CORTAN Code User Manual

**R. L. Cheatham
S. L. Crawford
E. U. Khan**

February 1981

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

The views, opinions and conclusions contained in this report are those of the contractor and do not necessarily represent those of the United States Government or the United States Department of Energy.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
Under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy \$ _____*; Microfiche \$3.00

*Pages	NTIS
	Selling Price
001-025	\$4.00
026-050	\$4.50
051-075	\$5.25
076-100	\$6.00
101-125	\$6.50
126-150	\$7.25
151-175	\$8.00
176-200	\$9.00
201-225	\$9.25
226-250	\$9.50
251-275	\$10.75
276-300	\$11.00

3 3679 00059 6892

CORTAN CODE USER MANUAL

R. L. Cheatham
S. L. Crawford
E. U. Khan

February 1981

Prepared for the
U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Dr. R. J. Neuhold for his direction and support in this work. The work of Mr. Tom Greene is also acknowledged for implementing a new solution scheme in the CORTRAN III model. The single assembly version of CORTRAN, called TRAN (I, II, III), was completed at the Argonne National Laboratory by one of the authors (E. U. Khan). Thanks are due to A. Hinds and P. Bertoncini for their help on the TRAN code.

SUMMARY

CORTRAN has been developed as a relatively fast running design code for core-wide steady-state and transient analysis of Liquid Metal Fast Breeder Reactor (LMFBR) cores. The preliminary version of this computer program uses subchannel analysis techniques to compute the velocity and temperature fields on a multiassembly basis for three types of transient forcing functions: total power, total flow, and inlet coolant temperature. Interassembly heat transfer, intra-assembly heat transfer, and intra-assembly flow redistribution due to buoyancy are taken into account. Heat generation within the fuel rods and assembly duct walls is also included. Individual pin radial peaking factors (peak to average for each assembly) can be either read in or calculated from specified normalized neutronic power densities (six per assembly).

CONTENTS

ACKNOWLEDGMENTS	iii
SUMMARY	v
INTRODUCTION	1
MODELS	2
THERMAL-HYDRAULIC MODEL AND EQUATIONS	2
Continuity	3
Axial Momentum	3
Energy	5
State	5
Fuel Rod Model	5
Solution of Equations	7
NUMERICAL METHODS	9
CALCULATION OF INPUT PARAMETERS NECESSARY FOR CORTAN	12
FLOW SPLIT	12
ASSEMBLY SIZE INDEPENDENT MIXING PARAMETERS, ϵ_{IL}^* AND C_{IL}	12
SHAPE FACTOR	12
LIMITATIONS	14
COMPUTATION TIMES	15
INPUT DATA DESCRIPTION	18
REFERENCES	26
APPENDIX A - CODE FLOW DESCRIPTION	A.1
APPENDIX B - ASSEMBLY, ROD, AND CHANNEL RELATIONSHIPS	B.1
ASSEMBLIES	B.1
CHANNELS	B.4
RODS	B.9
APPENDIX C - DATA MANAGEMENT	C.1
APPENDIX D - INTERASSEMBLY HEAT TRANSFER	D.1
APPENDIX E - CALCULATION OF ROD PEAKING FACTORS FROM POWER DENSITIES	E.1
APPENDIX F - COMMON VARIABLE DESCRIPTIONS	F.1
APPENDIX G - SAMPLE INPUT	G.1
APPENDIX H - SAMPLE OUTPUT	H.1

FIGURES

1	Two-Region Model Showing the Nodalization Used in the CORTAN Code	4
2	Node Structure for CORTAN Fuel Rod Model	6
3	Variation of Input Parameter ϵ_{IL}^* with p/d and H/P	13
4	Variation of Input Parameter C_{IL} with p/d and H/P	13
5	Major Computation Blocks in CORTAN Code	16
6	Core Layout for 10 - Assembly Test Case	17
7	Assembly Pitch and Duct Gap	21
8	Locations of Six Assembly Sections for Power Density Input	23
A.1	Logic Flow in CORTAN Code	A.2
B.1	Assembly Numbering Using Whole-Core Option	B.2
B.2	Assembly Numbering Using One-Sixth-Core Option	B.2
B.3	Rod and Channel Numbering for Two-Ring Assemblies	B.5
B.4	Rod and Channel Numbering for Four-Ring Assemblies	B.5
B.5	Indices Used to Find Rod and Channel Neighbors	B.6
C.1	Program Segmentation Structure in CORTAN	C.1
E.1	Location of Section Centroids and Axes Orientation for Assembly Power Density Specification	E.2
G.1	Core Layout for 10-Assembly Test Case	G.2

THE CORTRAN CODE USER MANUAL

INTRODUCTION

A computer program, CORTRAN, has been developed for calculating three-dimensional temperature distributions on a core-wide basis in Liquid Metal Fast Breeder Reactors (LMFBRs). One-dimensional thermal-hydraulic models can lead to a conservative prediction of the peak coolant and cladding temperatures since a number of thermal-hydraulic phenomena such as interassembly heat transfer (IAHT), mixing, and conduction between channels in an assembly are not included. These phenomena are modeled in CORTRAN. Flow redistribution within an assembly due to buoyancy effects is also taken into account, but flow redistribution between assemblies is not taken into account at this time. For transients where buoyancy effects are important on a core-wide basis, this is expected to yield a conservative prediction for temperature distribution and peak temperature in the hot assembly.

The CORTRAN code is able to operate either in the forced-convection (negligible natural convection) or the mixed-convection (both forced and natural convection) modes. The forced-convection mode has two method options for solution of the equations. The first method is explicit in space and semi-implicit in time; the second method is implicit in space and semi-implicit in time. The mixed-convection mode has two solution options that are included in the CORTRAN II and CORTRAN III models, corresponding to the ENERGY II and ENERGY III (Khan et al. 1975) models, respectively. CORTRAN II does not include the inertial terms in the axial momentum equation. The finite difference form of the CORTRAN III equations and the assumption of uniform radial pressures at each axial level are similar to the modified transient version of the THINC II (Chelemer, Weismann and Tong 1967) code. Due to the spatially explicit nature of the CORTRAN III model, the axial step size is limited.

The CORTRAN code models LMFBR assemblies by grouping subchannels. An assembly of up to eight rings of fuel rods (438 coolant channels, 217 rods) can be modeled by a configuration of up to four rings (126 coolant channels and 61 rods). Hot assembly calculations can be performed using one node per subchannel.

MODELS

The CORTRAN code has been developed to predict the coolant temperatures in LMFBR cores. The thermal-hydraulic models to calculate these temperatures are described in this section and followed by a discussion of the numerical methods used to implement these models. A more complete description of the basic thermal-hydraulic models can be found in Khan et al. (1975).

THERMAL-HYDRAULIC MODEL AND EQUATIONS

In the CORTRAN code model, the rod array in the wire-wrapped LMFBR assembly is divided into two predominant regions--the central and wall regions. This is because the region of flow next to the container wall is quite different from the flow in the central region. In the central region of the assembly, the mean flow appears to oscillate around each rod, progressing in an axial direction. This oscillation of flow can be imagined to contribute an effective eddy diffusivity superimposed on the normal eddy diffusivity associated with turbulence. Thus, the basis of the model is the existence of a uniform lateral effective enhanced eddy diffusivity for heat transfer in the inner region of the bundle, which is superimposed on a predominantly axial flow. In the wall region, since the wire wrap is spiraled around each rod in the same direction, the flow progresses axially with both an axial and a tangential component parallel to the wall. It is assumed that the swirl flow around the duct wall is uniform. With a few modifications, CORTRAN could also be used for grid-spaced assemblies.

In forced convection the axial velocities in the two regions of the bundle may differ in magnitude but remain constant with axial position. However, at low flow rates in the presence of a power skew, buoyancy effects are important within the bundle, and the axial velocity profile would no longer be constant but would tend to skew toward that side of the bundle with the higher power generation (heat addition). The cooler fluid from regions of higher density drifts towards the hotter fluid, which has a lower density. This density-

gradient-induced lateral flow provides an additional mechanism of energy redistribution within the assembly in the mixed-convection regime.

To treat buoyancy-induced flow redistribution, a simplified approach has been taken by assuming that the pressure is uniform in the transverse direction at any axial level in the bundle. Only the axial momentum equation is solved explicitly in the simplified CORTAN method, and buoyancy-induced crossflow is permitted between channels to satisfy the assumption of uniform pressure at any axial plane. The magnitudes, and momentum associated with the transverse flows are taken into account in a manner approximately similar to that of Chelemer, Weisman and Tong (1967).

The continuity, axial momentum, and energy equations can be written by taking a mass, momentum, and energy integral balance on a control volume of length dx of a channel having an area A . The equations given below are written for subchannel analysis of rod bundles.

Continuity (Regions I and II) (Figure 1)

$$A \frac{\partial}{\partial t} (\rho) = - \frac{\partial}{\partial x} (\rho AV) + (W_c) \quad (1)$$

where (W_c) is the net crossflow into the channel per unit axial length.

Axial Momentum (Region I)

$$A \frac{\partial}{\partial t} (\rho V) = - \frac{\partial}{\partial x} (V^2 \rho A) + (W_c) U^* - A \frac{\partial p}{\partial x} - AK \rho V^2 - \rho Ag \quad (2)$$

In region II, an additional term, $\bar{G} C t (V_1 - V_2)$, is added to the left side of the axial momentum equation. This term accounts for the net rate of momentum transported swirl flow into the control volume representing channel i from the upstream neighboring channel. The term V_2 is the axial velocity in this neighbor, and V_1 is the axial velocity in the control volume. The term C is the ratio of the uniform swirl velocity to the bundle average velocity; $\bar{G}$ is the bundle average mass velocity; and t is the thickness of Region II.

FIGURE 1. Two-Region Model Showing the Nodalization Used in the CORTRAN Code

Energy (Region II)

$$A \frac{\partial}{\partial t} (\rho h) = - \frac{\partial}{\partial x} (\rho V A h) + [\Sigma W_c] h^* + (\bar{G} c t)(h - h_2) + Q_i A_i + (Ex1) \quad (3)$$

where the net heat into the channel from adjacent fuel rods and duct wall has been modeled as a volumetric heat generation rate, Q_i , in the channel. The term $Ex1$ is the heat exchange between the channel and neighboring channels by wire-wrap mixing and thermal-conduction. In Region I, there is no net swirl and $C = 0$. The heat exchange between any channel and its neighboring channels (1, 2, 3), which form a triangular rod array, is given by

$$(Ex1) = \bar{G} d_e (\epsilon^* + \kappa \alpha^*) \left[\frac{h_1 + h_2 + h_3 - 3h}{n} \right] s \quad (4)$$

where κ is a shape factor which is required because the two-dimensional heat flow between neighboring channels is modeled by one-dimensional equations of heat transfer. The term ϵ^* is the dimensionless enhanced eddy diffusivity of heat, which models the mixing by wire wraps, and α^* is the inverse Peclet number. The term $\bar{G}$ is the average bundle mass velocity, and n is the centroid-to-centroid distance between channels.

State

$$\rho = \rho(h) \quad (5)$$

During a transient the heat transfer from the fuel rods to the coolant will change if the flow rate or power generation rate within the fuel rod changes with time. Similarly, the heat transferred between the coolant and the adjacent duct wall will change during a transient. A one-dimensional model for the fuel rod and duct wall temperature distribution has been used.

The terms u^* and h^* are the axial coolant velocity associated with cross-flow and the enthalpy associated with crossflow. An approximate method of determining u^* and h^* is discussed by Khan et al. (1975).

Fuel Rod Model

The fuel heat transfer model in CORTRAN considers radial conduction within the fuel by dividing the fuel into equally spaced concentric rings as shown in Figure 2. Axial and circumferential heat conduction are presently

FIGURE 2. Node Structure for CORTRAN Fuel Rod Model

ignored. Axial heat conduction can be ignored because axial temperature gradients are usually small. Circumferential heat conduction is ignored to maintain a reasonable limit on the number of fuel nodes. For liquid sodium coolant and for $p/d > 1.2$, this assumption is justified if the heat transfer coefficients and fluid temperatures are rather uniform around a fuel rod.

The fuel is divided into equal radial nodes with a single node in the cladding. A central void in the fuel is allowed. The thermal resistance of the gap between the fuel and the cladding is not taken into account explicitly. Instead, an effective gap conductance is used at the fuel-cladding interface. The effective gap conductance combines the gap resistance with the cladding resistance. The surface heat transfer coefficient is determined from existing correlations. For each fuel rod, a circumferentially weighted average heat transfer coefficient (in the subchannels surrounding the fuel rod) is calculated. A similar calculation is performed to obtain the average fluid temperature needed for estimating heat flux from the fuel rod.

The finite-difference forms of the equations are solved using a compact, Gaussian elimination routine for reduction of tridiagonal matrices. The fuel

heat transfer model is used only once per time step to calculate the fuel rod heat flux. For steady-state calculations, heat flux is calculated based on the arithmetic average of the fluid temperature at axial level x and $x + \Delta x$. For transients, the heat flux is calculated in a semi-implicit manner based on the average of the fluid temperature at axial level x at time $t + \Delta t$ and the temperature at axial level $x + \Delta x$ at time t . This is necessary since the CORTAN code uses the "marching scheme" through the core.

The fuel rod model capabilities include the following: up to ten radial nodes; temperature-dependent fuel and cladding properties; and the wire-wrap heat capacity effect during transients. This last effect is taken into account by lumping the wire wrap with the cladding.

The code provides two options for rod radial peaking factor. In one option, the user may specify a normalized value of the radial peaking factor for each rod in an assembly. These values are normalized to the average value in the bundle. The second option is to specify six (neutronics) power densities in the assembly and allow the code to calculate the rod radial peaking factors using a least squares planar fit method. Appendix E gives a detailed description. By allowing the user to specify the neutronic power density distribution and total power for each assembly, a capability is provided for coupling the CORTAN thermal-hydraulic code with a neutronic code.

Solution of Equations

The initial and boundary conditions are specified as follows. The fluid temperature distribution is specified at $x = 0$. The thermal boundary condition at the container wall is specified for a single assembly calculation. The temperature and heat flux are continuous between the interior region and the wall region of the bundle, as are the density and pressure. The forcing function is specified as a function of time and could be any or all of the following three: the power generation rate in the fuel rods, the total flow rate, and the inlet coolant temperature. For a multiassembly calculation, the adjacent assemblies may be thermally coupled.

Temperature-dependent fuel, structure, and coolant properties are taken into account in the code. The parameters that must be known before the start

of calculation are conduction shape factor (κ), and the interior and wall region turbulent mixing parameters (ϵ^* and C). The turbulent mixing parameters, (ϵ^* and C) have been determined by analysis of steady-state forced-convection data. It is assumed that these values will also be applicable during a transient. The shape factor κ and the method used for determining it have been described by Khan et al. (1975)

At each time step the calculation starts at $x = 0$ and marches upward. The incremental variation of density (or enthalpy), velocity, and the pressure drop is determined by a simultaneous solution of the equations for an incremental height Δx . The density, enthalpy, temperature, velocity, and pressure are calculated at $x + \Delta x$. Once the top of the bundle is reached, the old coolant densities, enthalpies, temperatures, and velocity are stored, as are the fuel rod temperature profiles; the new forcing functions are calculated, and the march up the bundle begins for the next time step. The coupling between the fuel and the coolant is semi-implicit; i.e., the heat flux from the fuel rod at the next time step is calculated using the average of the new coolant temperature at x and the old coolant temperature at $x + \Delta x$.

The equations (1) through (5) and the above method of solving the equations have been programmed for use on the computer, and the program is called CORTAN III.

In the CORTAN III model, the spatial density variations are taken into account, and thus large density variations can be accommodated by the method. However, for most LMFBR single-phase applications, even where buoyancy effects are important, the density variations are sufficiently small compared to the absolute magnitude of the density so that the Boussinesq approximation can be made.

An additional simplification can be made by neglecting the temporal and inertial term in the axial momentum equation to get the CORTAN II model. The neglect of the inertial term was justified by Khan et al. (1975). For relatively slow transients, typical of the natural circulation transient, it was found that the temporal term in the axial momentum equation can also be neglected.

Another interesting result has been found at relatively large Reynolds numbers of bundle operation. It has been observed that if the intra-assembly buoyancy effects are not important, as in forced-convection conditions, the velocity profile is not affected by the temperature field and only the energy transport equation needs to be solved since the velocity distribution does not change in the axial direction. This is the basis of the CORTRAN I model.

The CORTRAN I, II, and III models are incorporated into a single computer program which, when applied to core-wide calculations, is called the CORTRAN code. Most LMFBR calculations start in the steady state, where the forced-convection regime is prevalent. In this case the transient calculations start with the CORTRAN I model, and at each time step a check is made using the modified Grashof number criterion developed by Khan et al. (1975) to see if the buoyancy effects are important. If the Grashof number is greater than 0.025, the buoyancy effects are considered important. If the intra-assembly buoyancy effects are important, the CORTRAN II or III model is automatically used, depending on user specification.

NUMERICAL METHODS

As stated earlier, the CORTRAN code offers options as to how the equations are solved. The forced-convection method allows a solution of the energy equation using a spatially implicit form of the finite-difference equations, but the flow rate within each channel does not change axially and equals the inlet flow rate in the channel. The implicit solution scheme requires the simultaneous solution of the coolant enthalpies at a given level based on the values of the neighboring enthalpies at the same level and the enthalpy of the same channel at the previous level. Setting up the finite-difference form of such equations requires one equation for each channel to be included; thus the matrix used in the simultaneous system has as many rows and columns as channels in the assembly. The simultaneous system of equations then becomes one of the form $A \cdot x = B$ where A is the coefficient matrix for channel enthalpies, x is the vector of channel coolant temperatures, and B is the column vector

containing the volumetric heat generation term and enthalpy values for channel i at the previous level and time step. Since the matrix A is relatively sparse, containing only up to four nonzero terms per row, a scheme developed by S. K. Gupta and K. K. Tanji (1977) is used to solve directly for the unknown enthalpies. Instead of requiring storage of a matrix having n^2 terms, two smaller matrices are used. One of these smaller matrices stores the nonzero coefficients and the other stores the column index of each coefficient. Thus, storage is reduced from n^2 to $2 \cdot n \cdot m$, where m is a number corresponding to the maximum number of nonzero terms in each row. Although only four terms will become nonzero in the original A matrix in each row, some of the other terms will become nonzero as matrix manipulations are done to invert A . Therefore, m must be as large as this maximum value. It has been found that for a bundle having 126 coolant channels, the maximum number of nonzero elements in any one row at a given time is 20. Thus, CORTRAN II has the arrays dimensioned at 126×20 for this case. Still, the storage required is reduced by a factor of 3, from 15876 (126×126) to 5040 ($2 \times 126 \times 20$).

Recently, another method to solve the simultaneous set of equations in CORTRAN II model was implemented. This is an iterative method using successive over-relaxation (SOR) [Clark and Hansen 1964]. This solution method can reduce execution time by up to one half.

As with the forced-convection mode, the mixed- and natural-convection modes also allow two options. Both of these options, CORTRAN II and CORTRAN III, require simultaneous solutions of the energy equation. The CORTRAN II option was described earlier. CORTRAN III includes the inertial terms in the axial momentum equations for each channel as well as the overall continuity equation. This increases the size of the A matrix from n^2 as in CORTRAN II to $(2n + 1)^2$ for CORTRAN III.

The number of nonzero coefficients in the matrix is either two or three, and each coefficient is placed in a specifically defined location relative to the diagonal. In a communication to E. U. Khan, G. VanTuyle of Brookhaven National Laboratory took this into account, describing a method for solution requiring storage of only these nonzero terms. Since the position of these

terms is known, a second matrix for index location is not required as in the CORTRAN II model. Another feature of this solution scheme is that it generates no additional nonzero terms as solution proceeds, thus the storage required is reduced from $(2n + 1)^2$ elements to $(2n + 1) \cdot 4$, a factor of 63 for the 126-channel case. More importantly, the solution time required is negligible, allowing the CORTRAN III model to execute in 50 percent of the time required for the CORTRAN II direct-solution scheme and on the same order as the time required for the forced-convection model.

One other simultaneous solution is required in the CORTRAN code. This is the calculation of the internal node temperatures in the fuel rod. Since a one-dimensional fuel rod model is used, each radial fuel node has only two neighbors, creating a tridiagonal matrix in the simultaneous system. The tridiagonal matrix is inverted and the temperatures found by a method developed and coded at Argonne National Laboratory by Jack Dongarra (Dongarra et al. 1977).

CALCULATION OF INPUT PARAMETERS FOR CORTAN

FLOW SPLIT

Inlet flow division (flow split) to each channel within the assembly is calculated by the code using Novendstern's hydraulic diameter flow split correlations. (The flow split is defined as the local velocity in a channel divided by the bundle average velocity.) Recent correlations have shown that the hydraulic diameter flow split is not satisfactory. For this reason, an option to input the inlet flow split is provided in the code. It is recommended that the user determine the flow split from the correlations developed by Chiu et al. (1978; see also Khan 1980, Appendix B).

ASSEMBLY SIZE INDEPENDENT MIXING PARAMETERS, ϵ_{IL}^* AND C_{IL}

The turbulent mixing parameters ϵ_{IL}^* and C_{IL} are required input to the CORTAN code. These values are input as bundle size independent parameters. Values of these parameters may be obtained by using recent correlations developed at M.I.T. (Khan et al. 1979). Figures 3 and 4 show ϵ_{IL}^* and C_{IL} as functions of p/d following these correlations.

SHAPE FACTOR

In CORTAN, two-dimensional transverse conduction heat transfer between adjacent channels is modeled by a one-dimensional heat transfer model. Consequently, a correction factor, called the shape factor, is introduced to provide an accurate estimate of the transverse conduction heat transfer between adjacent channels. The shape factor is a function of p/d and perhaps the rod diameter. It becomes important at low Reynolds numbers when conduction is the predominant mode of heat transfer. Models for shape factor are scarce, and a value of 1.2 is recommended until better estimates are obtained.

FIGURE 3. Variation of Input Parameter ϵ_{IL}^* with p/d and H/P (Khan et al. 1979)

FIGURE 4. Variation of Input Parameter C_{IL} with p/d and H/P (Khan et al. 1979)

LIMITATIONS

The limitations applicable to the ENERGY models (Khan et al. 1975 and 1979) also apply to CORTRAN. These are:

- Empirical constants ϵ_{IL}^* and C_{IL} were determined from available data. Determination of these constants is shown by Khan et al. (1979).
- Bundles should contain one wire wrap per rod. This wrap should be of the same size and have the same starting location on all rods. The bundle duct wall should bound the rod array so as to prevent bypass flow other than for fabrication.
- Due to the explicit nature of the solution in the CORTRAN III model, an axial step size limitation of approximately 1 in. is imposed. This numerical stability limit is not present in the CORTRAN II form of the model.

In addition to the restrictions imposed by the ENERGY model, CORTRAN has other limitations.

- Low-flow conditions ($Re < 1000$) must be avoided because CORTRAN lacks an interassembly flow redistribution model. Peak temperature in the hot assembly is expected to be higher when interassembly flow redistribution is neglected.
- Approximately 200 assemblies are allowed for core-wide temperature calculations. See Appendix B for limitations.
- Each assembly in CORTRAN may represent an assembly of up to eight rings (438 channels, 217 rods).
- Each assembly in CORTRAN may model the actual assembly using:
 - A single node--one rod in one channel, insulated from all other assemblies.
 - Two rings--19 rods, 42 channels, and accounting for inter-assembly effects
 - Four rings--61 rods, 126 channels, and accounting for inter-assembly effects

COMPUTATION TIMES

In showing the average computation times required for a sample case (included later in this document), it is helpful to view the program flow for CORTRAN as shown in Figure 5. This figure shows only the major computation sections of input, steady-state calculations, transient calculations, and interassembly temperature difference calculations. A more complete flow diagram is included in Appendix A.

For comparison, based on results of this sample case, a simulation of 20,000 nodes for 200 time steps should require about 1.4 hours of execution time on the present system (CDC 7600 at Brookhaven National Laboratories). This estimate assumes the same distribution of assembly configurations as in the sample case; 50 percent are 1-node assemblies and 50 percent are 2- or 4-ring assemblies.

Table 1 shows the comparative running times for each of these sections for this particular sample case. Figure 6 shows the placement of the assemblies in the core for this case.

TABLE 1. CORTRAN Computation Times--10-Assembly Case

Program Section	CORTRAN Computation Times, sec			
	CORTRAN I	CORTRAN II Direct Sol'n	CORTRAN II SOR	CORTRAN III
Input(a)	2.143	2.143	2.143	2.143
Steady State				
4 Rings	2.624	5.965	2.967	3.035
2 Rings	0.834	1.309	0.963	0.961
1 Node	0.154	0.157	0.156	0.157
Transient				
4 Rings	2.442	5.698	2.790	2.90
2 Rings	0.783	1.264	0.911	0.915
1 Node	0.152	0.151	0.155	0.155
IAHT(b)	2.425	2.465	2.454	2.428

(a) Average time to read input data for this 10-assembly case

(b) 10 assemblies (2-4 rings, 3-2 rings, 5-1 node). Time may vary depending on placement of assemblies in core.

FIGURE 5. Major Computation
Blocks in CORTRAN Code

FIGURE 6. Core Layout for 10-Assembly Test Case

INPUT DATA DESCRIPTION

The input for the CORTRAN code is done on an assembly-by-assembly basis. The first few data cards specify parameters that are common to the whole core. After that, data for each assembly are read separately.

First, the parameters common to all assemblies are given. Cards A through L are required to be the first cards at the beginning of any data deck:

CARD A NASST,NALARG,NOHT, FORMAT(5I5,F10.3)
 ICORE,RESTR,TMAX

NASST.....Total number of assemblies to be modeled in this run

NALARG....Largest assembly number to be used in the simulation

NOHT.....Interassembly heat transfer option.

If NOHT = 0, interassembly heat transfer effects
 are ignored for all assemblies.

NOHT > 0, interassembly heat transfer effects
 are included for all assemblies with
 more than one node.

ICORE.....Assembly arrangement in core,

0 = whole core; 1 = one-sixth

RESTR.....Restart option - unused at this time

TMAX.....Time limit - unused at this time

CARD B FRIC1,FRIC2,FRIC3, FORMAT(3E10.4,2I5,
 NITER,IDUCT,CONVER, E10.4,2I5)
 NOMAXI,CHOICE

FRIC1.....Coefficients in friction factor correlation^(a)

FRIC2.....Coefficients in friction factor correlation^(a)

FRIC3.....Coefficients in friction factor correlation^(a)

NITER.....Maximum number of iterations for convergence in the
 SOR solution method in CORTRAN II (Recommended:50)

IDUCT.....Duct wall calculation flag.

If IDUCT = 0, skip duct wall calculation.

IDUCT > 0, include duct wall calculation.

CONVER....Convergence criterion for crossflow values in
 CORTRAN III. If the absolute value of the sum of the
 crossflow terms for all channels is greater than this
 value, the iteration on the solution is continued.
 (Recommended value: 10⁻⁶)

NOMAXI....Maximum number of iterations allowed in crossflow
 convergence in CORTRAN III (Recommended:10)

$$(a) f = FRIC1 + \frac{FRIC2}{Re^{FRIC3}}$$

CHOICE....< 0*, use forced-convection solution.
 = 0, use CORTRAN II with direct solution.
 = 1, use CORTRAN II with successive over-relaxation solution.
 = 2, use CORTRAN III.

CARD C NODATA FORMAT(I5)

NODATA....Number of data entries for sodium properties. This value will specify how many property data cards are to follow.

CARD D PP,TT,RHOFF,RHOGG, FORMAT(6F8.4)
 HHF,HHG

These cards contain the sodium properties at the specified pressure and temperature.

PP.....Pressure (psia)
 TT.....Temperature (°F)
 RHOFF.....Liquid Density (lb/ft³)
 RHOGG.....Vapor Density (lb/ft³)
 HHF.....Liquid Enthalpy (Btu/lb)
 HHG.....Vapor Enthalpy (Btu/lb)

Note: Card D is to be repeated as many times as NODATA specifies, up to 50. Each card is an entry into the properties table of sodium

CARD E NINROD,NINFUL FORMAT(2I5)

NINROD....Number of different rod types (up to 10)
 NINFUL....Number of different fuel types (up to 10 allowed)

CARD F RODDIA,CLADTH, FORMAT(3E10.3)
 HGAPCL

Repeat Card F NINROD times.

RODDIA....Rod diameter (in.)
 CLADTH....Cladding thickness (in.)
 HGAPCL....Heat transfer coefficient of the gap between fuel and cladding in the rod (Btu/ft²-hr-°F)

* If choice = -1, the code will switch from forced convection to CHOICE = 1 during transient if the mixed-convection criterion is satisfied.
 If choice = -2, the code will switch from forced convection to CHOICE = 2 during transient.

CARD G FUELD,VOIDD,RFSDIA, FORMAT(5E10.3)
 DENRES,DENNRS

Repeat Card G NINFUL times.

FUELD.....Fuel diameter (in.)
VOIDD.....Void diameter (in.)
RFSDIA....Diameter of restructured fuel (in.)
DENRES....Fraction of theoretical density in restructured region
DENNRS....Fraction of theoretical density in unrestructured
 region

CARD H NGEOM FORMAT(15)

NGEOM.....Number of entries in the geometry table. This value
 will specify how many cards are to follow, containing
 data, for the next two groups (up to 10 are allowed).

CARD I FSHAP,EPS,SWRL FORMAT(3E10.4)

FSHAP.....Shape factor for heat transfer rate between channels
 (Recommended value: 1.2)
EPS.....Interior turbulent mixing parameter
SWRL.....Wall region swirl flow parameter (see section on
 input parameters)

CARD J RGAP,DGAP,DIAW, FORMAT(6E10.4)
 LOD,Z,ZACT

RGAP.....Gap between adjacent fuel rods (in.)
DGAP.....Distance from outer edge of rod to edge of duct wall
 in inches if NORING > 0. For one node assembly
 (NORING = 0), DGAP is one-half duct flat-to-flat
 distance in inches.
DIAW.....Diameter of wire-wrap (in.)
LOD.....Lead over diameter (in./in.)
Z.....Total length of fuel rod (ft)
ZACT.....Active length of fuel rod (ft)

Repeat this pair of cards NGEOM times.

CARD K NDX,NDT,TTIME FORMAT(215,E10.4)

NDX.....Number of axial steps (up to 49)
NDT.....Number of time steps in total simulator time
TTIME.....Total time of simulation (sec)

CARD L APITCH,DUCGAP,TFLOW FORMAT(3E10.4)

APITCH....Assembly pitch (in.)

DUCGAP....Gap between assembly duct walls (in.)
 TFLOW.....Total coolant flow to all assemblies (lbm/hr)
 (see Figure 7)

FIGURE 7. Assembly Pitch and Duct Gap

The data that follow are divided into 6 groups (numbered 1 through 6). There must be a set of these data groups for each assembly. Some of the data groups are "OPTIONAL", as specified in the following description, and may be omitted from the set of data for any assembly except the first. If any group is omitted, the values used for the previous assembly will be retained. The first set must be a complete set to initialize all variables. Each set of data is terminated by "qq" card. This is shown in sample input.

The first card in each assembly data set is a card giving the assembly number. This card is required for each data set:

CARD 0	NUMASM	FORMAT(I3)
--------	--------	------------

NUMASM....Number of this assembly

The input format for each group requires that the first card specify the group number and other necessary parameters for the particular group. The format for each group follows:

GROUP 1	AXIAL HEAT FLUX	OPTIONAL
---------	-----------------	----------

```
CARD 1.1      NGROUP,NOOFAX      FORMAT(2I5)
```

```
NGROUP....Data group number.  NGROUP = 1.
NOOFAX....Number of axial data points per rod
```

CARD 1.2 AXIAL,FAX FORMAT(8E10.4)

```
AXIAL.....Normalized axial rod distance (X/L)
FAX.....Axial heat flux at location corresponding to AXIAL
           normalized so average is 1.0.
```

Note: Up to 50 pairs of data values for AXIAL and FAX may be specified, according to the value of NOOFAX. The data are entered four pairs per card. As many cards as necessary may be used.

GROUP 2	ASSEMBLY CONFIGURATION	REQUIRED
---------	------------------------	----------

CARD 2.1 NGROUP,NORING,NTLRNG FORMAT(3I5)

```

NGROUP....=2
NORING....Number of rings in the modeling assembly. Up to four
            rings are allowed. If NORING=0, one channel is
            assumed with a single rod in the center.
NTRNG....Number of rings in the actual assembly. Up to eight
            rings are allowed.

```

GROUP 3	ROD/CHANNEL INFORMATION	OPTIONAL
---------	-------------------------	----------

CARD 3.1 NGROUP,NODESF,IRADL FORMAT(3I5)

```
NGROUP....=3
NODESF....Number of radial nodes in fuel rods (>1)
IRADL.....Flag to read radial peaking factors (IRADL=1) or six
             power densities (IRADL=0)
```

```
CARD 3.2      IROD,IFUEL,IGEOM      FORMAT(3I5)
```

```

IROD.....Rod property index for use in assembly
IFUEL.....Fuel property index for use in assembly
IGEOM.....Geometry index for this assembly

```

CARD 3.3A PDEN FORMAT(6E10.4)

PDEN.....Six values of normalized power densities at centroids of each of the one-sixth-assembly sections (see Figure 8).

FIGURE 8. Locations of Six Assembly Sections for Power Density Input

CARD 3.3B I,RADIAL(I) FORMAT(I5,E10.4)

I.....Fuel rod number

RADIAL....Normalized radial power for rod I (normalized to
average power of 1.0)

Note: Card 3.3 is not read if there is only one node in
the assembly (NORING=0).

GROUP 4 INLET CONDUCTIONS/FORCING FUNCTIONS OPTIONAL

CARD 4.1 NGROUP,NH,NF,NP FORMAT(4I5)

NGROUP....=4

NH.....Number of inlet temperature versus time data pairs
to read

NF.....Number of inlet flow versus time data pairs

NP.....Number of power versus time data pairs

CARD 4.2 TIN,PREF,PTOT,FLOFRC FORMAT(7E10.4)
VEL1,VEL2,VEL3

TIN.....Inlet temperature (°F)

PREF.....Reference pressure at inlet (psia)

PTOT.....Total power generated in the assembly (million Btu/hr)

FLOFRC....Fraction of total flow to this assembly
 VEL1.....Inlet flow split for interior channels. If VEL1 is
 0.0, the code calculates VEL1, VEL2, VEL3 using
 Novendstern's hydraulic diameter correlation.
 VEL2.....Inlet flow split for wall channels
 VEL3.....Inlet flow split for corner channels

CARD 4.3 YH,TH FORMAT(8E10.4)

YH,TH.....Time (sec) and temperature (normalized to initial
 temperature) data pairs for the forcing function. Up
 to 30 such pairs are allowed with the number being
 specified by NH. Four data pairs are entered per
 card, using as many cards as necessary. Do not
 include card 4.3 if NH < 2.

CARD 4.4 YP,FP FORMAT(8E10.4)

YP,FP.....Time (sec) and power (normalized to initial power
 generation rate) data pairs for forcing function.
 NP specifies the number of pairs to read with the same
 format as CARD 4.3.
 Do not include CARD 4.4 if NP < 2.

CARD 4.5 YFIN,FFIN FORMAT(8E10.4)

YFIN,FFIN.....Time (sec) and flow (normalized to initial flow
 rate) data pairs for forcing function. NF
 specifies the number of data pairs to read with
 the same format as CARD 4.3.
 Do not include CARD 4.5 if NF < 2.

GROUP 5 PRINT/TIME STEP CONTROL OPTIONAL

CARD 5.1 NGROUP,NOUT,NPCHAN FORMAT(8I5)
 NPROD,NPNODE,NSKIPX,
 NSKIPT,NDEBUG

NGROUP....=5
 NOUT.....Rod, Channel, and duct print flag. If
 NOUT > 0, print results.
 NOUT < 0, do not print results.
 NPCHAN....Number of channels for which to print results.
 If NPCHAN = 0, print all channels.
 NPROD....Number of rods for which to print results.
 If NPROD = 0, print all rods.
 NPNODE....Number of internal rod nodes for which to print
 results. If NPNODE = 0, print all nodes including
 clad.
 NSKIPX....Axial step increment for printing (in number of
 axial steps)

NSKIPT....Time step increment for printing (in number of time steps)
 NDEBUG....Debug printout option. If
 NDEBUG < 1, standard output will be printed.
 NDEBUG = 1, debug printout will be included in ENT1;(a)
 partial debug printout in ENT2.(b)
 NDEBUG $\geq$ 2, debug printout will be included in ENT1;
 debug printout will be included in ENT2.

CARD 5.2 PRINTC FORMAT(16I5)

PRINTC....Channel number for printing results. The number of entries should be the same as NPCHAN. Sixteen entries per card are allowed. Use as many cards as necessary.

CARD 5.3 PRINTR FORMAT(16I5)

PRINTR....Rod numbers for printing results. The number of entries should be the same as NPROD. Use the same format as CARD 5.2.

CARD 5.4 PRINTN FORMAT(16I5)

PRINTN....Rod node number for printing results. The number of entries should be the same as NPNODE. Use the same format as CARD 5.2.

GROUP 6	DUCT PROPERTIES	OPTIONAL
---------	-----------------	----------

CARD 6.1	NGROUP	FORMAT(I5)
----------	--------	------------

NGROUP....=6

CARD 6.2	HDUCT,RHOWL,CPWLL, RKWLL,WALLTH,QDUCT, NINWND	FORMAT(6E10.4,I5)
----------	---	-------------------

HDUCT.....Heat transfer coefficient of duct wall (Btu/ft²-hr-°F)
 RHOWL.....Density of the duct wall (lb/ft³)
 CPWLL.....Specific heat of duct wall (Btu/lb-°F)
 RKWLL.....Thermal conductivity of the wall (Btu/hr-ft-°F)
 WALLTH....Wall thickness (in.)
 QDUCT.....Volumetric heat generation rate in the duct wall
 (Btu/hr-ft³)
 NINWND....Number of internal wall nodes (≥ 3)

(a) ENT1 is the main solution subroutine for CORTAN I and II.
 (b) ENT2 is the main solution subroutine for CORTAN III.

REFERENCES

- Chelemer, H., J. Weisman and L. S. Tong. 1967. Subchannel Thermal Analysis of Rod Bundle Core. WCAP-7015, Westinghouse Atomic Power Division.
- Chiu, C., N. E. Todreas and W. M. Rohsenow. 1978. Turbulent Flow Split Model and Supporting Experiments for Wire Wrapped Core Assemblies. C00-2245-56TR, Departments of Mechanical and Nuclear Engineering, Massachusetts Institute of Technology.
- Clark, M., Jr., and K. F. Hansen. 1964. Numerical Methods of Reactor Analysis. Academic Press.
- Dongarra, J. J., J. R. Bunch, C. B. Moler and G. W. Stewart. 1977. LINPACK Working Note No. 9, Preliminary LINPACK Users Manual. Technical Memorandum No. 313, Applied Mathematics Division, Argonne National Laboratory.
- Gupta, S. K., and K. K. Tanji. 1977. "Computer Program for Solution of Large, Sparse, Unsymmetrical Systems of Linear Equations." International Journal for Numerical Methods in Engineering. 11:1251-1259.
- Khan, E. U., W. M. Rohsenow, A. A. Sonin and N. E. Todreas. 1975. A Porous Body Model for Predicting Temperature Distributions in Wire Wrapped Fuel and Blanket Assemblies of LMFBR. C00-2245-16TR, Departments of Mechanical and Nuclear Engineering, Massachusetts Institute of Technology.
- Khan, E. U., W. M. Rohsenow, A. A. Sonin and N. E. Todreas. 1979. Input Parameters to Codes Which Analyze LMFBR Wire Wrapped Bundles. C00-2245-17TR, Departments of Mechanical and Nuclear Engineering, Massachusetts Institute of Technology. Revision 1 by S. F. Wang and N. E. Todreas, May 1979.
- Khan, E. U. 1970. LMFBR In-Core Thermal Hydraulics: The State of the Art and U.S. Research and Development Needs. PNL-3337, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX A

CODE FLOW DESCRIPTION

APPENDIX A

CODE FLOW DESCRIPTION

Logic flow for the CORTRAN code is shown diagrammatically in Figure A.1. As shown, the code consists of four major computation loops. These are 1) the input data loop on assemblies, 2) the time loop covering all assemblies, 3) the loop setting up calculations assembly by assembly, and 4) the loop stepping up each assembly by axial level. Loops 2 through 4 are nested in the computation scheme.

Initialization of the data files and reading of the input data is done in the main program, CORTRAN. CORTRAN calls ZERO to initialize the direct access disk files for the size of the problem being run. ASSEM is then called to number the assemblies in either a one-sixth-core or whole-core configuration. CHLNUM, RODNAY, and NABOR are called during the data input to find the channel, rod, and assembly neighbors (see Appendix B). Subroutine PRTINP is called to print the summary of the input data for each assembly. The input data for each assembly are then written out to the direct access disk files.

After reading in all data, the time step loop for solution is begun. This loop is also in the main program, CORTRAN. For each assembly, the data is read in to main memory from disk. CORTRAN then calls either the solution subroutine ENT1 (CORTRAN I or CORTRAN II models) or ENT2 (CORTRAN III model) depending on the user's selection of model to use. At each axial level, these routines in turn call HEAT, TEMROD, and TEMDUC to solve for the rod and wall temperatures as well as to solve for the coolant temperatures.

On return to the main program, summary results are printed and the new data saved for this assembly. This procedure is repeated for all assemblies. After each assembly has been updated at the present simulation time, CORTRAN calls IAHT to calculate the temperature difference across the interassembly duct gaps. The entire time loop is then repeated until the specified time limit is reached.

FIGURE A.1. Logic Flow in CORTAN Code

APPENDIX B

ASSEMBLY, ROD, AND CHANNEL RELATIONSHIPS

APPENDIX B

ASSEMBLY, ROD, AND CHANNEL RELATIONSHIPS

Numbering of the core entities (assemblies, rods, channels) follows a fixed scheme, assuming a hexagonal shape for the assembly. The numbering scheme and neighbor calculations follow for each of the core entities.

ASSEMBLIES

The method of numbering the assemblies is determined by the input parameter ICORE. A whole-core numbering scheme is used when the value of ICORE is set to 0; an ICORE value of 1 results in a one-sixth-core numbering arrangement. These two numbering schemes are shown in Figures B.1 and B.2.

Three indices are assigned to each assembly location. Subroutine ASSEM numbers the assemblies in the core by associating an assembly number with each set of indices. These indices will be called I, J, and K. Index I is the ring number with the center assembly being the only assembly in ring 1. The rings are defined concentrically outward. The code allows up to eight rings in the whole core arrangement and up to 20 for one-sixth core. Index J is the face number (1 through 6). The core can be divided into six triangular segments corresponding to each face. The center assembly is contained in each face. By extending the six sides of the center assembly radially outward, the edges of each face may be obtained. In Figure B.1 the border of face one consists of assemblies 2, 8, 20, and 38. Similarly, the border of face two contains assemblies 3, 10, 23, and 42. A face consists of the assemblies on the defined border and all those assemblies in a counterclockwise direction to the next border. For purposes of numbering the assemblies, each face contains only one border. Index K is the element (assembly) within the ring I on Face J. This index has meaning only when used in conjunction with I and J. These elements are numbered in a counterclockwise direction from the border of each face along the ring to the next border. There are $(I - 1)$ possible elements on each face in ring I.

FIGURE B.1. Assembly Numbering Using Whole-Core Option

FIGURE B.2. Assembly numbering Using One-Sixth-Core Option
B.2

In Figure B.1:

$(I,J,K) = (2,5,1)$ refers to assembly 6

$(I,J,K) = (4,3,3)$ refers to assembly 28

$(I,J,K) = (1,1,1)$ refers to assembly 1

In a whole-core configuration, the center assembly is assigned as assembly 1. Numbering continues in ring 2 at face 1 and progresses counter-clockwise around the ring. This numbering around the ring continues until the number of assemblies specified is included. All remaining assemblies above this user-specified limit will be assigned the next number and defined as insulating assemblies for purposes of code calculations. For example, if the user specified 80 assemblies to be included, all other assemblies will be assigned the number 81. The maximum number of assemblies allowed is 217 (eight rings). If the maximum number is used, the code assigns assemblies in ring 9 the number 218. This provides defined neighbors for all assemblies to be used in calculation.

In a one-sixth-core configuration, only assemblies in face 1 and the border of face 2 are used. Again, the center assembly is assigned number 1. Numbering proceeds as before (ring by ring, outward) but includes only those assemblies from the border of face 1 through the border of face 2. Again, an insulating ring of assemblies is placed around the section. This time not only the outer ring is included, but also all other elements in ring 2 (faces 3-6), the final element in face 6 and the second element in face 2 of each ring. See Figure B.2. Up to 210 assemblies (20 rings) can be used in a one-sixth-core configuration.

Having numbered all assemblies and assigned three indices to locate the assembly in the core, the relationships between assemblies can be calculated. It should be noted that since each assembly location is defined by the (I,J,K) indices, the neighbors to each assembly are independent of how the assemblies are numbered. Subroutine NABOR performs the task of finding the neighbors. Since ASSEM stores the assembly number for the assembly at the location defined by (I,J,K) in the triply dimensioned array $TABLE(I,J,K)$, to find the neighbors it is necessary only to calculate the indices of the neighbor and then look up the number in the array.

Given the assembly indices (I,J,K) and the side n (1 through 6), the neighbor on side n can be found as follows:

For assembly 1 (I = 1):

$$NEIGH(n) = TABLE(2,n,1)$$

For other assemblies (I > 1):

<u>NEIGH(n)</u>	<u>CONDITION</u>
TABLE(I+1,J,K)	J = n
TABLE(I+1,MOD(J+4,6)+1,I)	J = MOD(n,6)+1 ; K = 1
TABLE(I,J,K-1)	J = MOD(n,6)+1 ; K > 1
TABLE(I,MOD(J+4,6)+1,I-1)	J = MOD(n+1,6)+1 ; K = 1
TABLE(I-1,J,K-1)	J = MOD(n+1,6)+1 ; K > 1
TABLE(I-1,MOD(J,6)+1,1)	J = MOD(n+2,6)+1 ; K = I-1
TABLE(I-1,J,K)	J = MOD(n+2,6)+1 ; K < I-1
TABLE(I,MOD(J,6)+1,1)	J = MOD(n+3,6)+1 ; K = I-1
TABLE(I,J,K+1)	J = MOD(n+3,6)+1 ; K < I-1
TABLE(I+1,J,K+1)	J = MOD(n+4,6)+1

MOD(X,Y) refers to modulo arithmetic where $MOD(X,Y) = X - ZY$ such that Z is a whole number satisfying $0 \leq X - ZY < Y$.

CHANNELS

The channels within an assembly are numbered in much the same manner as the assemblies within a core. Again, three indices for ring number, face, and element can be assigned to each channel. As shown in Figures B.3 and B.4, the first ring of coolant channels are at the center of the assembly (channels 1 through 6) and all face outward. Elements in subsequent rings of these triangular channels alternate facing inward and outward on each face. The wall channels are then rectangular along the duct wall and the corner channels are semi-triangular behind each corner fuel rod. Numbering of the subchannels starts in the first ring and continues in a counterclockwise direction concentrically outwards for all rings up to the outer ring. This outer ring of triangular channels is numbered in two parts to make later calculations easier. First, all channels facing inward (those having only triangular channels for

FIGURE B.3. Rod and Channel Numbering for Two-Ring Assemblies (19 Rods, 42 Coolant Channels)

FIGURE B.4. Rod and Channel Numbering for Four-Ring Assemblies (61 rods, 126 coolant channels)

neighbors) are numbered. Next, the outward facing channels are numbered (those having one rectangular wall channel for a neighbor). Finally, the wall channels and the corner channels are numbered. Even though the outer ring of triangular channels is numbered in two parts, the element index, K, is kept consistent along the face. For example, the channels in the outer ring on face 1 (Figure B.4) are numbered 73, 55, 74, 56, 75, 57, 76. Channels 55, 56, 57 face inward and 73, 74, 75, 76 face outward. Figure B.5 shows the indices for a two-ring assembly.

Again, using the three indices, neighbors to any channel can be found much as the assembly neighbors are found. The channel numbers assigned to each location in routine CHLNUM are stored in the array CHNL(I,J,K). The neighbors can be found by calculating the indices of the neighbor channel location and looking up the channel number. The neighbors to CHNL(I,J,K) will be defined as CHNL[II(n),JJ(n),KK(n)] for the neighbor n. With M as the number of rings of triangular channels, calculation of the neighbors follows. Interior channels have three neighbors each.

FIGURE B.5. Indices Used to Find Rod and Channel Neighbors

All triangular channels except outer ring ($I < M$):

$$\begin{aligned} II(1) &= I \\ JJ(1) &= \text{MOD}(J+4,6)+1 \text{ for } K = 1 \\ &= J \quad \text{for } K > 1 \\ KK(1) &= \text{MOD}(K+2(I-1)-1, 2*I-1)+1 \end{aligned}$$
$$\begin{aligned} II(2) &= K \\ JJ(2) &= \text{MOD}(J,6)+1 \text{ for } K = 2*I-1 \\ &= J \quad \text{for } K < 2*I-1 \\ KK(2) &= \text{MOD}(K, 2*I-1)+1 \end{aligned}$$
$$\begin{aligned} II(3) &= I - 1 \text{ for } K \text{ even} \\ &= I + 1 \text{ for } K \text{ odd} \\ JJ(3) &= J \\ KK(3) &= K - 1 \text{ for } K \text{ even} \\ &= K + 1 \text{ for } K \text{ odd} \end{aligned}$$

For outer ring of channels ($I = M$):

$$\begin{aligned} II(1) &= I \\ JJ(1) &= \text{MOD}(J+4,6)+1 \text{ for } K = 1 \\ &= J \quad \text{for } K > 1 \\ KK(1) &= \text{MOD}(K+2*(I-1)-1, 2*I-1)+1 \end{aligned}$$
$$\begin{aligned} II(2) &= I \\ JJ(2) &= \text{MOD}(J,6)+1 \text{ for } K = 2*I-1 \\ &= J \quad \text{for } K < 2*I-1 \\ KK(2) &= \text{MOD}(K, 2*I-1)+1 \end{aligned}$$
$$\begin{aligned} II(3) &= I-1 \text{ for } K \text{ even} \\ &= I+1 \text{ for } K \text{ odd} \\ JJ(3) &= J \\ KK(3) &= (K+1)/2 \text{ for } K \text{ odd} \\ &= K - 1 \text{ for } K \text{ even} \end{aligned}$$

For wall channels ($I = M + 1$), there are four neighbors. The first neighbor is in the outer ring of triangular coolant channels. The second neighbor is the channel (either wall or corner) in a clockwise direction with the third neighbor being in a counter-clockwise direction (with respect to channel numbering). The fourth neighbor is the wall channel directly across the assembly duct gap, assuming the neighbor assembly has the same number of channels as this assembly does.

$$II(1) = I - 1$$

$$JJ(1) = J$$

$$KK(1) = 2 \cdot K - 1$$

$$II(2) = I + 1 \text{ for } K = 1$$

$$= I \quad \text{for } K > 1$$

$$JJ(2) = J$$

$$KK(2) = 1 \quad \text{for } K = 1$$

$$= K - 1 \text{ for } K > 1$$

$$II(3) = I + 1 \text{ for } K = I - 1$$

$$= I \quad \text{for } K < I - 1$$

$$JJ(3) = \text{MOD}(J, 6) + 1 \text{ for } K = I - 1$$

$$= J \quad \text{for } K < I - 1$$

$$KK(3) = 1 \quad \text{for } K = I - 1$$

$$= K + 1 \text{ for } K < I - 1$$

$$II(4) = I$$

$$JJ(4) = \text{MOD}(J + 2, 6) + 1$$

$$KK(4) = I - K$$

For the corner channels ($I = M + 2$), the first two neighbors are the wall channels in this assembly. The third and fourth neighbors are the corner channels in the two assemblies adjacent to this corner of the assembly.

$$II(1) = I - 1$$

$$JJ(1) = \text{MOD}(J + 4, 6) + 1$$

$$KK(1) = I - 2$$

$$II(2) = I - 1$$

$$JJ(2) = J$$

$$KK(2) = 1$$

$$II(3) = I$$

$$JJ(3) = \text{MOD}(J+1,6)+1$$

$$KK(3) = 1$$

$$II(4) = I$$

$$JJ(4) = \text{MOD}(J+3,6)+1$$

$$KK(4) = 1$$

RODS

The fuel rods within an assembly are numbered in the same manner as the assemblies. The center rod is alone in ring 1 and is assigned number 1. The rods are then numbered concentrically outward in a counterclockwise direction. Again the three indices (I,J,K) are applied to identify a rod location. The rod numbers are then stored in the array RODNAM(I,J,K).

Instead of determining which rods are neighbors to a given rod, the channels that are neighbors to each rod must be found. The rods have up to six neighbor channels each. These neighbors are found by calculating the channel indices [II(n),JJ(n),KK(n)] given the rod indices (I,J,K). These neighbor channels to rod (IR) are saved in array LR(IR,n).

The first rod, in the center of the assembly, has channels 1 through 6 as neighbors. The neighbors are calculated in a counterclockwise direction around the rod.

For all rods except the outer ring:

$$II(1) = I$$

$$JJ(1) = J$$

$$KK(1) = 2*K-1$$

$$II(4) = I - 1$$

$$JJ(4) = \text{MOD}(J+4,6)+1 \text{ for } K = 1$$

$$= J \text{ for } K > 1$$

$$KK(4) = 2*(I-1)-1 \text{ for } K = 1$$

$$= 2*(K-1)-1 \text{ for } K > 1$$

II(2) = I	II(5) = I for K = 1
JJ(2) = J	= I -1 for K > 1
KK(2) = 2*K	JJ(5) = MOD(J+4,6)+1 for K = 1
	= J for K > 1
	KK(5) = 2*(I - 1) for K = 1
	= 2*(K-1)-1 for K > 1

II(3) = I - 1	II(6) = I
JJ(3) = J	JJ(6) = MOD(J+4,6)+1 for K = 1
KK(3) = 2*K-1	= J for K > 1
	KK(6) = 2*I - 1 for K = 1
	= 2*(K-1) for K > 1

For the outer ring of rods, there are five neighbors, If K = 1 (first rod on the face), the first two neighbors are triangular channels, neighbors three and five are wall channels, and four is the corner channel. If K > 1, neighbors one through three are interior channels and four and five are wall channels.

II(1) = I - 1
JJ(1) = J
KK(1) = 2*K - 1

II(2) = I - 1
JJ(2) = MOD(J+4,6)+1 for K = 1
 = J for K > 1
KK(2) = 2*(I-1)-1 for K = 1
 = 2*(K-1) for K > 1

II(3) = I for K = 1
 = I - 1 for K > 1
JJ(3) = MOD(J+4,6)+1 for K = 1
 = J for K > 1
KK(3) = I - 1 for K = 1
 = 2*(K-1)-1 for K > 1

$II(4) = I + 1$ for $K = 1$
 $= I$ for $K > 1$
 $JJ(4) = J$
 $KK(4) = K$ for $K = 1$
 $= K - 1$ for $K > 1$

$II(5) = I$
 $JJ(5) = J$
 $KK(5) = K$

APPENDIX C

DATA MANAGEMENT

APPENDIX C

DATA MANAGEMENT

Storage requirements for the CORTAN code are fairly large, making in-core storage of all values for all assemblies impossible. A method has been developed where only the data necessary to do the calculations for a single assembly need be in core at a given time. The data for other assemblies are stored on disk during the time they are not needed. Another saving in space comes from the structure of the code itself, which allows segmentation. Figure C.1 shows the basic segmentation structure.

The transfer of data to and from disk is done by Control Data Corporation (CDC) system routines WRITMS and READMS. These routines read or write large contiguous blocks of data between the core (small- or large-core memory) and disk. A total of six direct access files are used to store the necessary data to run the code. Each file contains up to 219 records with the record number corresponding to the assembly number (i.e., record number 5 contains data from assembly 5). To ensure the data is contiguous in memory, the six data sets are stored in six common block areas.

FIGURE C.1. Program Segmentation Structure in CORTAN

In the input section of the code, each assembly data set is written to disk before a new set is read. When calculation begins on a given assembly, the data for that assembly is first read from disk, the calculation is made, and then finally the new data is rewritten to disk. This is repeated for each assembly during each time step.

The current core requirements on the CDC 7600 at Brookhaven National Laboratory are:

SCM (small core memory)	Code... 52703 (octal) words
	Data... 76163 (octal) words

Total SCM.....	151066 (octal) words
SCM Limit.....	160000 (octal) words
LCM (large core memory)	Data...225320 (octal) words

APPENDIX D

INTERASSEMBLY HEAT TRANSFER

APPENDIX D

INTERASSEMBLY HEAT TRANSFER

Interassembly heat transfer at time "t" is calculated based on the duct wall temperature profile at time $t - \Delta t$. This is a good assumption as long as the interassembly heat transfer does not change rapidly with time. For most protected transient calculations in LMFBR, this is a good assumption.

For the reason mentioned above, CORTRAN does not include interassembly heat transfer calculations initially (time $t = 0$), and the duct wall temperature profiles are flat. This flat profile is then modified, as described below, to get a temperature gradient across the duct walls of neighboring assemblies under steady-state conditions. The temperature difference across the gap between neighboring channels of adjacent assemblies is found in subroutine IAHT. This gap temperature difference is then used to calculate the interassembly heat transfer. Therefore, to include the effect of interassembly heat transfer under steady-state conditions another pass through the core is required at a small time increment ($t = 0.01$ seconds).

The temperature difference between the gap of adjacent assemblies is calculated as follows:

under steady-state conditions:

$$\Delta T(\text{gap}) = \Delta T(\text{coolant}) * R(\text{gap})/R(\text{total})$$

where

$$R(\text{total}) = R(\text{coolant to wall, assembly 1}) + R(\text{wall 1}) + R(\text{gap}) + R(\text{wall 2}) + R(\text{coolant to wall, assembly 2})$$

$\Delta T(\text{coolant})$ is the temperature difference between two adjacent coolant channels across the gap.

R is the thermal resistance to heat flow of the subscripted region.

From the calculation during steady state, a value for temperature difference can be computed for use in the first transient calculation of duct temperature.

For purposes of calculating the temperature difference between assemblies of different number of channels, an averaging method is used. When calculating the temperature difference for a given assembly, all neighbors are reconfigured to look as if they have the same number of wall channels as the current assembly. For example, if the current assembly has 2 rings (42 channels with 18 outer wall and corner channels) and the neighboring assembly has 4 rings (126 channels with 30 of them wall and corner channels), the neighbor is adjusted to have 18 equivalent wall and corner channels. The calculation can then be done directly on a one-to-one basis between equivalent neighbor channels.

If any neighbor assembly is represented with only one node (one channel and one rod), it is assumed to be insulated and no temperature difference is calculated. Likewise, if the current assembly is represented by only one node, it is insulated from all other neighbor assemblies and no temperature difference calculation is done for any neighbors.

APPENDIX E

CALCULATION OF ROD PEAKING FACTORS FROM POWER DENSITIES

APPENDIX E

CALCULATION OF ROD PEAKING FACTORS FROM POWER DENSITIES

CORTRAN allows the user to specify the radial peaking factor for each rod in an assembly by one of two different methods. One method is to specify a normalized value of radial peaking factor for each rod. This requires as many input values as number of rods. The second method is to specify a normalized power density at six locations in the assembly. The radial peaking factors for each rod may then be calculated with these power densities. This calculation is done by a least squares fit of a plane to the six power densities and then obtaining the radial peaking factors from the equation of the plane.

The six power densities are assumed to be specified at the centroid of the six sections of each assembly as shown in Figure E.1. The locations of each rod in the assembly can be found in the (X,Y) coordinate system (also shown in Figure E.1). The origin of the X,Y system is assumed to be in the center of the assembly. All distances are normalized such that the centroids of the sections (the points at which the power densities are specified) lie on the unit circle.

Using the six specified power densities, the equation of a plane can be obtained with coefficients normalized such that the average value (at $X = 0$, $Y = 0$) is 1.0. The equation of this plane is:

$$P_{x,y} = C_x \cdot X + C_y \cdot Y + 1$$

where $P_{x,y}$ is the value of the function at (X,Y)

C_x is coefficient of x displacement

C_y is coefficient of y displacement

Again, the X,Y coordinate system is oriented as shown in Figure E.1.

The location of each rod in the X,Y coordinate system is determined from the geometry parameters. With these coordinates, values of $P_{x,y}$ can be obtained. Since both power densities and radial peaking factors are normalized

FIGURE E.1. Location of Section Centroids and Axes Orientation for Assembly Power Density Specification

to 1.0 at the average value, no conversion is necessary. The value of $P_{x,y}$ at the X,Y coordinate of each rod is the value of the radial peaking factor for that rod.

During calculation of the plane equation to fit the six power densities, the code prints out a value that is the maximum error of planar fit of the six power densities. This is the maximum absolute value of the calculated power density at each point subtracted from the specified power density. This gives the user a measure of nonlinearity of the specified power skew. Since CORTAN fits the six power densities with a plane, the calculated power skew will be linear. If the error from this linear approximation in any assembly is too large, the user may wish to specify the radial peaking factors for each rod in that assembly.

APPENDIX F

COMMON VARIABLE DESCRIPTIONS

APPENDIX F

COMMON VARIABLE DESCRIPTIONS

Appendix F contains descriptions of all variables in common storage that are used in the CORTRAN code. Table F.1 describes the subscripts or array indices used for those variables that are dimensioned. The actual value of this dimension is tabulated under the column heading "Maximum Dimension."

Each variable description contains the variable name and index, the common block in which the variable is stored, and a short description with units.

TABLE F.1. Index Table for Variable Arrays

<u>Index</u>	<u>Description</u>	<u>Maximum Dimension</u>
I	Coolant channel number	126
J	Axial level	49
K	Wall coolant channel number	30
N	Entry in assembly/ring table	218
IN	Radial fuel node	10
IR	Fuel rod number	61
NP	Entry in sodium property table	50

Common Block Variables

<u>Variable</u>	<u>Common Block</u>	<u>Description</u>
A(I)	/BLCOM/	Flow area of channel I (ft ²)
ACORN	/TRCOM/	Flow area of corner channel (ft ²)
ACTIVE	/DDUCT/	Active length of rod (ft)
AIJ	/BLCOM/	Distance between neighboring rod (ft)
APITCH	/BLCOM/	Assembly pitch (in.)
ASMTBL(N)	/DATAP/	Table containing assembly numbers to be used
ATOTAL	/BLCOM/	Total flow area of assembly (ft ²)

<u>Variable</u>	<u>Common Block</u>	<u>Description</u>
AUNIT	/TRCOM/	Flow area of triangular (interior) channel (ft ²)
AWALL	/TRCOM/	Flow area of wall channel (ft ²)
AXIAL(NP)	/BLCOM/	Normalized axial distance corresponding to heatflux FAX(NP) for rod
C1	/BLCOM/	Swirl flow parameter
CHOICE	/BLCOM/	Solution option CHOICE: -1, -2 = CORTAN I 0, 1 = CORTAN II, 2 = CORTAN III
CONAVG	/BLCOM/	Average conductivity of sodium (Btu/hr-ft-°F)
CONVER	/BLCOM/	Convergence criterion used for crossflow convergence in CORTAN III
CPAVG	/BLCOM/	Average specific heat of sodium (Btu/lb-°F)
CPWLL	/DDUCT/	Specific heat of the duct wall (Btu/lb-°F)
DDUCT	/BLCOM/	Duct flat-to-flat distance (ft)
DE(I)	/BLCOM/	Hydraulic diameter of channel I
DECORN	/TRCOM/	Hydraulic diameter of corner channel
DELV(I)	/BLCOM/	Change in velocity for channel I from step J to J+1 (ft/sec)
DEUNIT	/TRCOM/	Hydraulic diameter of triangular coolant channel
DEWALL	/TRCOM/	Hydraulic diameter of wall channel
DFLUX	/TRCOM/	Heat flux from fuel rod (for printout) (million Btu/hr)
DFUEL	/FUELT/	Diameter of fuel (ft)
DLTGAP(K,J)	/COUPLE/	Temperature difference across duct gap for wall channel K at axial level J (°F)
DRESTR	/BLCOM/	Diameter of the restructured fuel (ft)
DROD	/FUELT/	Diameter of rod (ft)
DT	/BLCOM/	Time step size (Δt)
DUCGAP	/DDUCT/	Duct gap between assemblies (ft)
DVOID	/BLCOM/	Diameter of void in fuel (ft)
DWIRE	/FUELT/	Diameter of wire wrap (ft)
DX	/BLCOM/	Axial step size (Δx) (ft)
DX1	/INPRT/	Fuel diameter (for printout) (in.)

<u>Variable</u>	<u>Common Block</u>	<u>Description</u>
EHSTA	/BLCOM/	Turbulent mixing parameter
ETA1	/BLCOM/	Centroid-to-centroid spacing between adjacent interior channels (ft)
ETA2	/BLCOM/	Centroid-to-centroid spacing between interior and wall channels (ft)
ETA3	/BLCOM/	Centroid-to-centroid spacing between adjacent wall channels (ft)
ETA4	/BLCOM/	Centroid-to-centroid spacing between wall and corner channels (ft)
ETIME	/BLCOM/	Total elapsed transient time (sec)
F(I,J)	/BLCOM/	Flow in channel I at axial level J (lbm/hr)
FAX(NP)	/BLCOM/	Normalized axial heat flux in rod at location AXIAL(NP) (Average = 1.0)
FF(L)	/TRCOM/	Normalized values of flow for forcing function
FH(L)	/TRCOM/	Normalized values of enthalpy for forcing function
FLO(I)	/BLCOM/	Flow in channel I (lbm/hr)
FLOFRC	/TRCOM/	Fraction of total flow to this assembly
FLUX(IR,J)	/FUELT/	Heat flux from rod IR at axial level J (Btu/hr)
FOLD(I,J)	/DPFOLD/	Flow in channel I at axial level J at previous time step (lbm/hr)
FP(L)	/TRCOM/	Normalized values of power for forcing function
FRIC1	/BLCOM/	Constant in friction factor expression
FRIC2	/BLCOM/	Multiplier in friction factor expression
FRIC3	/BLCOM/	Exponent in friction factor expression
FTDS	/BLCOM/	Fraction of theoretical density in restructured region
FTDU	/BLCOM/	Fraction of theoretical density in unrestructured region
GAP	/BLCOM/	Distance between out ring of rods and duct wall
GBAR	/BLCOM/	Mass flux of coolant
GRSTA	/BLCOM/	Modified Grashof number for determination of buoyancy effect importance
H(I,J)	/BLCOM/	Enthalpy in channel I at axial level J (Btu/lbm)
HCOEFF	/FUELT/	Heat transfer coefficient (in HTCOF)

<u>Variable</u>	<u>Common Block</u>	<u>Description</u>
HDUCT	/DDUCT/	Heat transfer coefficient of the duct wall (Btu/ft-hr-°F)
HGAP1	/TRCOM/	Gap conductance (for printout) (Btu/hr-°F)
HGAP	/FUELT/	Gap conductance (Btu/sec-°F)
HHF(NP)	/NAPROP/	Fluid enthalpy entries in sodium property table (Btu/lbm)
HHG(NP)	/NAPROP/	Vapor enthalpy entries in sodium property table (Btu/lbm)
HIN	/INPRT/	Enthalpy at inlet to assembly (Btu/lbm)
HOLD(I,J)	/BLCOM/	Enthalpy of channel I at axial level J at previous time step (Btu/lbm)
HPCORN	/TRCOM/	Heated perimeter of corner channel (ft)
HPERIM(I)	/BLCOM/	Heated perimeter of channel I (ft)
HPTOTAL	/BLCOM/	Total heated perimeter (ft)
HPUNIT	/TRCOM/	Heated perimeter of triangular coolant channel (ft)
HPWALL	/TRCOM/	Heated perimeter of wall channel (ft)
HSAT	/BLCOM/	Saturation enthalpy (Btu/lbm)
HTRANF(I)	/DDUCT/	Rate of convective heat transfer at coolant node I
HTWALL(J)	/DDUCT/	Total rate of convective heat transfer at level J
HVSAT	/BLCOM/	Vapor saturation enthalpy at inlet pressure (PREF) (Btu/lbm)
HWLTCL	/DDUCT/	Total rate of convective heat transfer in the assembly
IDUCT	/DDUCT/	Flag for duct calculations. IDUCT = 0: no duct temperatures; IDUCT = 1: calculate duct temperatures
IUNIT	/DATAP/	Unused
KT	/TRCOM/	Counter to print results at each time step
LC(I,4)	/BLCOM/	Channel numbers of channels having flow connections with channel I
LEADOD	/BLCOM/	Lead over diameter of wire wrap
LENGTH	/BLCOM/	Total length of fuel rod (ft)
LR(IR,6)	/FUELT/	Channel numbers that connect with rod IR
LW(K)	/DDUCT/	Channel numbers of the K wall/corner channels

Variable	Common Block	Description
N1	/BLCOM/	Largest channel number of an interior (triangular) channel connecting with only other interior channels
N2	/BLCOM/	Largest channel number of an interior channel
N3	/BLCOM/	Largest channel number of a wall channel
N4	/BLCOM/	Largest channel number of a corner channel
NCHANL	/BLCOM/	Number of channels in this assembly
NDEBUG	/BLCOM/	Debug flag
NDT	/INPRT/	Number of time steps
NDTP1	/DATAP/	Number of time steps +1
NDXP1	/DATAP/	Number of axial steps +1
NDX	/BLCOM/	Number of axial steps
NEIGH(6)	/COUPLE/	Assembly numbers of the six neighboring assemblies
NF	/TRCOM/	Number of points in the forcing function for flow
NH	/TRCOM/	Number of points in the forcing function for enthalpy
NINWND	/DDUCT/	Number of internal wall nodes in the duct
NITER	/BLCOM/	Number of iterations to perform in ENT1
NK1	/TRCOM/	Channel number of first wall channel
NK2	/TRCOM/	Channel number of first corner channel
NODATA	/BLCOM/	Number of data points in the sodium property table
NODESF	/FUELT/	Number of nodes in the fuel rod
NOHT	/DATAP/	Interassembly heat transfer flag. NOHT = 0: IAHT effects ignored: NOHT > 0: IAHT included for more than one node
NOMAXI	/BLCOM/	Maximum number of iterations for crossflow convergence in ENT2
NOOFAX	/BLCOM/	Number of points in the axial flux profile for the rod
NOROD	/FUELT/	Number of rods in the assembly
NOUT	/TRCOM/	Rod, channel, and duct print flag
NP	/TRCOM/	Number of points in the forcing function for power

Variable	Common Block	Description
NPCHAN	/TRCOM/	Number of channels for printout
NPNODE	/TRCOM/	Number of wall nodes for printout
NPROD	/TRCOM/	Number of rods for printout
NSKIPT	/TRCOM/	Number of time steps to skip in printout
NSKIPX	/TRCOM/	Number of axial steps to skip in printout
NTDON	/DATAP/	Unused
NTLROD	/BLCOM/	Total number of rods in assembly to be modeled
NWNODE	/DDUCT/	Number of nodes in duct wall
OUTPUT(15)	/TRCOM/	Auxiliary array for printout
PCWET(K)	/DDUCT/	Duct length associated with wall channel K (ft)
PHI(IR,6)	/FUELT/	Fraction of power to each of the six neighboring channels of rod IR
POD	/BLCOM/	Pitch over diameter (p/d) for assembly
POWER	/FUELT/	Value of assembly power at time ETIME in transient, normalized.
PP	/NAPROP/	Pressure entries for sodium properties table (psia)
PREF	/BLCOM/	Pressure at inlet to assembly (psia)
PRESS(I,J)	/DPFOLD/	Pressure in channel I at axial node J (psia)
PRINTC(126)	/TRCOM/	Channel numbers for which to print results
PRINTN(10)	/TRCOM/	Rod node numbers for which to print results
PRINTR(61)	/TRCOM/	Rod numbers for which to print results
PWRF(I,IR)	/FUELT/	Fraction of power at rod IR delivered to channel I
QBAR	/BLCOM/	Average heat flux (million Btu/hr-ft ²)
QDUCT	/DDUCT/	Volumetric heat generation rate in the duct wall
QPRAD	/BLCOM/	Radial peak to average power ratio
QTOT(J)	/BLCOM/	Energy added at level J
QTPRIM(I)	/BLCOM/	Heat generation rate in channel I (Btu/hr-ft ³)
RADIAL(IR)	/FUELT/	Normalized radial peaking factor for rod IR
RHAVG(J)	/BLCOM/	Average coolant density at axial level J (lbm/ft ³)

Variable	Common Block	Description
RHO(I,J)	/DPFOLD/	Density in channel I at axial level J (lbm/ft ³)
RHOFF(NP)	/NAPROP/	Liquid density entries for sodium properties table (lbm/ft ³)
RHOGG(NP)	/NAPROP/	Vapor density entries for sodium properties table (lbm/ft ³)
RHOIN	/BLCOM/	Inlet density (lbm/ft ³)
RHOOLD(I,J)	/DPFOLD/	Density in channel I at axial level J at previous time step (lbm/ft ³)
RHOWL	/DDUCT/	Density of duct wall (lb/ft ³)
RHSAT	/BLCOM/	Saturation liquid density at inlet pressure (PREF) (lbm/ft ³)
RHVSAT	/BLCOM/	Saturation vapor density at inlet pressure (PREF) (lbm/ft ³)
RKWL	/DDUCT/	Thermal conductivity of duct wall (Btu/hr-ft-°F)
RMU(I)	/BLCOM/	Viscosity of channel I
RNGTBL(N)	/DATAP/	Table containing number of rings in assembly ASMTBL(N)
SAVEDT	/DATAP/	Save transient Δt (steady state)
SCALE	/BLCOM/	Scale factor used to lump channels and rods in this assembly
SHAPEF	/BLCOM/	Shape factor
T(I)	/BLCOM/	Temperature in channel I (°F)
TAVGZ	/BLCOM/	Assembly average saturation temperature (°F)
TBAR(I,J)	/BLCOM/	Average temperature of channel I in node J (°F)
TCLAD1	/INPRT/	Cladding thickness for printout (in.)
TCOUP(L,K,J)	/COUPLE/	Outside wall temperature of wall channel K at axial level J (used for IAHT)
TDUMY(10)	/TRCOM/	Utility temperature array for rod temperature profile
TFLOW	/TRCOM/	Total flow to all assemblies (lbm/hr)
TFLOWN	/TRCOM/	Assembly flow at time (ETIME) into the transient
TFLUID	/FUELT/	Coolant fluid temperature used for flux calculation in HEAT (°F)
THCLAD	/FUELT/	Cladding thickness (ft)

<u>Variable</u>	<u>Common Block</u>	<u>Description</u>
TMAX	/DATAP/	Unused - user specified time limit
TROD(IN,IR,J)	/FUELT/	Rod temperature at node IN in rod IR at level J (°F)
TSAT	/BLCOM/	Saturation temperature (°F)
TT(NP)	/NAPROP/	Temperature entries into sodium properties table (°F)
TTIME	/INPRT/	Total time of transient (sec)
TWALL(IN,K,J)	/DDUCT/	Temperature at wall node IN in duct associated with wall channel K at level J
UEQ	/DDUCT/	Equivalent gap conductance for fuel rod lumping gap and cladding
UUF(NP)	/NAPROP/	Unused
V(I)	/BLCOM/	Coolant velocity in channel I (ft/sec)
V11	/BLCOM/	Inlet velocity in interior channels (ft/sec)
V22	/BLCOM/	Inlet velocity in wall channels (ft/sec)
V33	/BLCOM/	Inlet velocity in corner channels (ft/sec)
VB	/INPRT/	Bundle average velocity (ft/sec)
VEL1	/BLCOM/	Inlet flow split ratio for interior channels
VEL2	/BLCOM/	Inlet flow split ratio for wall channels
VEL3	/BLCOM/	Inlet flow split ratio for corner channels
VISSAT	/BLCOM/	
WALLTH	/DDUCT/	Duct wall thickness (ft)
WP(I)	/BLCOM/	Wetted perimeter of channel I (ft)
WPITCH	/FUELT/	Wire wrap pitch (ft)
X(J)	/BLCOM/	Axial distance to level J (ft)
YF(30)	/TRCOM/	Time values of flow for forcing function (sec)
YH(30)	/TRCOM/	Time values of enthalpy for forcing function (sec)
YP(30)	/TRCOM/	Time values of power for forcing function (sec)

APPENDIX G

SAMPLE INPUT

APPENDIX G

SAMPLE INPUT

This section describes the input necessary to run the CORTRAN code as applied to a specific sample problem. In this problem there are ten assemblies (shown in Figure G.1). Two of the assemblies are modeled with 126 coolant nodes; three assemblies are modeled with 42 coolant nodes; and 5 assemblies are modeled with 1 node. The sample input begins with the control cards and segmentation directives necessary to run the code. Following is the actual input data. At the right of each data record is the card number as described in the section on data input.

FIGURE G.1. Core Layout for 10-Assembly Test Case

5.
ω

-- EOR --

```

CORTRAN GLOBAL TRCOM,COUPLE,DPFOLD,INPRT,NAPROP
CORTRAN GLOBAL FUELT,DUCT,RDNAM
MAIN TREE CORTRAN=(CHLEUM,ASSEM,IAHT,ENT1,ENT2,PRTINP,RDPEAK)
END CORTRAN

```

-- EOR --

10	10	1	1						[Card A]
0.0		0.316		0.25	50	1	1.0E-6	25	1
38									[Card B]
.1526E-3	540.0055	.174		.328E-6	106.806	2032	.78		[Card C]
.2368E-3	560.0055	.007		.498E-6	113.0750	2036.			[Card D]
.3606F-3	580.0054	.840		.746E-6	114.3276	2041.78			[Card E]
.5408E-3	600.0054	.673		.109E-5	125.5646	2045.			[Card F]
.7988E-3	620.0054	.506		.159E-5	131.7862	2048.			[Card G]
.1163E-2	640.0054	.339		.227E-5	137.9930	2052.			[Card H]
.1670E-2	660.0054	.172		.321E-5	144.1854	2056.			[Card I]
.2368E-2	680.0054	.005		.448E-5	150.3639	2059.			[Card J]
.3317E-2	700.0	53.839		.6181E-5	156.5287	2063.293			[Card K]
.4593E-2	720.0	53.672		.8420E-5	162.6805	2066.567			[Card L]
.6289E-2	740.0	53.505		.1135E-4	168.8195	2069.716			[Card M]
.8521E-2	760.0	53.338		.1514E-4	174.9463	2072.741			[Card N]
.1143E-1	780.0	53.171		.2001E-4	181.0612	2075.640			[Card O]
.1519E-1	800.0	53.004		.2620E-4	187.1647	2078.413			[Card P]
.2001E-1	820.0	52.837		.3401E-4	193.2573	2081.061			[Card Q]
.2612E-1	840.0	52.670		.4378E-4	199.3393	2083.584			[Card R]
.3383E-1	860.0	52.503		.5592E-4	205.4112	2085.987			[Card S]
.4347E-1	880.0	52.336		.7087E-4	211.4733	2088.267			[Card T]
.5543E-1	900.0	52.169		.8919E-4	217.5262	2090.427			[Card U]
.7018E-1	920.0	52.002		.1115E-3	223.5703	2092.447			[Card V]
.8825E-1	940.0	51.835		.1384E-3	229.6060	2094.368			[Card W]
.1102	960.0	51.668		.1707E-3	235.6337	2096.176			[Card X]
.1368	980.0	51.501		.2094E-3	241.6538	2097.873			[Card Y]
.1688	1000.0	51.335		.2552E-3	247.6668	2099.463			[Card Z]
.2071	1020.0	51.168		.3095E-3	253.6742	2100.948			[Card AA]
.2527	1040.0	51.001		.3732E-3	259.6732	2102.332			[Card AB]
.3066	1060.0	50.834		.4478E-3	265.6675	2103.619			[Card AC]
.3702	1080.0	50.667		.5347E-3	271.6563	2104.814			[Card AD]
.4447	1100.0	50.500		.6355E-3	277.6402	2105.919			[Card AE]
.5317	1120.0	50.333		.7518E-3	283.6195	2106.941			[Card AF]
.6328	1140.0	50.166		.8855E-3	289.5947	2107.883			[Card AG]
.7499	1160.0	49.999		.1039E-2	295.5662	2108.7502			[Card AH]
.8848	1180.0	49.832		.1213E-2	301.5344	2109.5472			[Card AI]
1.040	1200.0	49.665		.1412E-2	307.4998	2110.2802			[Card AJ]
1.217	1220.0	49.498		.1637E-2	313.4620	2110.9532			[Card AK]

G.4

```
[Card 0]
[Card 0]
[Card 0]
[Card 0]
[Card F]
[Card G]
[Card H]
[Card I]
[Card J]
[Card K]
[Card L]
[Card M]
[Card 1.1]
[Card 1.2]
[Card 2.1]
[Card 3.1]
[Card 3.2]
[Card 3.3A]
[Card 4.1]
[Card 4.2]
[Card 4.3]
[Card 4.3]
[Card 4.3]
[Card 4.3]
[Card 4.5]
[Card 4.5]
[Card 4.5]
[Card 4.5]
[Card 5.1]
[Card 5.2]
[Card 5.3]
[Card 5.4]
[Card 6.1]
[Card 6.2]
[END OF ASSEMBLY DATA]
```

```
[Card 0]
[Card 2.1]
[END OF ASSEMBLY DATA]
```

```
[Card 0]
[Card 2.1]
[Card 3.1]
[Card 3.2]
[Card 3.3A]
[Card 5.1]
[Card 5.2]
[Card 5.3]
[Card 5.4]
[Card 6.1]
[Card 6.2]
[END OF ASSEMBLY DATA]
```

[Card 0]

```
(Card 2.1)
[END OF ASSEMBLY DATA]
```

[illegible]

```
[Card 0]
[Card 2.1]
[Card 3.1]
[Card 3.2]
[Card 5.1]
[Card 5.2]
[Card 5.3]
[Card 5.4]
[Card 6.1]
[Card 6.2]
[END OF ASSEMBLY DATA]
```

```

[Card 0]
[Card 2.1]
[END OF ASSEMBLY DATA]

```

```
[Card 0]
[Card 2.1]
[END OF ASSEMBLY DATA]
```

```
[Card 0]
[Card 2.1]
[END OF ASSEMBLY DATA]
```

```
[Card 0]
[Card 2.1]
[END OF ASSEMBLY DATA]
```

1

APPENDIX H

SAMPLE OUTPUT

APPENDIX H

SAMPLE OUTPUT

This appendix contains a partial listing of the CORTRAN output using the input included in Appendix G. Only the results of calculations for one assembly of each of the three types is shown because of space limitations. The results included are for assembly 1 (having 126 nodes and 61 rods), assembly 3 (having 42 nodes and 19 rods), and assembly 4 (a single-node assembly). The results shown are for the steady-state calculation and one transient calculation at 0.3 sec. As noted earlier, the steady-state calculation involves two time steps. First, at 0 sec, a steady-state result is provided without inter-assembly heat transfer effects. Second, at 0.01 sec, the calculation is done again, including the temperature differences between assemblies as calculated at 0 sec.

COOLANT RESULTS FOR ASSEMBLY 1 AT TIME 0.000 SECONDS INTO TRANSIENT

COMPUTATION TIME = 2.706

POWER = .1000E+01 GRAB = .1523E+07 FREQUENCY = .6000E+04 DT = .1000E+11
 GRSTA = .1231E+01
 ENY BALANCE DOES NOT INDICATE
 FLOWIN = 19.16667 ENYIN = 5540.06178 ENYADD = 1757.61635
 FLOWOUT = 19.15447 ENYOUT = 5231.72478 ENYEND = -6.94855
 HULYCL = -.00000

CHANNEL	H(T,J)	TEMP	F(T,J)	V(T)	PRESS(T,J)
1	290.468703	1142.927247	.152597	8.159328	26.827690
2	301.600456	1180.221462	.152893	8.226442	26.827676
3	301.600824	1180.222698	.152893	8.226444	26.827676
4	290.469461	1142.929787	.152597	8.154336	26.827690
5	279.252570	1105.393172	.152330	8.094414	26.827705
6	279.252387	1105.392562	.152330	8.094418	26.827705
7	279.182818	1105.159861	.152328	8.094028	26.827705
8	290.468192	1142.848552	.152596	8.159206	26.827690
9	301.600551	1179.913370	.152890	8.225778	26.827676
10	312.533840	1216.864253	.153214	8.294698	26.827661
11	312.617924	1217.166273	.153216	8.295231	26.827661
12	323.484603	1253.627664	.153562	8.365528	26.827646
13	323.487540	1253.637520	.153562	8.365548	26.827646
14	312.619433	1217.171334	.153216	8.295240	26.827661
15	312.542650	1216.913800	.153214	8.294752	26.827661
16	301.520518	1179.953480	.152891	8.225851	26.827676
17	290.465188	1142.869580	.152596	8.159228	26.827690
18	279.196436	1105.205412	.152329	8.094101	26.827705
19	267.919172	1067.519609	.152091	8.031358	26.827720
20	267.942121	1067.596250	.152091	8.031475	26.827720
21	256.547350	1024.580499	.151876	7.970338	26.827735
22	256.542744	1029.565147	.151876	7.970300	26.827735
23	267.940683	1067.591446	.152091	8.031467	26.827720
24	267.910414	1067.490362	.152090	8.031302	26.827720
25	266.666892	1063.337535	.152066	8.024528	26.827721
26	278.824477	1103.961257	.152320	8.091992	26.827705
27	289.032373	1135.117796	.152561	8.150869	26.827691
28	301.055674	1178.375743	.152878	8.223002	26.827676
29	310.560862	1210.266853	.153154	8.282181	26.827662
30	321.190844	1245.929839	.153487	8.350505	26.827648
31	322.899611	1251.664438	.153543	8.361685	26.827647
32	332.335410	1282.949419	.154454	8.423507	26.827633
33	333.736198	1287.572002	.153901	8.432750	26.827632
34	342.815988	1316.883565	.154202	8.491857	26.827619
35	342.652243	1317.003240	.154203	8.492100	26.827619
36	333.760819	1287.653272	.153902	8.432912	26.827632
37	332.486520	1283.440892	.153859	8.424501	26.827633
38	322.957698	1251.859377	.153545	8.362068	26.827647
39	321.469586	1246.865295	.153496	8.352328	26.827648
40	310.858394	1211.264781	.153163	8.284068	26.827662
41	301.130778	1178.677588	.152850	8.223517	26.827676
42	289.780776	1139.217019	.152569	8.152798	26.827691
43	278.921475	1104.285704	.152323	8.092542	26.827705
44	267.044110	1064.603961	.152073	8.024588	26.827721
45	256.002774	1027.765248	.151867	7.967462	26.827735

CHANNEL	H(T, J)	TEMP	F(I, J)	V(I)	PHASE(T, J)
46	256.425489	1029.174164	.151870	7.964690	26.827735
47	244.852702	990.649454	.151676	7.969550	26.827750
48	245.025165	991.213587	.151679	7.910443	26.827750
49	233.411188	952.625676	.151491	7.851550	26.827765
50	233.304180	952.270831	.151489	7.851021	26.827765
51	244.985296	991.080974	.151678	7.910237	26.827750
52	244.670962	990.608768	.151673	7.908647	26.827750
53	256.367186	1028.979453	.151873	7.969383	26.827735
54	255.748038	1026.916126	.151862	7.964120	26.827735
55	261.631515	1046.533925	.151959	7.997350	26.827725
56	282.438504	1117.722154	.152414	8.115466	26.827676
57	303.008283	1164.934734	.152932	8.234993	26.827668
58	322.785974	1251.283075	.153339	8.360540	26.827640
59	333.988094	1288.390267	.153910	8.434388	26.827626
60	343.469022	1319.435294	.154228	8.497037	26.827612
61	343.686917	1320.418625	.150238	8.499038	26.827612
62	334.950177	1291.579261	.153942	8.400781	26.827625
63	324.366787	1256.588262	.153591	8.371320	26.827640
64	304.769354	1190.845723	.152983	8.245900	26.827667
65	285.009769	1124.653464	.152463	8.127410	26.827695
66	263.866744	1053.991771	.152012	8.009363	26.827723
67	243.081000	984.747084	.151647	7.900490	26.827752
68	232.556148	949.788630	.151477	7.847260	26.827766
69	221.637380	913.603943	.151301	7.792410	26.827780
70	220.883593	911.109650	.151289	7.789071	26.827781
71	231.450907	946.121429	.151460	7.841727	26.827767
72	241.714930	980.203325	.151625	7.843526	26.827752
73	242.524580	982.896324	.151638	7.897654	26.827748
74	262.414909	1049.164401	.151984	8.001581	26.827721
75	281.338602	1112.370680	.152377	8.106292	26.827695
76	295.971666	1161.356754	.152739	8.192127	26.827672
77	303.994532	1184.265102	.152961	8.241131	26.827660
78	311.799314	1234.549375	.153378	8.329472	26.827644
79	327.685584	1267.599348	.153700	8.393007	26.827630
80	332.637062	1283.613801	.153661	8.424830	26.827621
81	332.543143	1263.633810	.153861	8.424870	26.827621
82	329.771476	1274.491332	.153769	8.406660	26.827629
83	321.612362	1247.344450	.153501	8.353258	26.827641
84	309.677163	1207.302910	.153127	8.276600	26.827656
85	301.123639	1178.623500	.152879	8.223418	26.827669
86	287.198123	1131.978255	.152516	8.140130	26.827691
87	268.980165	1071.062868	.152112	8.037150	26.827716
88	249.198915	1005.101608	.151749	7.931430	26.827744
89	239.743077	973.652187	.151593	7.883508	26.827756
90	231.034986	944.741397	.151453	7.839640	26.827768

CHANNEL	H(I,J)	T(I,J)	F(I,J)	V(I)	PHYS(I,J)
91	221.207974	912.143035	.151294	7.700682	26.827782
92	211.037205	878.561241	.151121	7.700211	26.827795
93	209.727615	874.240654	.151097	7.734710	26.827796
94	218.244238	902.392540	.151245	7.775990	26.827784
95	227.476548	932.943811	.151396	7.821867	26.827771
96	234.909624	957.597506	.151515	7.854088	26.827759
97	220.554892	910.038524	.175404	9.004316	26.827784
98	231.308661	945.644456	.175606	9.066233	26.827769
99	243.902065	987.478013	.175841	9.139850	26.827753
100	255.944819	1027.572065	.176079	9.212086	26.827738
101	265.398623	1059.102892	.176283	9.270456	26.827724
102	275.674986	1093.431663	.176526	9.335911	26.827716
103	284.531724	1123.053367	.176759	9.394187	26.827705
104	290.470143	1144.606692	.176942	9.437704	26.827694
105	291.835930	1147.506421	.176967	9.443639	26.827699
106	293.024938	1151.488697	.177002	9.451811	26.827699
107	290.617521	1143.425677	.176931	9.435290	26.827703
108	285.198511	1125.251742	.176777	9.398582	26.827710
109	274.662396	1040.047281	.176501	9.329362	26.827725
110	267.058839	1064.646472	.176320	9.280880	26.827735
111	256.636184	1029.876614	.176094	9.216301	26.827748
112	244.324499	988.883086	.175849	9.142358	26.827764
113	230.361768	942.507651	.175588	9.060751	26.827780
114	222.681942	917.060412	.175445	9.016494	26.827788
115	215.424709	893.056251	.175304	8.974856	26.827796
116	206.290950	869.500834	.175158	8.933905	26.827805
117	202.714033	851.112612	.175036	8.901750	26.827810
118	204.291174	856.310788	.175072	8.918868	26.827806
119	208.773151	871.091706	.175168	8.936677	26.827799
120	214.114630	888.727485	.175278	8.967342	26.827792
121	214.108239	888.706370	.047507	9.497875	26.827793
122	255.723512	1026.834374	.047723	9.755711	26.827743
123	288.139872	1135.130444	.047936	9.975717	26.827707
124	280.034110	1108.007326	.047876	9.918431	26.827722
125	239.322024	972.253364	.047637	9.662081	26.827772
126	205.827635	861.373896	.047461	9.447477	26.827808

CHANNEL AXIAL RESULTS FOR ASSEMBLY 1 AT TRANSIENT TIME 0.0000 SECONDS

TIME = 0.00000 SEC

DATA FOR CHANNEL 1

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.152465	184.694550	8.154326	791.920000
12.000000	.152593	245.264070	8.154326	992.008234
24.000000	.152597	290.468703	8.154326	1142.927247

TIME = 0.00000 SEC

DATA FOR CHANNEL 97

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.176774	184.698886	9.004315	791.920000
12.000000	.176124	203.950518	9.004315	855.222707
24.000000	.175404	220.559592	9.004315	910.038524

TIME = 0.00000 SEC

DATA FOR CHANNEL 124

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.047913	184.698886	9.918431	791.920000
12.000000	.047872	229.116410	9.918431	934.377685
24.000000	.047876	240.034110	9.918431	1108.007326

OUTLET TAVGZ = 1098.040803 AT TIME = 0.000000

POD AXIAL RESULTS FOR ASSEMBLY 1 AT TRANSIENT TIME 0.000 SECONDS

ELAPSED TIME =	0.0000	WOD NO.	1	2	3	4	5	6						
AXIAL DIST =	.500	FLUX =	.27671	NODE TEMP =	1413.	1390.	1298.	1150.	954.5	813.0				
AXIAL DIST =	12.500	FLUX =	.27671	NODE TEMP =	1663.	1630.	1535.	1371.	1153.	1014.				

ELAPSED TIME =	0.0000	WOD NO.	48	49	50	51	52	53	54	55	56			
AXIAL DIST =	.500	FLUX =	.45867	NODE TEMP =	1817.	1767.	1626.	1381.	1057.	822.6				
AXIAL DIST =	12.500	FLUX =	.45867	NODE TEMP =	2133.	2078.	1921.	1649.	1288.	1059.				

WALL NODE
AND LEVEL

	TEMPERATURES		
(1,13)	852.403	852.403	852.403
(3,13)	894.667	894.667	894.667
(5,13)	928.711	928.711	928.711
(7,13)	959.088	959.088	959.088
(9,13)	966.214	966.214	966.214
(11,13)	959.686	959.686	959.686
(13,13)	928.033	928.033	928.033
(15,13)	895.986	895.986	895.986
(17,13)	851.829	851.829	851.829
(19,13)	831.113	831.113	831.113
(21,13)	813.714	813.713	813.713
(23,13)	830.389	830.389	830.389
(25,13)	838.117	838.117	838.117
(27,13)	953.841	953.841	953.841
(29,13)	861.633	861.633	861.633

WALL NODE
AND LEVEL

	TEMPERATURES		
(2,13)	872.724	872.724	872.724
(4,13)	915.452	915.452	915.452
(6,13)	945.634	945.634	945.634
(8,13)	969.267	969.267	969.267
(10,13)	966.496	966.496	966.496
(12,13)	948.892	948.892	948.892
(14,13)	914.892	914.892	914.892
(16,13)	874.861	874.861	874.861
(18,13)	841.745	841.745	841.745
(20,13)	820.019	820.019	820.019
(22,13)	820.494	820.494	820.494
(24,13)	840.624	840.624	840.624
(26,13)	907.749	907.749	907.749
(28,13)	930.430	930.430	930.430
(30,13)	814.924	814.924	814.924

WALL NODE
AND LEVEL

	TEMPERATURES		
(1,25)	909.660	909.660	909.660
(3,25)	987.152	987.152	987.152
(5,25)	1058.231	1058.231	1058.231
(7,25)	1121.660	1121.660	1121.660
(9,25)	1145.375	1145.375	1145.375
(11,25)	1140.821	1140.821	1140.821
(13,25)	1087.120	1087.120	1087.120
(15,25)	1027.041	1027.041	1027.041
(17,25)	939.988	939.988	939.988
(19,25)	891.231	891.231	891.231
(21,25)	849.881	849.881	849.881
(23,25)	870.559	870.559	870.559
(25,25)	898.061	898.061	898.061
(27,25)	1132.565	1132.565	1132.565
(29,25)	969.124	969.124	969.124

WALL NODE
AND LEVEL

	TEMPERATURES		
(2,25)	945.394	945.394	945.394
(4,25)	1027.145	1027.145	1027.145
(6,25)	1092.355	1092.355	1092.355
(8,25)	1143.019	1143.019	1143.019
(10,25)	1149.155	1149.155	1149.155
(12,25)	1122.542	1122.542	1122.542
(14,25)	1061.808	1061.808	1061.808
(16,25)	986.122	986.122	986.122
(18,25)	914.966	914.966	914.966
(20,25)	867.872	867.872	867.872
(22,25)	855.535	855.535	855.535
(24,25)	888.307	888.307	888.307
(26,25)	1025.715	1025.715	1025.715
(28,25)	1104.476	1104.476	1104.476
(30,25)	859.603	859.603	859.603

COOLANT RESULTS FOR ASSEMBLY 3 AT TIME 0.000 SECONDS INTO TRANSIENT (COMPUTATION TIME = 8.563)

POWER = .1000E+01 GRAN = .1523E+07 THERMALPOWERAC = .6900E+05 DT = .1000E+01
 GRSTA = .1117E-01
 ENY BALANCE DOES NOT INDICATE
 FLOWIN = 19.16667 FLOWOUT = 3540.06199 ENYADN = 1757.63579
 FLOWHT = 19.15827 ENYDHT = 5291.32980 ENYEND = -6.56797
 HWLTCL = -.00000

CHANNEL	H(I,J)	TEMP	F(I,J)	V(I)	PRESS(I,J)
1	290.389229	1142.661072	.613423	8.159444	26.828140
2	310.498126	1210.056034	.612652	8.222381	26.828113
3	310.501715	1210.075190	.612653	8.222417	26.828113
4	290.401142	1142.700970	.612424	8.149518	26.828140
5	270.016979	1074.525370	.608575	8.043420	26.828167
6	270.016646	1074.504226	.608575	8.043394	26.828167
7	289.093924	1138.323819	.610293	8.151821	26.828141
8	328.424007	1270.036830	.614442	8.394431	26.828088
9	328.535975	1270.406440	.614456	8.394165	26.828088
10	289.332414	1139.122084	.610317	8.153222	26.828141
11	248.989968	1004.405861	.607024	7.931437	26.828194
12	248.863401	1003.984421	.607016	7.930782	26.828194
13	262.474656	1049.347066	.607985	8.002458	26.828173
14	299.236489	1172.279377	.611353	8.212456	26.828123
15	316.703537	1230.872950	.613418	8.321996	26.828098
16	335.192570	1292.379383	.615846	8.482993	26.828073
17	339.501183	1293.398092	.615887	8.485034	26.828073
18	318.419821	1236.631231	.613636	8.333087	26.828097
19	301.131715	1178.650565	.611563	8.224062	26.828122
20	264.799614	1057.104294	.609162	8.014982	26.828172
21	246.481233	996.056655	.606956	7.918498	26.828197
22	227.365702	932.576508	.605621	7.821880	26.828222
23	226.651665	930.210465	.605575	7.818329	26.828223
24	244.944485	991.111542	.606758	7.910863	26.828197
25	226.213713	928.759261	.605104	7.837480	26.828226
26	245.741293	993.595519	.605179	7.915128	26.828201
27	262.161147	1048.301043	.605248	8.250958	26.828181
28	276.432493	1095.963478	.605317	8.341503	26.828164
29	280.237636	1108.688764	.605312	8.366380	26.828162
30	276.533734	1096.301857	.605312	8.342161	26.828168
31	263.078213	1051.360835	.605288	8.246653	26.828187
32	246.060365	994.656794	.605179	7.915332	26.828209
33	227.293759	932.338120	.605108	7.804370	26.828232
34	214.853478	891.188613	.605061	7.722275	26.828246
35	208.512719	870.232490	.605052	7.715830	26.828252
36	214.636495	890.451832	.605060	7.970998	26.828282
37	214.338786	889.468144	.604751	7.999475	26.828243
38	245.720320	993.527425	.604767	7.992760	26.828203
39	274.239069	1088.632393	.604784	8.879178	26.828172
40	271.939164	1080.945416	.604782	8.863528	26.828179
41	241.169724	978.391802	.604750	7.964275	26.828219
42	212.043035	882.047730	.604750	7.486323	26.828251

CHANNEL AXIAL RESULTS FOR ASSEMBLY 3 AT TRANSIENT TIME 0.000 SECONDS

TIME = 0.00000 SEC

DATA FOR CHANNEL 3

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.609859	184.694886	8.159446	791.920000
12.000000	.610208	245.257408	8.159448	991.967387
24.000000	.610423	296.349229	8.159448	1142.661072

TIME = 0.00000 SEC

DATA FOR CHANNEL 25

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.353548	184.694886	9.037480	791.920000
12.000000	.352287	207.050477	9.037480	865.421479
24.000000	.351048	226.213713	9.037480	928.759261

TIME = 0.00000 SEC

DATA FOR CHANNEL 40

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.047913	184.694886	9.863528	791.920000
12.000000	.047844	226.103334	9.863528	928.393518
24.000000	.047824	271.939164	9.863528	1090.945416

OUTLET TAVGZ = 3097.772947 AT TIME = 0.000000

RDD AXIAL RESULTS FOR ASSEMBLY 3 AT TRANSIENT TIME 0.000 SECONDS

ELAPSED TIME = 0.0000 RDD NO. 1 NODES = 1 2 3 4 5 6
 AXIAL DIST = .500 FLUX = .27071 NODE TEMP = 1413. 1487. 1248. 1150. 954.5 813.0
 AXIAL DIST = 12.500 FLUX = .27071 NODE TEMP = 1058. 1625. 1531. 1768. 1153. 1010.

ELAPSED TIME = 0.0000 RDD NO. 13 NODES = 1 2 3 4 5 6
 AXIAL DIST = .500 FLUX = .44137 NODE TEMP = 1779. 1731. 1595. 1750. 1047. 821.2
 AXIAL DIST = 12.500 FLUX = .44137 NODE TEMP = 2070. 2018. 1868. 1600. 1265. 1047.

WALL NODE
 AND LEVEL TEMPERATURES
 (1,13) 862.186 862.186 862.186
 (3,13) 924.348 924.348 924.348
 (5,13) 948.646 948.646 948.646
 (7,13) 911.122 911.122 911.122
 (9,13) 848.940 848.940 848.940
 (11,13) 824.308 824.308 824.308
 (13,13) 837.067 837.067 837.067
 (15,13) 934.544 934.544 934.544
 (17,13) 866.476 866.476 866.476

WALL NODE
 AND LEVEL TEMPERATURES
 (2,13) 897.637 897.637 897.637
 (4,13) 947.123 947.123 947.123
 (6,13) 938.511 938.511 938.511
 (8,13) 880.368 880.368 880.368
 (10,13) 830.542 830.542 830.542
 (12,13) 839.191 839.191 839.191
 (14,13) 892.461 892.461 892.461
 (16,13) 921.591 921.591 921.591
 (18,13) 824.038 824.038 824.038

WALL NODE
 AND LEVEL TEMPERATURES
 (1,25) 928.299 928.299 928.299
 (3,25) 1047.536 1047.536 1047.536
 (5,25) 1106.922 1106.922 1106.922
 (7,25) 1048.873 1048.873 1048.873
 (9,25) 930.109 930.109 930.109
 (11,25) 869.027 869.027 869.027
 (13,25) 888.597 888.597 888.597
 (15,25) 1086.685 1086.685 1086.685
 (17,25) 975.439 975.439 975.439

WALL NODE
 AND LEVEL TEMPERATURES
 (2,25) 993.180 993.180 993.180
 (4,25) 1094.830 1094.830 1094.830
 (6,25) 1090.163 1090.163 1090.163
 (8,25) 992.186 992.186 992.186
 (10,25) 889.406 889.406 889.406
 (12,25) 889.718 889.718 889.718
 (14,25) 992.633 992.633 992.633
 (16,25) 1077.992 1077.992 1077.992
 (18,25) 880.124 880.124 880.124

COOLANT RESULTS FOR ASSEMBLY # AT TIME 0.000 SECONDS INTO TRANSIENT (COMPUTATION TIME = 11.367)

POWER = .1000E+01 GRAM = .142E+07 TFLUX+FLOWRAC = .0000E+05 DT = .1000E+11
 GRSTA = 0.
 ENY BALANCE DOES NOT THE PRODUCT
 FLOWIN = 19.16667 ENYTH = 3540.00146 ENYADD = 1757.60487
 FLOWOUT = 19.16667 ENYHOUT = 5297.97165 ENYENR = -.00000
 MULTCL = -.00000
 CHANNEL H(I,J) TEMP F(I,J) V(I) PRES9(I,J)
 1 276.400270 1095.855781 19.166667 7.797406 27.505734

CHANNEL AXIAL RESULTS FOR ASSEMBLY # AT TRANSIENT TIME 0.000 SECONDS

TIME = 0.00000 SEC DATA FOR CHANNEL 1

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	19.166667	180.678886	7.797406	791.920000
12.000000	19.166667	247.049577	7.797406	968.870275
24.000000	19.166667	276.400270	7.797406	1095.855781
OUTLET AVGZ =	1095.855781	AT TIME =	0.000000	

POD AXIAL RESULTS FOR ASSEMBLY # AT TRANSIENT TIME 0.000 SECONDS

ELAPSED TIME = 0.0000 MOD NO. 1 MODS = 1
 AXIAL DIST = .500 FLOW = .27671E+06 TEMP = 1206.
 AXIAL DIST = 12.500 FLOW = .27671E+06 TEMP = 1574.

COOLANT RESULTS FOR ASSEMBLY 1 AT TIME .010 SECONDS INTO TRANSIENT (COMPUTATION TIME = 14.549)

POWER = .9954E+00 GEAR = .1521E+07 TFLW*FLOWRAC = .0610E+05 DT = .1000E-01
 GRTA = .1233E-01
 ENY BALANCE DOES NOT INDICATE
 FLOWIN = 19.14224 FLOWOUT = 5545.55017 ENYADD = 1754.40451
 FLOWOUT = 19.13406 FLOWOUT = 5243.41551 ENYERR = -6.03417
 HWLTCL = -3.05848
 CHANNEL H(I,J) TEMP FL(I,J) V(I) PRESS(I,J)

1	290.468839	1142.927704	.152403	8.144964	26.831827
2	301.600407	1180.221972	.152699	8.215024	26.831812
3	301.600975	1180.223204	.152699	8.215924	26.831812
4	290.469596	1142.930234	.152403	8.143972	26.831827
5	279.252687	1105.393564	.152136	8.084110	26.831842
6	279.252504	1105.392952	.152136	8.084114	26.831842
7	279.182969	1105.160166	.152135	8.083724	26.831842
8	290.448306	1142.858934	.152402	8.143847	26.831827
9	301.508720	1179.913243	.152697	8.215360	26.831812
10	312.534055	1216.844674	.153020	8.284214	26.831797
11	312.618145	1217.167014	.153023	8.284750	26.831797
12	323.484862	1253.628534	.153368	8.354970	26.831783
13	323.487762	1253.638331	.153368	8.354994	26.831783
14	312.614602	1217.171902	.153023	8.284750	26.831797
15	312.542820	1216.914370	.153021	8.284271	26.831797
16	301.520670	1179.943990	.152697	8.215434	26.831812
17	290.451619	1142.870020	.152402	8.143866	26.831827
18	279.196554	1105.205806	.152135	8.083401	26.831842
19	267.919273	1067.519947	.151897	8.021104	26.831857
20	267.942222	1067.596587	.151897	8.021230	26.831857
21	256.547436	1029.540786	.151682	7.963142	26.831871
22	256.542829	1029.565432	.151682	7.960118	26.831871
23	267.940783	1067.591783	.151897	8.021224	26.831857
24	267.910496	1067.490636	.151896	8.021057	26.831857
25	266.667443	1063.339378	.151472	8.014288	26.831857
26	278.824973	1103.962916	.152127	8.081696	26.831842
27	289.032998	1134.119890	.152367	8.140521	26.831828
28	301.056223	1178.397585	.152684	8.212589	26.831812
29	310.560683	1210.266252	.152960	8.271700	26.831799
30	321.190174	1245.927591	.153293	8.339964	26.831784
31	322.894769	1251.661613	.153349	8.351134	26.831784
32	332.434582	1282.945365	.153661	8.412890	26.831769
33	333.735317	1287.569094	.153708	8.422134	26.831769
34	342.614763	1316.879587	.154008	8.481184	26.831755
35	342.651407	1317.000482	.154009	8.481431	26.831755
36	333.761026	1287.653957	.153709	8.422308	26.831769
37	332.486679	1283.487424	.153666	8.413901	26.831769
38	322.057864	1251.859934	.153351	8.351524	26.831783
39	321.469723	1246.865755	.153303	8.341792	26.831784
40	310.854527	1211.265220	.152964	8.273592	26.831798
41	301.139919	1178.678056	.152586	8.213101	26.831812
42	289.360646	1139.217385	.152375	8.142446	26.831828
43	278.921586	1104.286072	.152129	8.082244	26.831842
44	267.048197	1064.614252	.151879	8.014340	26.831857
45	256.002458	1027.755527	.151472	7.967272	26.831872

CHANNEL	H(T, J)	TIME	F(T, J)	V(T)	PRECIP(T, J)
46	236.425538	1029.174444	.151000	7.349500	26.831872
47	244.852770	990.640180	.151482	7.899010	26.831887
48	245.025236	991.213824	.151484	7.900302	26.831886
49	233.411245	952.625802	.151296	7.941460	26.831901
50	233.804241	952.270420	.151295	7.340938	26.831902
51	244.985363	991.081202	.151484	7.900098	26.831886
52	244.675011	990.048929	.151479	7.894500	26.831887
53	256.867247	1028.980157	.151679	7.859192	26.831872
54	255.748453	1028.917510	.151668	7.965935	26.831872
55	261.622559	1046.504042	.151775	7.987091	26.831861
56	282.929673	1117.692617	.152220	8.105096	26.831832
57	302.997825	1184.956376	.152739	8.224518	26.831804
58	322.807177	1251.354232	.153346	8.350536	26.831777
59	334.007081	1288.466167	.153717	8.423920	26.831762
60	343.412701	1319.513457	.154035	8.486527	26.831749
61	343.687511	1320.420587	.154045	8.488367	26.831749
62	334.950408	1291.580219	.153749	8.430168	26.831762
63	324.866955	1256.588825	.153397	8.380778	26.831774
64	304.764474	1190.848127	.152789	8.235468	26.831804
65	285.009880	1124.653835	.152269	8.117088	26.831831
66	263.866839	1053.992090	.151817	7.999138	26.831660
67	243.081067	984.747271	.151452	7.890368	26.831689
68	232.556208	949.788834	.151283	7.837182	26.831902
69	221.637435	913.604128	.151106	7.782775	26.831917
70	220.883634	911.107990	.151094	7.779038	26.831917
71	231.450936	946.121527	.151265	7.831647	26.831903
72	241.715256	980.204412	.151430	7.883402	26.831689
73	242.513535	982.859586	.151443	7.887468	26.831680
74	262.407645	1049.123488	.151790	7.991298	26.831657
75	281.826835	1112.331328	.152183	8.095910	26.831831
76	295.974236	1161.367369	.152545	8.181758	26.831608
77	304.015913	1188.319685	.152768	8.230798	26.831797
78	317.829153	1254.649888	.153186	8.318152	26.831780
79	327.714538	1267.708127	.153508	8.382650	26.831767
80	332.567440	1283.714014	.153669	8.414438	26.831757
81	332.564876	1283.703898	.153668	8.414412	26.831758
82	329.774427	1274.494474	.153575	8.396085	26.831765
83	321.612652	1247.305421	.153307	8.342725	26.831777
84	309.677301	1207.303577	.152934	8.266138	26.831793
85	301.123808	1178.624068	.152686	8.213002	26.831805
86	287.198276	1131.978768	.152322	8.129798	26.831827
87	268.980299	1071.063315	.151918	8.026908	26.831853
88	249.199036	1005.102010	.151554	7.921781	26.831880
89	239.743177	973.642514	.151398	7.873342	26.831893
90	231.035070	940.741677	.151258	7.829568	26.831905

CHANNEL	H(I, J)	TEMP	F(I, J)	V(I)	PRESS(I, J)
91	221.206048	912.143279	.151099	7.740046	26.831414
92	211.037272	878.561462	.150926	7.730210	26.831432
93	204.727867	874.240332	.150902	7.723723	26.831933
94	218.240273	902.392657	.151050	7.745471	26.831420
95	227.476737	932.944434	.151201	7.011400	26.831407
96	234.902345	957.573354	.151320	7.040954	26.831896
97	220.647223	910.315421	.175180	8.943190	26.831420
98	231.347469	945.944121	.175382	9.045092	26.831906
99	243.985455	987.755374	.175617	9.128633	26.831890
100	256.021067	1027.826223	.175656	9.200769	26.831875
101	265.231417	1058.546675	.176054	9.247581	26.831865
102	275.454142	1092.696876	.176296	9.322590	26.831853
103	284.318141	1122.338469	.176526	9.390810	26.831842
104	290.734992	1143.815764	.176710	9.424114	26.831835
105	291.811457	1147.424455	.176742	9.431485	26.831835
106	293.022535	1151.440650	.176778	9.435801	26.831835
107	290.817633	1143.426050	.176707	9.425321	26.831839
108	285.184433	1125.252823	.176552	9.346634	26.831847
109	274.662731	1090.048401	.176276	9.317480	26.831861
110	267.059106	1064.647363	.176095	9.269040	26.831871
111	256.636379	1024.877262	.175864	9.204517	26.831885
112	244.324634	988.883532	.175624	9.130638	26.831900
113	230.361909	942.508114	.175363	9.049102	26.831917
114	222.682055	917.060786	.175219	9.004884	26.831925
115	215.424792	893.056526	.175078	8.963280	26.831933
116	208.291005	869.501014	.174932	8.922360	26.831941
117	202.713113	851.112875	.174810	8.890247	26.831946
118	204.291300	856.311204	.174845	8.899348	26.831942
119	208.773402	871.092534	.174942	8.925135	26.831936
120	214.111424	888.716694	.175052	8.955750	26.831923
121	214.181152	888.947247	.047447	9.486063	26.831930
122	255.724232	1026.833438	.047662	9.743232	26.831879
123	287.896492	1134.322505	.047873	9.961318	26.831840
124	280.034310	1108.067995	.047815	9.905812	26.831858
125	239.322090	972.253543	.047376	9.639690	26.831906
126	205.827663	861.373490	.047399	9.435264	26.831945

CHANNEL AXIAL RESULTS FOR ASSEMBLY 1 AT TRANSIENT TIME 0.010 SECONDS

TIME = .01000 SEC DATA FOR CHANNEL 1

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.152273	184.694086	8.148968	791.920000
12.000000	.152399	245.258153	8.148968	942.021796
20.000000	.152403	296.464839	8.148968	1142.927705

TIME = .01000 SEC DATA FOR CHANNEL 97

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.176549	184.694086	8.993194	791.920000
12.000000	.175899	204.033105	8.993194	855.460745
20.000000	.175180	226.643723	8.993194	910.315921

TIME = .01000 SEC DATA FOR CHANNEL 124

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.047852	184.694086	9.905812	791.920000
12.000000	.047811	229.118465	9.905812	934.384497
20.000000	.047615	280.034310	9.905812	1108.007995

OUTLET TAVGZ = 1048.027633 AT TIME = .010000

POD AXIAL RESULTS FOR ASSEMBLY 1 AT TRANSIENT TIME 1010 SECONDS

ELAPSED TIME = .0100	NO. NO.	1	2	3	4	5	6				
AXIAL DIST = .500	FLUX = .27567	NO. TEMP = 1413.						1384.	1298.	1150.	954.5
AXIAL DIST = 12.500	FLUX = .27659	NO. TEMP = 1063.						1630.	1535.	1371.	1153.

ELAPSED TIME = .0100	NO. NO.	48	49	50	51	52	53				
AXIAL DIST = .500	FLUX = .45400	NO. TEMP = 1817.						1767.	1626.	1381.	1057.
AXIAL DIST = 12.500	FLUX = .45792	NO. TEMP = 2133.						2078.	1921.	1640.	1244.

WALL NODE
AND LEVEL

	TEMPERATURES		
(1,13)	855.104	860.701	866.307
(3,13)	897.521	903.433	909.355
(5,13)	920.616	923.277	927.033
(7,13)	950.132	951.576	952.990
(9,13)	966.211	966.214	966.214
(11,13)	959.686	959.686	959.686
(13,13)	924.033	924.033	924.033
(15,13)	895.487	895.946	895.946
(17,13)	851.830	851.829	851.824
(19,13)	831.113	831.113	831.114
(21,13)	813.713	813.713	813.713
(23,13)	830.389	830.389	830.389
(25,13)	840.877	846.595	852.184
(27,13)	947.040	932.946	919.239
(29,13)	861.633	861.633	861.633

WALL NODE
AND LEVEL

	TEMPERATURES		
(2,13)	875.649	881.841	888.035
(4,13)	917.752	922.515	927.288
(6,13)	936.077	946.276	956.044
(8,13)	959.434	959.042	918.456
(10,13)	966.496	966.496	966.496
(12,13)	948.993	948.802	948.892
(14,13)	914.892	914.802	914.892
(16,13)	874.461	874.461	874.461
(18,13)	841.755	841.705	841.795
(20,13)	820.019	820.019	820.019
(22,13)	820.494	820.494	820.494
(24,13)	840.625	840.624	840.624
(26,13)	905.963	902.256	898.450
(28,13)	930.930	930.930	930.930
(30,13)	814.924	814.924	814.924

WALL NODE
AND LEVEL

	TEMPERATURES		
(1,25)	909.690	909.661	909.660
(3,25)	987.182	987.143	987.152
(5,25)	1058.170	1058.229	1058.231
(7,25)	1121.584	1121.658	1121.659
(9,25)	1145.369	1145.375	1145.375
(11,25)	1140.821	1140.821	1140.821
(13,25)	1087.120	1087.120	1087.120
(15,25)	1027.041	1027.041	1027.041
(17,25)	939.988	939.988	939.988
(19,25)	891.231	891.231	891.231
(21,25)	849.881	849.881	849.881
(23,25)	870.559	870.559	870.559
(25,25)	868.092	868.062	868.061
(27,25)	1132.484	1132.563	1132.565
(29,25)	969.124	969.124	969.124

WALL NODE
AND LEVEL

	TEMPERATURES		
(2,25)	945.426	945.355	945.394
(4,25)	1027.170	1027.145	1027.145
(6,25)	1092.277	1092.343	1092.355
(8,25)	1142.936	1143.017	1143.019
(10,25)	1149.154	1149.155	1149.155
(12,25)	1122.542	1122.542	1122.542
(14,25)	1061.808	1061.808	1061.808
(16,25)	986.122	986.122	986.122
(18,25)	914.966	914.966	914.966
(20,25)	867.872	867.872	867.872
(22,25)	855.535	855.535	855.535
(24,25)	888.307	888.307	888.307
(26,25)	1025.710	1025.715	1025.715
(28,25)	1104.476	1104.476	1104.476
(30,25)	859.683	859.683	859.683

COOLANT RESULTS FOR ASSEMBLY 3 AT TIME .010 SECONDS INTO TRANSIENT (COMPUTATION TIME = 20.061)

POWER = .9958E+00 CHAN = .1521E+07 (FLUX*FLUXFRAC = .0000E+00 DT = .1000E-01
 GRATA = .1119E-01
 ENY BALANCE DOES NOT INC. PRODUCT
 FLOWIN = 19.14220 ENYIN = 3545.55017 ENYADN = 1765.59283
 FLOWOT = 19.13590 ENYOUT = 5245.39703 ENYERD = -15.74597
 MULTCL = 12.40531
 CHANNEL H(T,J) TEMP F(I,J) V(I) PRESS(T,J)

1	290.391003	1142.667012	.609714	8.109940	26.832340
2	310.490056	1210.056200	.611944	8.272805	26.832313
3	310.503632	1210.074903	.611944	8.272805	26.832313
4	290.402377	1142.705105	.609715	8.150051	26.832340
5	270.020910	1074.538505	.607866	8.034071	26.832367
6	270.015049	1074.518431	.607866	8.034050	26.832367
7	269.095423	1134.328834	.609585	8.142362	26.832341
8	328.424182	1270.037407	.614233	8.344761	26.832288
9	328.536145	1270.406992	.614249	8.344761	26.832288
10	269.334272	1134.128404	.609608	8.143760	26.832341
11	248.967698	1004.331706	.606312	7.922032	26.832394
12	248.833879	1003.886117	.606303	7.921340	26.832394
13	262.445034	1049.248232	.607272	7.992952	26.832373
14	299.230420	1172.279146	.610644	8.202932	26.832323
15	316.703670	1230.873397	.612710	8.312391	26.832298
16	335.192853	1292.340316	.615138	8.433282	26.832273
17	335.501465	1293.349020	.615179	8.435327	26.832273
18	318.419993	1236.631808	.612928	8.323470	26.832297
19	301.132463	1178.653070	.610555	8.214530	26.832322
20	264.780680	1057.041122	.607451	8.005521	26.832372
21	246.441479	995.924429	.606142	7.904012	26.832397
22	227.307059	932.342190	.604905	7.812392	26.832422
23	226.587199	929.996849	.604858	7.808807	26.832423
24	244.438096	990.923984	.606043	7.901300	26.832394
25	226.224648	928.795093	.606035	7.826906	26.832426
26	245.742464	993.599413	.601366	9.100706	26.832401
27	202.161568	1048.302448	.602036	9.240155	26.832381
28	276.432979	1095.965104	.602705	9.330628	26.832364
29	280.234317	1108.690373	.602901	9.355409	26.832362
30	276.534134	1096.303194	.602711	9.331285	26.832368
31	263.078956	1051.363315	.602076	9.245847	26.832387
32	246.047940	994.615481	.601378	9.142510	26.832409
33	227.532241	933.128522	.600684	9.034436	26.832432
34	215.069467	891.882458	.600207	8.962892	26.832446
35	208.807174	871.203954	.600950	8.926974	26.832451
36	214.433129	891.441973	.600201	8.962112	26.832441
37	214.698095	890.655371	.600745	9.040947	26.832442
38	245.721388	943.529314	.604761	9.081402	26.832404
39	274.230412	1088.633540	.604764	9.347670	26.832372
40	271.934418	1080.946265	.604769	9.352032	26.832379
41	241.322350	978.896855	.604759	9.055846	26.832414
42	212.363732	882.942166	.604745	9.475770	26.832450

CHANNEL AXIAL RESULTS FOR ASSEMBLY 3 AT TRANSIENT TIME .010 SECONDS

TIME = .01000 SEC DATA FOR CHANNEL 1

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.609082	180.694886	8.149984	791.920000
12.000000	.609419	245.262450	8.149984	992.002861
24.000000	.609714	290.391003	8.149984	1142.667012

TIME = .01000 SEC DATA FOR CHANNEL 25

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.353097	180.694886	9.026906	791.920000
12.000000	.351828	207.067336	9.026906	865.463903
24.000000	.350635	226.224648	9.026906	928.795493

TIME = .01000 SEC DATA FOR CHANNEL 40

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.047852	180.694886	9.852033	791.920000
12.000000	.047782	226.105546	9.852033	928.400834
24.000000	.047769	271.919418	9.852033	1080.946265

OUTLET TAVGZ = 1097.808013 AT TIME = .010000

PON AXIAL RESULTS FOR ASSEMBLY 4 AT TRANSIENT TIME 2010 SECONDS

ELAPSED TIME = .0160 RND NO. 1 NODES = 1 2 3 4 5 6
 AXIAL DIST = .500 FLUX = .27667 NODE TEMP = 1413. 1484. 1244. 1150. 954.5 813.0
 AXIAL DIST = 12.500 FLUX = .27653 NODE TEMP = 1658. 1625. 1531. 1464. 1153. 1014.

ELAPSED TIME = .0160 RND NO. 13 NODES = 1 2 3 4 5 6
 AXIAL DIST = .500 FLUX = .44130 NODE TEMP = 1779. 1731. 1595. 1450. 1047. 821.2
 AXIAL DIST = 12.500 FLUX = .44121 NODE TEMP = 2070. 2014. 1868. 1600. 1265. 1043.

WALL NODE
 AND LEVEL TEMPERATURES
 (1,13) 862.184 862.186 862.184
 (3,13) 924.349 924.348 924.348
 (5,13) 948.647 948.646 948.646
 (7,13) 911.122 911.122 911.122
 (9,13) 860.306 863.850 907.434
 (11,13) 836.945 863.124 884.352
 (13,13) 848.593 872.419 895.720
 (15,13) 934.544 934.544 934.544
 (17,13) 875.445 894.012 912.164

WALL NODE
 AND LEVEL TEMPERATURES
 (2,13) 897.637 897.637 897.637
 (4,13) 947.124 947.123 947.124
 (6,13) 938.511 938.511 938.511
 (8,13) 880.367 880.368 880.368
 (10,13) 840.939 862.476 884.055
 (12,13) 851.646 877.445 903.294
 (14,13) 842.462 862.461 892.061
 (16,13) 921.591 921.591 921.591
 (18,13) 533.033 852.061 872.337

WALL NODE
 AND LEVEL TEMPERATURES
 (1,25) 928.303 928.300 928.299
 (3,25) 1047.536 1047.536 1047.536
 (5,25) 1106.922 1106.922 1106.922
 (7,25) 1048.873 1048.873 1048.873
 (9,25) 930.193 930.111 930.109
 (11,25) 869.132 869.030 869.027
 (13,25) 868.723 885.601 885.594
 (15,25) 1086.685 1086.645 1086.685
 (17,25) 975.502 975.440 975.430

WALL NODE
 AND LEVEL TEMPERATURES
 (2,25) 993.180 993.140 993.140
 (4,25) 1094.830 1094.830 1094.830
 (6,25) 1094.164 1094.163 1094.163
 (8,25) 992.184 992.185 992.185
 (10,25) 889.442 889.408 889.406
 (12,25) 889.922 889.720 889.718
 (14,25) 992.633 992.633 992.633
 (16,25) 1077.992 1077.902 1077.992
 (18,25) 880.221 880.127 880.124

COOLANT RESULTS FOR ASSEMBLY 4 AT TIME .010 SECONDS INTO TRANSIENT (COMPUTATION TIME = 22.647)

POWER = .9958E+00 GMAH = .141E+07 TFLUX*FLOWRAC = .6900E+05 DT = .1000E-01
 GRSTA = 0.
 ENY BALANCE DOES NOT INC. PRODUCT
 FLOWIN = 19.14224 ENYIN = 3535.55017 ENYADD = 1756.91004
 FLOWOUT = 19.14224 ENYOUT = 5299.42303 ENYERR = -1.53723
 HMLTCL = -.00125
 CHANNEL H(I,J) TEMP F(I,J) V(I) PRESS(I,J)
 1 276.400431 1095.856317 19.142239 7.787469 27.504361

CHANNEL AXIAL RESULTS FOR ASSEMBLY 4 AT TRANSIENT TIME .010 SECONDS

TIME = .01000 SEC DATA FOR CHANNEL 1

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	19.142239	144.648886	7.787469	791.920000
12.000000	19.142239	247.103157	7.787469	964.881835
28.000000	19.142239	276.400431	7.787469	1095.856317

 OUTLET TAVGZ = 1095.856317 AT TIME = .010000

ROD AXIAL RESULTS FOR ASSEMBLY 4 AT TRANSIENT TIME .010 SECONDS

ELAPSED TIME = .0100 ROD NO. 1 NODES = 1
 AXIAL DIST = .500 FLUX = .27666000E TEMP = 1200.
 AXIAL DIST = 12.500 FLUX = .27666000E TEMP = 1374.

COOLANT RESULTS FOR ASSEMBLY 1 AT TIME 1.300 SECONDS INITIAL ADJUSTMENT COMPUTATION TIME = 46.522

POWER = .8749E+00 GCRN = .1465E+07 TFLUXFLGFRAC = .5000E+05 DT = .1000E+00
 GRSTA = .1310E-01
 INY BALANCE DOES NOT INC PRODUCT
 FLOWIN = 1K.0338K FLOWOUT = 5090.48156
 FLOWIN = 1K.0338K FLOWOUT = 5090.48156
 HWLTCI = -3.08714

CHANNEL	H(I,J)	TEMP	F(I,J)	V(I)	PRESS(I,J)
1	290.686793	1143.657685	.146783	7.849425	26.950124
2	301.840238	1141.025373	.147083	7.914816	26.950109
3	301.840566	1141.026473	.147083	7.914816	26.950109
4	290.687306	1143.659403	.146783	7.849425	26.950124
5	279.444214	1106.047576	.146511	7.786076	26.950139
6	279.444002	1106.046867	.146511	7.786076	26.950139
7	279.474690	1105.815030	.146510	7.785691	26.950139
8	290.686346	1143.549202	.146782	7.849405	26.950124
9	301.747646	1140.714944	.147080	7.914257	26.950109
10	312.794495	1217.758495	.147407	7.981483	26.950094
11	312.878148	1214.039064	.147409	7.982001	26.950094
12	323.765992	1254.572002	.147756	8.050550	26.950080
13	323.768517	1254.540075	.147756	8.050556	26.950080
14	312.880410	1214.046656	.147409	7.982014	26.950094
15	312.803597	1217.789021	.147407	7.981530	26.950094
16	301.759912	1140.756068	.147081	7.914550	26.950109
17	290.6869238	1143.598888	.146782	7.849321	26.950124
18	279.492045	1105.859700	.146510	7.785764	26.950139
19	268.092277	1068.097706	.146266	7.724508	26.950154
20	268.115256	1068.174445	.146266	7.724631	26.950154
21	256.697602	1030.081339	.146045	7.664936	26.950169
22	256.692929	1030.065765	.146045	7.664911	26.950169
23	268.113717	1068.169304	.146266	7.724625	26.950154
24	268.083667	1068.068952	.146266	7.724465	26.950154
25	266.829460	1063.840445	.146240	7.717805	26.950155
26	279.017392	1104.606533	.146501	7.783695	26.950139
27	279.237934	1138.805804	.146746	7.841113	26.950125
28	301.292223	1179.180443	.147067	7.911532	26.950109
29	310.815561	1211.121114	.147346	7.969263	26.950096
30	321.086959	1246.923597	.147662	8.036028	26.950081
31	323.190275	1252.639903	.147737	8.046673	26.950080
32	332.663922	1284.032492	.148050	8.107239	26.950066
33	334.052717	1288.616400	.148097	8.116156	26.950066
34	342.974738	1314.067773	.148396	8.173936	26.950052
35	343.006847	1314.173762	.148400	8.174130	26.950052
36	334.066102	1288.660989	.148097	8.116242	26.950066
37	332.787295	1284.439737	.148055	8.108030	26.950066
38	323.234767	1252.805992	.147739	8.047180	26.950080
39	321.744933	1247.802777	.147690	8.037692	26.950081
40	311.116785	1212.131426	.147355	7.971114	26.950096
41	301.479121	1179.479646	.147070	7.912052	26.950109
42	289.576235	1139.938193	.146755	7.843046	26.950125
43	279.117021	1104.939773	.146504	7.782245	26.950139
44	267.217702	1065.177003	.146248	7.713861	26.950154
45	256.152119	1026.264063	.146036	7.642147	26.950169

H.20

CHANNEL	H(T,J)	F(T,J)	F(T,J)	V(T)	PNRSS(T,J)
46	256.574628	1029.674760	.145044	7.664306	26.950169
47	244.970038	991.060164	.145037	7.664390	26.950184
48	245.152114	991.635837	.145040	7.664354	26.950184
49	233.514229	952.967562	.145044	7.504456	26.950199
50	233.406840	952.611244	.145043	7.504320	26.950199
51	245.112249	991.553404	.145049	7.664256	26.950184
52	244.600952	970.467525	.145034	7.664700	26.950184
53	256.517487	1029.480956	.145042	7.664000	26.950169
54	255.894315	1027.403716	.145030	7.566310	26.950169
55	261.756808	1046.951960	.145140	7.661130	26.950154
56	283.090428	1118.260427	.146596	7.665381	26.950130
57	303.216400	1185.649187	.147122	7.923055	26.950102
58	323.117658	1252.396202	.147735	8.046410	26.950074
59	334.366419	1289.652312	.148107	8.118178	26.950059
60	343.697286	1320.452852	.148423	8.178630	26.950046
61	344.037964	1321.577408	.148434	8.180860	26.950046
62	335.264862	1292.618013	.148138	8.123958	26.950059
63	324.640973	1257.538620	.147786	8.056206	26.950073
64	305.006823	1191.651937	.147174	7.933856	26.950101
65	285.212751	1125.332979	.146647	7.818255	26.950124
66	264.029252	1054.533979	.146185	7.703020	26.950157
67	243.201297	985.147173	.145807	7.596727	26.950186
68	232.654334	950.117737	.145630	7.544754	26.950200
69	221.714703	913.859806	.145447	7.491994	26.950214
70	220.957657	911.354731	.145434	7.487926	26.950215
71	231.545466	946.435178	.145012	7.539333	26.950200
72	241.824428	980.567529	.145793	7.589883	26.950186
73	242.749618	983.644828	.145799	7.594480	26.950182
74	262.700035	1050.099045	.146159	7.696062	26.950154
75	281.654719	1113.428056	.146562	7.798316	26.950128
76	296.332022	1162.566340	.146931	7.882200	26.950105
77	304.007451	1188.291317	.147145	7.927812	26.950094
78	317.719185	1234.280535	.147561	8.012216	26.950077
79	327.567600	1267.209890	.147881	8.074720	26.950064
80	332.102795	1282.180250	.148032	8.103642	26.950056
81	332.493612	1283.470312	.148045	8.106147	26.950055
82	330.030761	1275.370320	.147963	8.090055	26.950062
83	321.875973	1248.229125	.147695	8.038500	26.950075
84	309.920518	1208.119126	.147319	7.963761	26.950090
85	301.352377	1179.390023	.147069	7.911897	26.950102
86	287.405472	1132.672284	.146700	7.830664	26.950124
87	269.153742	1071.642540	.146288	7.730165	26.950150
88	249.434216	1005.548803	.145912	7.627440	26.950177
89	239.857762	974.033196	.145750	7.580146	26.950190
90	231.133353	945.067780	.145605	7.537322	26.950202

CHANNEL	H(T, J)	T(T, J)	F(T, J)	V(T)	PRESS(T, J)
91	221.286760	912.443734	.125434	7.489510	26.950216
92	211.094658	878.740790	.145260	7.400246	26.950229
93	209.787484	874.415047	.145236	7.413240	26.950230
94	218.317237	902.617542	.145358	7.473136	26.950218
95	227.561601	933.225643	.145545	7.519939	26.950205
96	234.484845	957.460361	.145559	7.556175	26.950194
97	221.484636	913.115054	.168633	8.660947	26.950217
98	232.498834	944.508440	.168447	8.722796	26.950202
99	245.162452	991.670221	.169093	8.795040	26.950186
100	257.124958	1031.505861	.169340	8.865182	26.950171
101	264.314670	1055.502961	.169499	8.908451	26.950163
102	273.405505	1085.846371	.169716	8.964441	26.950152
103	281.926366	1114.346642	.169938	9.016613	26.950142
104	287.917310	1134.325493	.170105	9.057636	26.950135
105	290.528466	1143.127408	.170152	9.074902	26.950134
106	292.706174	1150.421080	.170247	9.089427	26.950133
107	290.682430	1143.643070	.170186	9.075926	26.950137
108	285.375109	1125.876318	.170033	9.040976	26.950144
109	274.877678	1090.766818	.167753	8.973731	26.950159
110	267.263319	1065.324346	.167567	8.926428	26.950169
111	256.812214	1030.463380	.169333	8.863321	26.950182
112	244.465573	989.352312	.169079	8.781050	26.950194
113	230.473066	942.876454	.168808	8.711362	26.950214
114	222.777143	917.375435	.168658	8.664150	26.950222
115	215.501402	893.310321	.168512	8.627476	26.950230
116	208.348461	869.690573	.168361	8.587476	26.950234
117	202.761456	851.272109	.168236	8.556117	26.950244
118	204.351890	856.510746	.168272	8.565057	26.950240
119	206.851632	871.350628	.168372	8.590294	26.950233
120	214.216762	889.064949	.168480	8.620298	26.950226
121	214.551063	890.169549	.045668	9.132310	26.950227
122	256.401760	1022.095265	.045494	9.385150	26.950176
123	285.077086	1124.878786	.045084	9.573846	26.950145
124	280.222627	1108.647889	.046048	9.540621	26.950156
125	239.446436	972.686686	.045801	9.280688	26.950206
126	205.877894	861.539711	.045018	9.040890	26.950242

CHANNEL AXIAL RESULTS FOR ASSEMBLY 1 AT TRANSIENT TIME 1400 SECONDS

TIME = .30000 SEC DATA FOR CHANNEL 1

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.146635	124.674480	7.849422	791.920000
12.000000	.146773	245.436175	7.849422	892.780226
20.000000	.146783	290.636793	7.849422	1143.657685

TIME = .30000 SEC DATA FOR CHANNEL 07

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.170015	124.698446	8.660947	791.920000
12.000000	.169353	204.343646	8.660947	856.483626
20.000000	.168633	221.449636	8.660947	913.115058

TIME = .30000 SEC DATA FOR CHANNEL 124

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.046081	124.698446	9.540621	791.920000
12.000000	.046040	229.296554	9.540621	938.974614
20.000000	.046048	290.222627	9.540621	1106.637889

OUTLET TAVGZ = 1098.412352 AT TIME = .300000

POD AXIAL RESULTS FOR ASSEMBLY 1 AT TRANSIENT TIME 1500 SECONDS

ELAPSED TIME =	.3000	POD NO.	1	2	3	4	5	6				
AXIAL DIST =	.500	FLUX =	.26745	POD TEMP =	1402.	1372.	1267.	1140.	949.2	812.7		
AXIAL DIST =	12.500	FLUX =	.26662	POD TEMP =	1652.	1610.	1523.	1361.	1148.	1014.		

ELAPSED TIME =	.3000	POD NO.	4	5	6						
AXIAL DIST =	.500	FLUX =	.40279	POD TEMP =	1798.	1704.	1607.	1365.	1048.	622.1	
AXIAL DIST =	12.500	FLUX =	.40235	POD TEMP =	2115.	2060.	1902.	1433.	1281.	1059.	

WALL NODE AND LEVEL	TEMPERATURES	
(1,13)	855.648	860.260
(3,13)	898.276	902.904
(5,13)	914.958	904.896
(7,13)	948.652	931.975
(9,13)	965.897	966.132
(11,13)	960.068	959.801
(13,13)	928.382	928.137
(15,13)	896.244	896.064
(17,13)	851.981	851.874
(19,13)	831.211	831.181
(21,13)	813.769	813.729
(23,13)	830.490	830.420
(25,13)	841.084	845.806
(27,13)	945.407	933.620
(29,13)	861.801	861.682

WALL NODE AND LEVEL	TEMPERATURES	
(2,13)	876.384	841.362
(4,13)	918.483	921.943
(6,13)	930.169	915.112
(8,13)	957.344	938.186
(10,13)	966.750	966.577
(12,13)	949.283	949.009
(14,13)	915.205	914.985
(16,13)	874.667	874.522
(18,13)	841.922	841.832
(20,13)	820.083	820.039
(22,13)	820.572	820.517
(24,13)	840.761	840.665
(26,13)	905.818	900.563
(28,13)	931.268	931.031
(30,13)	814.979	814.900

WALL NODE AND LEVEL	TEMPERATURES	
(1,25)	911.649	910.294
(3,25)	989.709	987.951
(5,25)	1055.546	1057.336
(7,25)	1116.162	1119.914
(9,25)	1143.224	1104.745
(11,25)	1140.099	1140.873
(13,25)	1087.501	1087.228
(15,25)	1027.344	1027.127
(17,25)	940.175	940.080
(19,25)	891.354	891.267
(21,25)	849.958	849.902
(23,25)	870.687	870.545
(25,25)	889.139	888.417
(27,25)	1126.387	1130.027
(29,25)	969.337	969.184

WALL NODE AND LEVEL	TEMPERATURES	
(2,25)	947.858	946.170
(4,25)	1029.523	1027.884
(6,25)	1097.346	1090.746
(8,25)	1136.785	1141.062
(10,25)	1148.732	1149.036
(12,25)	1122.895	1122.683
(14,25)	1062.163	1061.908
(16,25)	986.365	986.101
(18,25)	915.125	915.011
(20,25)	867.065	867.808
(22,25)	855.633	855.512
(24,25)	888.409	888.362
(26,25)	1028.855	1028.088
(28,25)	1104.824	1104.576
(30,25)	859.763	859.705

COOLANT RESULTS FOR ASSEMBLY 3 AT TIME 300 SECONDS INTO TRANSIENT (COMPUTATION TIME = 54.060)

POWER = .8749E+00 GRAB = .1465E+07 FLOW FLUORAC = .0900E+05 DT = .1000E+00
 GKSTA = .1103E-01
 ENY BALANCE DOES NOT INC. PRODUCT
 FLOIN = 1M.03384 ENYTO = 3800.70771 ENYADD = 1700.67666
 FLOOUT = 1M.42804 ENYOUT = 5100.40896 ENYEND = -6.97559
 HWLTCL = 9.42262
 CHANNEL H(I,J) TEMP F(I,J) V(I) PRESS(T,J)

1	290.635411	1143.485594	.587215	7.050312	26.950950
2	310.757118	1210.925077	.543466	7.970102	26.950924
3	310.759687	1210.933713	.504466	7.977118	26.950924
4	290.635399	1143.485553	.587215	7.050312	26.950950
5	270.235530	1075.255243	.505330	7.737120	26.950977
6	270.236482	1075.258422	.585330	7.737120	26.950977
7	289.280240	1134.947444	.547078	7.842540	26.950951
8	328.743008	1271.089832	.591769	8.083400	26.950898
9	328.853554	1271.454730	.591783	8.084100	26.950898
10	289.572510	1139.925726	.507107	7.844212	26.950951
11	248.800717	1003.775695	.503702	7.625911	26.951005
12	248.881867	1003.046974	.583086	7.624815	26.951005
13	262.294652	1048.746482	.544692	7.695112	26.950984
14	299.439223	1172.978866	.588152	7.901711	26.950933
15	316.080988	1231.803820	.590238	8.008782	26.950909
16	335.515456	1293.445205	.592673	8.126782	26.950884
17	335.824718	1294.466057	.592715	8.128732	26.950883
18	318.713991	1237.618195	.590458	8.019681	26.950908
19	301.393395	1179.527479	.588370	7.913333	26.950932
20	264.778137	1057.032639	.504886	7.709137	26.950982
21	246.484906	996.068872	.503541	7.614282	26.951007
22	227.021470	931.445857	.542234	7.518462	26.951033
23	226.317401	929.102841	.532187	7.515040	26.951034
24	244.816126	990.518297	.583426	7.605937	26.951008
25	227.632950	943.462068	.537557	6.646710	26.951036
26	246.217341	995.178917	.534280	8.002523	26.951011
27	262.410547	1049.163330	.534964	8.008287	26.950991
28	276.695413	1096.842235	.539650	8.986561	26.950975
29	280.494609	1109.547637	.539850	9.010772	26.950972
30	276.774589	1097.108866	.539654	8.987062	26.950974
31	263.286208	1052.054814	.539003	8.903532	26.950998
32	246.146188	990.942253	.539277	8.802111	26.951020
33	230.536551	943.087583	.537669	8.714052	26.951034
34	218.402545	902.899837	.537194	8.645010	26.951053
35	213.087924	885.335043	.536976	8.615312	26.951058
36	219.340280	906.032594	.537232	8.650305	26.951048
37	219.177751	905.465004	.545701	9.161102	26.951049
38	246.098022	990.782041	.545843	9.322610	26.951014
39	274.481092	1089.441304	.546014	9.503470	26.950982
40	272.355427	1081.658233	.545999	9.488050	26.950990
41	242.076395	981.405603	.545822	9.298054	26.951026
42	216.11792	895.349639	.545084	9.142990	26.951057

CHANNEL AXIAL RESULTS FOR ASSEMBLY 3 AT TRANSIENT TIME 300 SECONDS

TIME = .30000 SEC

DATA FOR CHANNEL 1

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.586541	184.648146	7.850312	791.920000
12.000000	.586842	245.431701	7.850312	992.764678
20.000000	.587215	290.635411	7.850312	1143.465594

TIME = .30000 SEC

DATA FOR CHANNEL 25

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.340030	184.694086	8.696714	791.920000
12.000000	.338697	207.484290	8.696714	866.839510
20.000000	.337557	227.632450	8.696714	933.462068

TIME = .30000 SEC

DATA FOR CHANNEL 40

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	.046081	184.678086	9.488059	791.920000
12.000000	.046004	226.255000	9.488059	924.929206
20.000000	.045999	272.155427	9.488059	1081.669233

OUTLET TAVGZ = 1099.297654 AT TIME = .300000

POD AXIAL RESULTS FOR ASSEMBLY 3 AT TRANSIENT TIME 2300 SECONDS

ELAPSED TIME = .3000 ROD NO. 13 NODES = 1 2 3 4 5 6
 AXIAL DIST = .500 FLUX = .26744 NODE TEMP = 1402. 1372. 1286. 1400. 909.2 912.7
 AXIAL DIST = 12.500 FLUX = .26679 NODE TEMP = 1647. 1614. 1520. 1450. 1148. 1014.
 ELAPSED TIME = .3000 ROD NO. 13 NODES = 1 2 3 4 5 6
 AXIAL DIST = .500 FLUX = .42064 NODE TEMP = 1701. 1713. 1576. 1443. 1030. 820.7
 AXIAL DIST = 12.500 FLUX = .42004 NODE TEMP = 2053. 2000. 1450. 1493. 1257. 1043.

WALL NODE
 AND LEVEL TEMPERATURES
 (1,13) 862.927 862.410 862.296
 (3,13) 924.701 924.454 924.399
 (5,13) 949.022 948.762 948.703
 (7,13) 911.427 911.213 911.166
 (9,13) 862.960 863.304 903.673
 (11,13) 839.964 862.609 885.196
 (13,13) 851.436 870.497 888.201
 (15,13) 934.879 940.607 934.595
 (17,13) 876.184 801.909 905.813

WALL NODE
 AND LEVEL TEMPERATURES
 (2,13) 897.997 807.704 897.680
 (4,13) 947.508 907.201 947.181
 (6,13) 938.878 938.622 938.565
 (8,13) 880.549 880.420 880.392
 (10,13) 843.589 862.168 880.810
 (12,13) 854.728 870.424 899.090
 (14,13) 892.765 802.552 892.505
 (16,13) 921.802 921.685 921.636
 (18,13) 837.766 857.409 881.360

WALL NODE
 AND LEVEL TEMPERATURES
 (1,25) 930.741 929.018 928.646
 (3,25) 1047.974 1047.660 1047.545
 (5,25) 1107.375 1107.051 1106.983
 (7,25) 1049.236 1048.976 1048.921
 (9,25) 936.897 932.249 931.181
 (11,25) 878.265 871.915 870.467
 (13,25) 898.493 891.711 890.155
 (15,25) 1087.109 1086.806 1086.742
 (17,25) 977.700 976.109 975.825

WALL NODE
 AND LEVEL TEMPERATURES
 (2,25) 993.962 903.403 993.286
 (4,25) 1095.289 1004.961 1090.892
 (6,25) 1094.586 1094.284 1094.220
 (8,25) 992.284 992.206 992.193
 (10,25) 896.536 891.628 890.512
 (12,25) 899.205 892.679 891.193
 (14,25) 993.250 992.806 992.716
 (16,25) 1074.372 1070.100 1070.045
 (18,25) 888.342 882.603 881.405

COOLANT RESULTS FOR ASSEMBLY 4 AT TIME .300 SECONDS INTO TRANSIENT (COMPUTATION TIME = 56.725)

POWER = .8749E+00 CHAN = .1355E+07 TFLUX*FLOWRAC = .6998E+05 DT = .1000E+00
 GCRAT = 0.
 ENY BALANCE DOES NOT INC INDICAT
 FLOWIN = 18.43383 ENYTH = 5694.76771 ENYADN = 1690.22532
 FLOWOUT = 18.43383 ENYOUT = 5097.22552 ENYENR = 2.24949
 MULTCL = -.03329
 CHANNEL H(I,J) TEMP F(I,J) V(I) PRESS(I,J)
 1 276.514742 1096.238380 18.433827 7.499746 27.583438

CHANNEL AXIAL RESULTS FOR ASSEMBLY 4 AT TRANSIENT TIME .300 SECONDS

TIME = .30000 SEC DATA FOR CHANNEL 1

AXIAL DIST	FLOW	ENTHALPY	VELOCITY	TEMPERATURE
0.000000	18.433829	1646.648886	7.499746	791.920000
12.000000	18.433829	247.193450	7.499746	965.141742
20.000000	18.433829	276.514742	7.499746	1096.238380

 OUTLET TAVGZ = 1096.238380 AT TIME = .300000

POD AXIAL RESULTS FOR ASSEMBLY 4 AT TRANSIENT TIME .300 SECONDS

ELAPSED TIME = .300000000 1 PODS = 1
 AXIAL DIST = .500 FLOW = .26631000E TEMP = 1155.
 AXIAL DIST = 12.500 FLOW = .26612000E TEMP = 1352.

DISTRIBUTION

<u>No. of Copies</u>		<u>No. of Copies</u>	
	<u>OFFSITE</u>		John Ford Acting Chief Chief Components Section Department of Energy Germantown, MD 20545
	A. A. Churm U.S. Department of Energy Chicago Patent Group Argonne, IL 60439		W. Bennett Chief, Fuel Systems Section Department of Energy Germantown, MD 20545
27	DOE Technical Information Center U.S. Department of Energy Assistant Director for Materials Germantown, MD 20767	10	Argonne Code Center Argonne National Laboratory 9700 S. Cass Avenue Argonne, IL 60439
	U.S. Department of Energy Assistant Director for Engineering Germantown, MD 20767		Director, Components Technology Argonne National Laboratory 9700 S. Cass Avenue Argonne, IL 60439
	U.S. Department of Energy Assistant Director for Reactor Safety Chief, Safety Analysis Branch Germantown, MD 20767		P. Betten Argonne National Laboratory 9700 S. Cass Avenue Argonne, IL 60439
	U.S. Department of Energy Chief, Engineering Component Branch Germantown, MD 20767		P. Lottes Argonne National Laboratory 9700 S. Cass Avenue Argonne, IL 60439
	R. J. Neuhold U.S. Department of Energy Reactor Analysis Branch Germantown, MD 20767		R. Singer Argonne National Laboratory 9700 S. Cass Avenue Argonne, IL 60439
	Carl Ockert Department of Energy Germantown, MD 20767		Dr. John G. Bartzis Components Technology Division Argonne National Laboratory 9700 S. Cass Avenue Argonne, IL 60439
	D. K. Magnus Chief, Fuels Branch Department of Energy Germantown, MD 20545		

No. of
Copies

L. Felten
Atomics International
P.O. Box 309
Canoga Park, CA 91304

Billy Bingham
Babcock and Wilcox
P.O. Box 1260
Lynchburg, VA 24502

C. Morgan
Babcock and Wilcox
P.O. Box 1260
Lynchburg, VA 24502

P. Lorenzfui
Bettis Atomic Power
Laboratory
P.O. Box 79
West Mifflin, PA 15122

A. Agrawal
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Bahman Atefi
Brookhaven National Laboratory
Building 130
Upton, NY 11973

B. Chan
Brookhaven National Laboratory
Building 130
Upton, NY 11973

W. Wulff
Brookhaven National Laboratory
Upton, Long Island, NY 11973

J. E. Casterline
Department of Chemical
Engineering
Columbia University
New York, NY 10027

No. of
Copies

R. Noyes
Combustion Engineering
1000 Prospect Hill Road
Windsor, CT 06095

G. diLauro
Combustion Engineering
1000 Prospect Hill Road
Windsor, CT 06095

P. North
EG & G
P.O. Box 1625
Idaho Falls, ID 83401

T. Fernandez
Electric Power Research
Institute
3412 Hillview Avenue
P.O. Box 10412
Palo Alto, CA 94304

F. Gelhaus
Fault Analysis & Modeling
Electric Power Research
Institute
3412 Hillview Avenue
P.O. Box 10412
Palo Alto, CA 94304

J. Kim
Electric Power Research
Institute
P.O. Box 10412
Palo Alto, CA 94303

R. Sehgal
Electric Power Research
Institute
P.O. Box 10412
Palo Alto, CA 94303

K. Sun
Electric Power Research
Institute
P.O. Box 10412
Palo Alto, CA 94303

No. of
Copies

Dr. Chandu Baxi
General Atomic Co.
P.O. Box 81608
San Diego, CA 92138

General Electric Company
Manager, Reactor Systems
Safety Development
San Jose, CA 95114

P. McGee
General Electric Company
Manager, Design Engineering
Breeder Reactor Development
Operation
310 DeGuigne Drive
Sunnyvale, CA 94086

H. S. Bailey
General Electric Company
310 DeGuigne Drive
P.O. Box 5020
M/C S28
Sunnyvale, CA 94086

J. Stephen
General Electric Company
310 DeGuigne Drive
P.O. Box 5020
Sunnyvale, CA 94086

D. Serrell
General Electric Company
310 DeGuigne Drive
P.O. Box 5020
Sunnyvale, CA 94086

G. H. Halsey
Knolls Atomic Power Laboratory
General Electric Company
P.O. Box 1072
Schenectady, NY 12301

No. of
Copies

N. Todreas
Massachusetts Institute of
Technology
77 Massachusetts Avenue
Cambridge, MA 02139

E. Davidson
U.S. Nuclear Regulatory Commission
Division of Reactor Safety
Research
Washington, DC 20555

S. Fabric
U.S. Nuclear Regulatory Commission
Division of Reactor Safety
Research
Washington, DC 20555

S. Israel
U.S. Nuclear Regulatory Commission
Division of Technical Review
Reactor Systems Branch
Washington, DC 20555

P. Norian
U.S. Nuclear Regulatory Commission
Division of Technical Review
Core Performance Branch
Washington, DC 20555

Zoltan Rostoczy
U.S. Nuclear Regulatory Commission
Division of Technical Review
Reactor Systems Branch
Washington, DC 20555

D. F. Ross
U.S. Nuclear Regulatory Commission
Division of Technical Review
Core Performance Branch
Washington, DC 20555

No. of
Copies

L. Shotkin
U.S. Nuclear Regulatory Commission
Division of Reactor Safety
Research
Washington, DC 20555

L. S. Tong
U.S. Nuclear Regulatory Commission
Division of Reactor Safety
Research
Washington, DC 20555

J. Dearing
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37830

M. Fontana
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37830

J. Wantland
Oak Ridge National Laboratory
P.O. Box Y
Oak Ridge, TN 37830

C. Wilson
Oak Ridge National Laboratory
CRBRP Project Office
Oak Ridge, TN 37830

L. Peddicord
Oregon State University
Corvallis, OR 97331

R. Lahey
Rensselaer Polytechnic Institute
Department of Nuclear Engineering
Troy, NY 12181

D. S. Rowe
Rowe and Associates
14400 Bellevue-Redmond Road,
Suite 208
Bellevue, WA 98007

No. of
Copies

M. Corradini
Light Water Reactor Safety
Division
Sandia Laboratories
Albuquerque, NM 87185

G. E. Giles
Union Carbide Corp.
P.O. Box P
Bldg K-1007 MS-49
Oak Ridge, TN 37830

J. Weisman
University of Cincinnati
Cincinnati, OH 45221

H. S. Isbin
Department of Chemical
Engineering
University of Minnesota
Minneapolis, MN 55455

A. Bishop
University of Pittsburgh
Pittsburgh, PA 15261

Dr. Robert Berringer
Westinghouse Corporation
Box 19218
Tampa, FL 33616

C. L. Caso
Westinghouse Electric
Corporation
P.O. Box 355
Pittsburgh, PA 15230

M. Carelli
Westinghouse Electric Corporation
Advanced Reactors Branch
Waltz Mill Site
Box 158
Madison, PA 15663

No. of
Copies

No. of
Copies

R. Markley
Westinghouse Electric Corporation
Advanced Reactors Branch
Waltz Mill Site
Box 158
Madison, PA 15663

E. Novendstern
Westinghouse Electric Corporation
Advanced Reactors Branch
Waltz Mill Site
Box 158
Madison, PA 15663

3 D. Spencer
Westinghouse Electric Corporation
Advanced Reactors Branch
Waltz Mill Site
Box 158
Madison, PA 15663

Y. Tang
Westinghouse Electric Corporation
Advanced Reactors Branch
Waltz Mill Site
Box 158
Madison, PA 15663

B. Vektor
Westinghouse Electric Corporation
Advanced Reactors Branch
Waltz Mill Site
Box 158
Madison, PA 15663

ONSITE

DOE Richland Operations Office

H. E. Ransom

Westinghouse Hanford Company
Hanford Engineering Development
Laboratory

S. Additon
R. Bennett
H. Birney
C. Cox
E. Evans
J. Hanson
T. Horning
R. Jackson
H. Johnson
D. E. Mahagin/J. E. Irvin
J. Muraoka

48 Pacific Northwest Laboratory

J. M. Bates
R. L. Cheatham (20)
S. L. Crawford
J. M. Creer
J. M. Cuta
T. L. George
C. R. Hann
G. M. Hesson
J. M. Kelly
E. U. Khan (5)
W. W. Laity
F. Panisko
W. A. Prather
A. M. Sutey
C. W. Stewart
M. J. Thurgood
D. S. Trent
C. L. Wheeler
Technical Information (5)
Publishing Coordination (2)
PA