000	0.000	4.5395	.0654	.3137	36.00000
36.0	.2926	250.18	280.98	57.89	0.000	0.000	4.5394	.0654	.3137	36.00000
39.0	.2409	250.19	280.99	57.89	0.000	0.000	4.5593	.0654	.3136	36.00000
42.0	.1893	250.19	280.99	57.89	0.000	0.000	4.5392	.0654	.3136	36.00000
45.0	.1377	250.20	281.00	57.89	0.000	0.000	4.5392	.0654	.3136	36.00000
48.0	.0860	250.20	281.00	57.89	0.000	0.000	4.5391	.0654	.3136	36.00000
51.0	.0345	250.20	281.00	57.88	.000	.000	4.5381	.0653	.3136	36.00000
54.0	.0073	251.74	281.00	31.79	.002	.452	2.4924	.0359	.3136	36.00000
57.0	.0004	262.91	281.00	7.45	.014	.873	.5844	.0084	.3136	36.00000
60.0	.0004	296.35	281.00	2.26	.050	.963	.1775	.0026	.3136	36.00000
63.0	.0003	395.62	281.00	.74	.158	.989	.0573	.0008	.3136	36.00000
66.0	.0002	732.17	281.00	.22	.522	.998	.0175	.0003	.3136	36.00000
69.0	.0002	1168.55	281.00	.12	.994	1.000	.0095	.0001	.3136	36.00000
72.0	.0001	1174.06	281.03	.12	1.000	1.000	.0092	.0001	.3136	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.50 1

TIME = 1.91831 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.9173	1174.00	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	.8129	250.20	281.00	57.89	0.000	0.000	-9.1919	-.1324	-.6351	36.00000
6.0	.6871	250.20	281.00	57.89	0.000	0.000	-4.5412	-.0654	-.3138	36.00000
9.0	.5383	250.20	281.00	57.89	0.000	0.000	-4.5413	-.0654	-.3138	36.00000
12.0	.3890	250.20	281.00	57.89	0.000	0.000	-4.5394	-.0654	-.3138	36.00000
15.0	.2402	250.20	281.00	57.87	.000	.000	-4.2924	-.0618	-.3138	36.00000
18.0	.1016	250.31	281.00	54.72	.000	.055	-1.2195	-.0176	-.3138	36.00000
21.0	.0244	255.32	281.00	15.54	.006	.733	-.0903	-.0013	-.3141	36.00000
24.0	.0065	342.87	281.00	1.15	.100	.982	-.0091	-.0001	-.3171	36.00000
27.0	.0049	1182.99	297.67	.11	1.000	1.000	-.0094	-.0001	-.3200	36.00000
30.0	.0046	1174.05	281.01	.12	1.000	1.000	-.0095	-.0001	-.3228	36.00000
33.0	.0043	1174.05	281.03	.12	1.000	1.000	-.0096	-.0001	-.3255	36.00000
36.0	.0040	1174.07	281.06	.12	1.000	1.000	-.0096	-.0001	-.3281	36.00000
39.0	.0037	1174.09	281.09	.12	1.000	1.000	-.0097	-.0001	-.3306	36.00000
42.0	.0034	1174.10	281.11	.12	1.000	1.000	-.0098	-.0001	-.3328	36.00000
45.0	.0031	1174.09	281.10	.12	1.000	1.000	-.0098	-.0001	-.3350	36.00000
48.0	.0028	1174.08	281.07	.12	1.000	1.000	-.0099	-.0001	-.3369	36.00000
51.0	.0025	1174.05	281.02	.12	1.000	1.000	-.0099	-.0001	-.3386	36.00000
54.0	.0022	1174.04	281.00	.12	1.000	1.000	-.0100	-.0001	-.3400	36.00000
57.0	.0019	1174.04	281.00	.12	1.000	1.000	-.0100	-.0001	-.3413	36.00000
60.0	.0015	1174.04	281.00	.12	1.000	1.000	-.0100	-.0001	-.3423	36.00000
63.0	.0012	1174.04	281.00	.12	1.000	1.000	-.0101	-.0001	-.3430	36.00000
66.0	.0009	1174.04	281.00	.12	1.000	1.000	-.0101	-.0001	-.3436	36.00000
69.0	.0006	1174.04	281.00	.12	1.000	1.000	-.0101	-.0001	-.3436	36.00000
72.0	.0003	1174.04	281.00	.12	1.000	1.000	-.0101	-.0001	-.3438	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT). DATE 04/22/76 0 TIME 12.10.50 1

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = 1.91831 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	-36.76713
3.0 - 6.0	16.60345
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 165

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.51 1

TIME = 2.00136 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	1.0734	250.20	281.00	57.89	0.000	0.000	0.0000	0.0000	0.0000	36.00000
3.0	.9729	250.20	281.00	57.89	0.000	0.000	.5116	.0074	.0355	36.00000
6.0	.8918	250.20	281.00	57.89	0.000	0.000	-14.2165	-.2047	-.9823	36.00000
9.0	.8367	250.20	281.00	57.89	0.000	0.000	-14.2341	-.2050	-.9835	36.00000
12.0	.7847	250.20	281.00	57.89	0.000	0.000	-14.2519	-.2052	-.9848	36.00000
15.0	.7325	250.20	281.00	57.89	0.000	0.000	-14.2696	-.2055	-.9860	36.00000
18.0	.6801	250.20	281.00	57.89	0.000	0.000	-14.2868	-.2057	-.9872	36.00000
21.0	.6275	250.20	281.00	57.89	0.000	0.000	-14.3033	-.2060	-.9883	36.00000
24.0	.5746	250.19	280.99	57.89	0.000	0.000	-14.3188	-.2062	-.9894	36.00000
27.0	.5215	250.19	280.99	57.89	0.000	0.000	-14.3330	-.2064	-.9903	36.00000
30.0	.4682	250.18	280.99	57.89	0.000	0.000	-14.3457	-.2066	-.9912	36.00000
33.0	.4148	250.18	280.98	57.89	0.000	0.000	-14.3567	-.2067	-.9920	36.00000
36.0	.3612	250.18	280.99	57.89	0.000	0.000	-14.3656	-.2069	-.9926	36.00000
39.0	.3074	250.19	280.99	57.89	0.000	0.000	-14.3728	-.2070	-.9931	36.00000
42.0	.2536	250.20	281.00	57.89	.000	.000	-14.3760	-.2070	-.9935	36.00000
45.0	.1997	250.20	281.00	57.88	.000	.000	-14.3453	-.2066	-.9937	36.00000
48.0	.1457	250.20	281.00	57.75	.000	.003	-13.8042	-.1988	-.9938	36.00000
51.0	.0920	250.28	281.00	55.56	.000	.040	-7.4178	-.1068	-.9938	36.00000
54.0	.0370	251.96	281.00	29.86	.002	.485	-.9073	-.0131	-.9939	36.00000
57.0	.0057	278.09	281.00	3.65	.030	.939	-.2796	-.0040	-.9940	36.00000
60.0	.0022	344.96	281.00	1.12	.103	.983	-.0822	-.0012	-.9942	36.00000
63.0	.0057	576.88	281.00	.33	.354	.996	-.0287	-.0004	-.9947	36.00000
66.0	.0033	1180.26	292.59	.12	1.000	1.000	-.0291	-.0004	-.9951	36.00000
69.0	.0032	1175.17	283.10	.12	1.000	1.000	-.0292	-.0004	-.9952	36.00000
72.0	.0001	1174.05	281.02	.12	1.000	1.000	-.0292	-.0004	-.9952	36.00000

DAMPED U-TUBE MANOMETER PROBLEM OUTPUT (Continued)

CHANNEL RESULTS
CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION DATE 04/22/76 0 TIME 12.10.51 1

TIME = 2.00136 SECONDS PRESSURE = 50.0 PSIA DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL. QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)	VELOCITY (FT/SEC)	AREA (SQ-IN)
0.0	.9883	1174.09	281.00	.12	1.000	1.000	0.0000	0.0000	0.0000	36.00000
3.0	.8875	250.20	281.00	57.89	0.000	0.000	-.5439	-.0078	-.0376	36.00000
6.0	.7661	250.20	281.00	57.89	0.000	0.000	14.1532	.2038	.9779	36.00000
9.0	.6101	250.20	281.00	57.89	0.000	0.000	14.1448	.2037	.9773	36.00000
12.0	.4598	250.20	281.00	57.89	0.000	0.000	14.1387	.2036	.9769	36.00000
15.0	.3094	249.75	280.56	57.90	0.000	0.000	14.1381	.2036	.9767	36.00000
18.0	.1595	250.21	281.00	57.62	.000	.005	14.0682	.2026	.9766	36.00000
21.0	.0449	253.75	281.00	20.03	.004	.655	4.8893	.0704	.9765	36.00000
24.0	.0098	286.88	281.00	2.82	.040	.953	.6882	.0099	.9762	36.00000
27.0	.0053	548.64	281.00	.36	.323	.996	.0882	.0013	.9750	36.00000
30.0	.0045	1060.60	281.00	.13	.877	1.000	.0329	.0005	.9721	36.00000
33.0	.0042	1165.31	281.00	.12	.991	1.000	.0287	.0004	.9692	36.00000
36.0	.0039	1173.39	281.00	.12	.999	1.000	.0284	.0004	.9664	36.00000
39.0	.0036	1174.06	281.05	.12	1.000	1.000	.0283	.0004	.9639	36.00000
42.0	.0033	1174.09	281.10	.12	1.000	1.000	.0282	.0004	.9616	36.00000
45.0	.0030	1174.09	281.10	.12	1.000	1.000	.0282	.0004	.9595	36.00000
48.0	.0027	1174.08	281.08	.12	1.000	1.000	.0281	.0004	.9577	36.00000
51.0	.0024	1174.05	281.02	.12	1.000	1.000	.0281	.0004	.9562	36.00000
54.0	.0021	1174.04	281.00	.12	1.000	1.000	.0280	.0004	.9548	36.00000
57.0	.0018	1174.04	281.00	.12	1.000	1.000	.0280	.0004	.9537	36.00000
60.0	.0015	1174.04	281.00	.12	1.000	1.000	.0280	.0004	.9528	36.00000
63.0	.0012	1174.04	281.00	.12	1.000	1.000	.0280	.0004	.9521	36.00000
66.0	.0009	1174.04	281.00	.12	1.000	1.000	.0279	.0004	.9517	36.00000
69.0	.0006	1174.04	281.00	.12	1.000	1.000	.0279	.0004	.9515	36.00000
72.0	.0003	1174.04	281.00	.12	1.000	1.000	.0279	.0004	.9515	36.00000

DATA FROM EXPLICIT SOLUTION....

NO. TRIES	TIME STEP	COURANT NUMBER	VELOCITY COMPONENTS U/DX	V/DY	(U/DX+V/DY)	TOTAL TIME	VOLUME ERROR
20	.02076	.079	3.70	1.96	3.8301	1.9391	.0004
SURFACE LEVEL	53.170	18.691					
61	.02077	.106	5.13	2.64	5.1251	1.9598	.0005
SURFACE LEVEL	53.081	18.771					
44	.02078	.134	6.45	3.35	6.4513	1.9806	.0005
SURFACE LEVEL	52.910	18.931					
65	.02079	.166	7.71	4.06	7.9942	2.0014	.0005
SURFACE LEVEL	52.662	19.175					

NUMBER OF TIME STEPS = 305
TOTAL ITERATIONS = 10637
ITERATIONS/TIME STEP = 34

DATE 04/22/76 0 TIME 12.10.51 1

DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J), (LB/SEC-FT),

CASE 1 ISOTHERMAL U-TUBE MANOMETER DEMONSTRATION

TIME = 2.00136 SECONDS

AXIAL ZONE	W(1, 2)
0.0 - 3.0	-2.12527
3.0 - 6.0	56.83081
6.0 - 9.0	0.00000
9.0 - 12.0	0.00000
12.0 - 15.0	0.00000
15.0 - 18.0	0.00000
18.0 - 21.0	0.00000
21.0 - 24.0	0.00000
24.0 - 27.0	0.00000
27.0 - 30.0	0.00000
30.0 - 33.0	0.00000
33.0 - 36.0	0.00000
36.0 - 39.0	0.00000
39.0 - 42.0	0.00000
42.0 - 45.0	0.00000
45.0 - 48.0	0.00000
48.0 - 51.0	0.00000
51.0 - 54.0	0.00000
54.0 - 57.0	0.00000
57.0 - 60.0	0.00000
60.0 - 63.0	0.00000
63.0 - 66.0	0.00000
66.0 - 69.0	0.00000
69.0 - 72.0	0.00000

ITERATIONS = 65

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