ENERGY LABORATORY

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

USER'S GUIDE FOR THERMIT-2: A VERSION OF THERMIT FOR BOTH CORE-WIDE AND SUBCHANNEL ANALYSIS OF LIGHT WATER REACTORS

by

J. E. Kelly, S. P. Kao, M. S. Kazimi

MIT Energy Laboratory Electric Utility Program
Report No. MIT-EL-81-029

August, 1981

DEPARTMENT OF NUCLEAR ENGINEERING

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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March 29, 1983

MEMO TO: THERMIT-2 Users

FROM: M. S. Kazimi M.S. Kazimi

SUBJECT: Correction in THERMIT-2 User's Guide and THERMIT-2 Code

Recently we found errors that need to be corrected in the report "User's Guide for THERMIT-2: A Version of THERMIT for Both Core-Wide and Subchannel Analysis of Light Water Reactors," by J. E. Kelly, S. P. Kao and M. S. Kazimi, MIT Energy Laboratory Electric Utility Program, Report No. MIT-EL 81-029, August 1981.

1) From p. 51 to p. 76, the computer printout is "Sample Problem 2 Output (Transient Restart)" and from p. 78 to p. 86, the computer printout is "Sample Problem 2 Output (Steady-State)." Please switch the titles on p. 57 and p. 78.

2) In the code listing, three statements in "SUBROUTINE FWALL" restrict the code capability to describing problems which contain nine or less channels. These three statements are on p. 198 and p. 200. They are

```
DIMENSION GFAC(9)                          p. 198

DATA GFAC/1.,1.,1.,1.,1.,1.,1.,1.,1./      p. 198

TS = .5*RD*A*(REY**B)*GFAC(I)              p. 200
```

Please remove the first two statements and remove "*GFAC(I)" in the third statement. After doing this, the code is allowed to handle problems with more than nine channels.

Energy Laboratory

and

Department of Nuclear Engineering

Massachusetts Institute of Technology
Cambridge, Mass. 02139

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REPORTS IN REACTOR THERMAL HYDRAULICS RELATED TO THE MIT ENERGY LABORATORY ELECTRIC POWER PROGRAM

A. Topical Reports (For availability check Energy Laboratory Headquarters, Headquarters, Room E19-439, MIT, Cambridge, Massachusetts 02139)

A.1 General Applications
A.2 PWR Applications
A.3 BWR Applications
A.4 LMFBR Applications

A.1 J.E. Kelly, J. Loomis, L. Wolf, "LWR Core Thermal-Hydraulic Analysis--Assessment and Comparison of the Range of Applicability of the Codes COBRA-IIIC/MIT and COBRA-IV-1," MIT Energy Laboratory Report No. MIT-EL-78-026, September 1978.

M. S. Kazimi and M. Massoud, "A Condensed Review of Nuclear Reactor Thermal-Hydraulic Computer Codes for Two-Phase Flow Analysis," MIT Energy Laboratory Report No. MIT-EL-79-018, February 1979.

J.E. Kelly and M.S. Kazimi, "Development and Testing of the Three Dimensional, Two-Fluid Code THERMIT for LWR Core and Subchannel Applications," MIT Energy Laboratory Report No. MIT-EL-79-046.

J.N. Loomis and W.D. Hinkle, "Reactor Core Thermal-Hydraulic Analysis--Improvement and Application of the Code COBRA-IIIC/MIT," MIT Energy Laboratory Report No. MIT-EL-80-027, September 1980.

D.P. Griggs, A.F. Henry and M.S. Kazimi, "Development of a Three-Dimensional Two-Fluid Code with Transient Neutronic Feedback for LWR Applications," MIT Energy Laboratory No. MIT-EL-81-013, April 1981.

J.E. Kelly, S.P. Kao and M.S. Kazimi, "THERMIT-2: A Two-Fluid Model for Light Water Reactor Subchannel Transient Analysis," MIT Energy Laboratory Report No. MIT-EL-81-014, April 1981.

H.C. No and M.S. Kazimi, "The Effect of Virtual Mass on the Characteristics and the Numerical Stability in Two-Phase Flows," MIT Energy Laboratory Report No. MIT-EL-81-023, April 1981.

J.W. Jackson and N.E. Todreas, "COBRA IIIC/MIT-2: A Digital Computer Program for Steady State and Transient Thermal-Hydraulic Analysis of Rod Bundle Nuclear Fuel Elements," MIT-EL-81-018, June 1981.

J.E. Kelly, S.P. Kao, and M.S. Kazimi, "User's Guide for THERMIT-2: A Version of THERMIT for both Core-Wide and Subchannel Analysis of Light Water Reactors," MIT Energy Laboratory Report No. MIT-EL 81-029, August 1981.

A.2 P. Moreno, C. Chiu, R. Bowring, E. Khan, J. Liu, and N. Todreas, "Methods for Steady-State Thermal/Hydraulic Analysis of PWR Cores," MIT Energy Laboratory Report No. MIT-EL 76-006, Rev. 1, July 1977, (Orig. 3/77).

J. Liu and N. Todreas, "Transient Thermal Analysis of PWR's by a Single Pass Procedure Using a Simplified Model Layout," MIT Energy Laboratory Report No. MIT-EL 77-008, Final, February 1979 (Draft, June 1977).

J. Liu and N. Todreas, "The Comparison of Available Data on PWR Assembly Thermal Behavior with Analytic Predictions," MIT Energy Laboratory Report No. MIT-EL 77-009, Final February 1979, (Draft, June 1977).

A.3 L. Guillebaud, A. Levin, W. Boyd, A. Faya, and L. Wolf, "WOSUB-A Subchannel Code for Steady-State and Transient Thermal-Hydraulic Analysis of Boiling Water Reactor Fuel Bundles," Vol. II, Users Manual, MIT-EL 78-024, July 1977.

L. Wolf, A. Faya, A. Levin, W. Boyd, L. Guillebaud, "WOSUB-A Subchannel Code for Steady State and Transient Thermal-Hydraulic Analysis of Boiling Water Reactor Fuel Pin Bundles," Vol. III, Assessment and Comparison, MIT-EL 78-025, October 1977.

L. Wolf, A. Faya, A. Levin, L. Guillebaud, "WOSUB-A Subchannel Code for Steady-State Reactor Fuel Pin Bundles," Vol. I, Model Description, MIT-EL 78-023, September 1978.

A. Faya L. Wolf and N. Todreas, "Development of a Method for BWR Subchannel Analysis," MIT-EL 79-027, November 1979.

A. Faya, L. Wolf and N. Todreas, "CANAL User's Manual," MIT Energy Laboratory No. MIT-EL 79-028, November 1979.

A.4 W.D. Hinkle, "Water Tests for Determining Post-Voiding Behavior in the LMFBR," MIT Energy Laboratory Report MIT-EL-76-005, June 1976.

W.D. Hinkle, Ed., "LMFBR Safety and Sodium Boiling - A State of the Art Report," Draft DOE Report, June 1978.

M.R. Granziera, P. Griffith, W.D. Hinkle, M.S. Kazimi, A. Levin, M. Manahan, A. Schor, N. Todreas, G. Wilson, "Development of Computer Code for Multi-dimensional Analysis of Sodium Voiding in the LMFBR," Preliminary Draft Report, July 1979.

M. Granziera, P. Griffith, W.D. Hinkle, M.S. Kazimi, A. Levin, M. Manahan, A. Schor, N. Todreas, R. Vilim, G. Wilson, "Development of Computer Code Models for Analysis of Subassembly Voiding in the LMFBR," Interim Report of the MTI Sodium Boiling Project Covering Work Through September 30, 1979, MIT-EL-80-005.

A. Levin and P. Griffith, "Development of a Model to Predict Flow Oscillations in Low-Flow Sodium Boiling, "MIT-EL-80-006, April 1980.

M. R. Granziera and M. S. Kazimi, "A Two-Dimensional, Two-Fluid Model for Sodium Boiling in LMFBR Assemblies," MIT-EL-80-011, May 1980.

G. Wilson and M. Kazimi, "Development of Models for the Sodium Version of the Two-Phase Three Dimensional Thermal Hydraulics Code THERMIT," MIT-EL-80-010, May 1980.

R.G. Zielinski and M.S. Kazimi, "Development of Models for the Two-Dimensional, Two-Fluid Code for Sodium Boiling NATOF-2D," MIT Energy Laboratory Report No. MIT-EL-81-030, September 1981.

B. Papers

B.1 J.E. Kelly and M.S. Kazimi, "Development of the Two-Fluid Multi-Dimensional Code THERMIT for LWR Analysis," Heat Transfer-Orlando 1980, AIChE Symposium Series 199, Vol. 76, August 1980.

J.E. Kelly and M.S. Kazimi, "THERMIT, A Three-Dimensional, Two-Fluid Code for LWR Transient Analysis," Transactions of American Nuclear Society, 34, p. 893, June 1980.

B.2 P. Moreno, J. Kiu, E. Khan, N. Todreas, "Steady State Thermal Analysis of PWR's by a Single Pass Procedure Using a Simplified Method," American Nuclear Society Transactions, Vol. 26.

P. Moreno, J. Liu, E. Khan, N. Todreas, "Steady-State Thermal Analysis of PWR's by a Single Pass Procedure Using a Simplified Nodal Layout," Nuclear Engineering and Design, Vol. 47, 1978, pp. 35-48.

C. Chiu, P. Moreno, R. Bowring, N. Todreas, "Enthalpy Transfer between PWR Fuel Assemblies in Analysis by the Lumped Subchannel Model," Nuclear Engineering and Design, Vol. 53, 1979, 165-186.

B.3 L. Wolf and A. Faya, "A BWR Subchannel Code with Drift Flux and Vapor Diffusion Transport," American Nuclear Society Transactions, Vol. 28, 1978, p. 553.

S.P. Kao and M.S. Kazimi, "CHF Predictions In Rod Bundles," Trans. ANS, 35, 766 June 1981.

B.4 W.D. Hinkle, (MIT), P.M. Tschamper (GE), M.H. Fontana (ORNL), R.E. Henry (ANL), and A. Padilla (HEDL), for U.S. Department of Energy, "LMFBR Safety & Sodium Boiling," paper presented at the ENS/ANS International Topical Meeting on Nuclear Reactor Safety, October 16-19, 1978, Brussels, Belgium.

M.I. Autruffe, G.J. Wilson, B. Stewart and M. Kazimi, "A Proposed Momentum Exchange Coefficient for Two-Phase Modeling of Sodium Boiling," Proc. Int. Meeting Fast Reactor Safety Technology, Vol. 4, 2512-2521, Seattle, Washington, August 1979.

M.R. Granziera and M.S. Kazimi, "NATOF-2D: A Two Dimensional Two-Fluid Model for Sodium Flow Transient Analysis," Trans. ANS, 33, 515, November 1979.

Table of Contents

1.0 INTRODUCTION

This report provides the THERMIT-2 user with programming and input information. THERMIT-2 is the most recent version of THERMIT. This new version contains all of the features and options of the original version of THERMIT documented in References 1 and 2. Additionally, the ability to analyze subchannels as well as improved modeling have been added to the code. These new additions are described in detail in Reference 3. The interested reader is referred to these references for further information about the physical modeling.

In this report, the programming information is given first. This information includes details concerning the code and data structure. The description of the required input variables is presented next. After the meanings of these variables are given, the sample problems are described and the THERMIT-2 results are presented.

THERMIT-2 contains subroutines from the IMSL Library, a proprietary package from International Mathematical and Statistical Libraries, Inc., Houston, Texas. These routines may not be redistributed or removed from this software for use in other software development, IMSL routines included are: LEQT1B, UERTST and UGETIO.

2.0 PROGRAMMING INFORMATION

2.1 Code Structure

The first information a user will need to understand the internal structure of THERMIT-2 is a description of the names, functions and organization of the various subroutines. Figure 2.1 illustrates the structure and calling sequences in the code. The main program calls five subroutines: INPUT reads the input data for the problem; INIT initializes certain variables and arrays; TRANS controls the transient calculations; DUMP writes the common blocks to a dump file for a possible restart; and ERROR writes an error message if any of a variety of error conditions are encountered during program execution.

Subroutine TRANS controls the major part of the execution. The transient calculation begins with a call to TIMSTP to determine the time step size. Subroutines POWER, BOTBCV, and TOPBCV are then called to set the boundary conditions for the time step. Next, the heat transfer coefficients are calculated in HTCOR with HCONV controlling the calling sequence. The "forward elimination" part of the fuel rod conduction problem is then performed in subroutine HCONDO. The fluid dynamics equations are then solved in NEWTON followed by the "backward substitution" part of the fuel rod conduction problem performed in subroutine HCOND1. At the end of the time step subroutine EDIT would, if requested, print the thermal and fluid field information. Finally, the "old time" variables are replaced with the "new time" variables by subroutine MOVE in anticipation of the beginning of a new time step. Once these variables have been updated, a new time step is selected and the calculation continues until the end of the transient (controlled by the user) is reached.

As seen in Fig. 2.1, the two major subroutines called by TRANS are HCONV and NEWTON. Subroutine HCONV, in turn, calls HTCOR which determines the heat transfer regime and heat transfer coefficient using the modified BEEST heat transfer model. It should be noted that the calculation of the heat transfer coefficients is based on "old time" variables.

Subroutine NEWTON controls the solution of the fluid dynamics equations for a given time step. The first part of this solution is the evaluation of the explicit terms in the momentum equations performed in subroutine EXPLCT. Subroutine JACOB is then called to set up the Jacobian matrix for a Newton iteration and reduces the equations to a pressure only problem. The pressure problem is then solved by first initializing the pressure changes in subroutine CLEAR and then using an iterative Gauss-Seidel technique in subroutine INNER. Once the pressure distribution has been found the other variables are updated in UPDATE and the Newton iteration error is calculated in NEWERR. If the error is too large, control returns to subroutine JACOB for another Newton iteration. If the solution is converged, then velocities, fluid properties and boundary cell variables are updated in subroutines VSET, PSET and QSET, respectively.

Table 2.1 lists all subroutines used in THERMIT-2. Included in this table is a brief description of the function of each subroutine. An ample number of comment cards are included in the THERMIT-2 source listing providing additional internal documentation in the code.

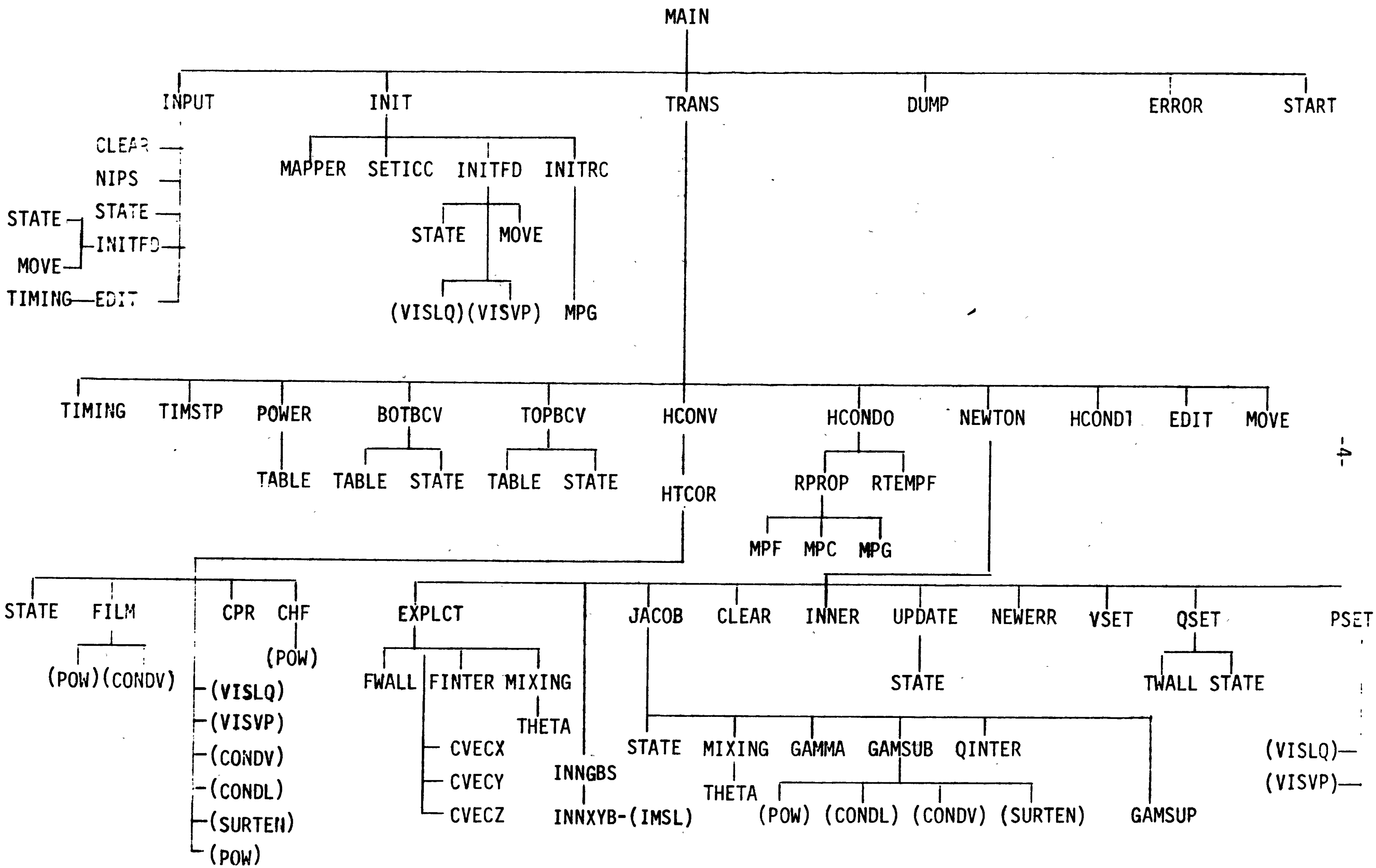


Figure 2.1: THERMIT-2 Flow Chart

Table 2.1

Subroutine:	Description
INPUT	reads input data for one problem, sets storage requirements for variably dimensioned arrays
START	reads commons from a dump for restart
DUMP	writes commons onto a dump file
NIPS	free-format input processor for array data
INIT	initialization for a problem and initial state printout
MAPPER	prints a map of horizontal arrangement of channels
SETICC	initializes an array which identifies channel neighbors
INITFD	initializes fluid dynamics arrays
INITRC	initializes variables and arrays for rod conduction
TRANS	governs transient calculation
TIMSTP	determines time step size
POWER	changes total rod heat generation rate
HCONV	explicit phase of heat transfer
NEWTON	fluid dynamics for one time step
NEWERR	finds error in last Newton iteration
EDIT	prints out thermal and flow state information
MOVE	moves one array into another
VSET	finds new velocities when Newton iterations converge
PSET	finds new fluid properties
QSET	sets conditions in boundary cells
EXPLCT	evaluates explicit expressions in momentum equations
CVECX	computes explicit convection terms in x-direction momentum equations
CVECY	ditto for y-direction
CVECZ	ditto for z-direction
JACOB	forms Jacobian matrix and reduces to pressure problem
INNER	solves pressure problem
UPDATE	gets new void and temperatures from new pressures
STATE	evaluates thermodynamic equations of state and their derivatives
HCONDO	initial phase of fuel rod temperature calculation

Table 2.1 (continued)

Subroutine:	Description
HCOND1	final phase of heat transfer calculation for new rod temperatures
RPROP	finds fuel rod material and gap properties
MPF	materials properties of fuel
MPC	material properties of clad
MPG	material properties of gap (conductance)
RTEMP	solves radial rod heat conduction equation
HTCOR	heat transfer coefficients or fluxes
FILM	film boiling heat transfer coefficients
CHF	calculation of critical heat flux
CPR	critical power calculation
POW	may be replaced by a fast, engineering accuracy exponentiation routine
CONDL	liquid thermal conductivity
CONDV	steam thermal conductivity
VISLQ	liquid water viscosity
VISVP	steam viscosity
SURTEN	surface tension of water
FWALL	wall friction laws for momentum equations
FINTER	interfacial momentum exchange coefficients
GAMMA	phase change rate and its derivatives
QINTER	interfacial energy exchange rate and derivatives
GAMSUB	contains subcooled boiling model
GAMSUP	contains post-CHF vaporization model
INNBGS	solves pressure problem by block Gauss-Seidel iteration
INNXYB	solves pressure problem by successive xy-block relaxation
MIXING	contains two-phase mixing model
THETA	calculates two-phase mixing model multiplier
TOPBCV	determines core outlet boundary conditions
BOTBCV	determines core inlet boundary conditions

2.2 Data Structure

The constants and variables which are used in THERMIT-2 are stored in one of the following common blocks:

```
common /IC/
common /RC/
common /PROP/
common /UNITS/
common /FORCE/
common /FRICMD/
common /POINT/
blank common.
```

Common block IC contains all the integer constants important to the program as a whole, while common block RC contains the real constants. Common block PROP contains information associated with the material properties of the fuel. Common block UNITS contains the integer constants which define the Fortran unit numbers for input and output files. The information required for the transient forcing functions is stored in common block FORCE. The constants required for the friction correlations are stored in common block FRICMD.

The array data is stored in blank common with the pointers for these arrays being stored in common block POINT. The use of this type of storage allows for object-time dimensioning of the arrays. This feature is quite useful and means that the minimum amount of computer core memory is used for each problem analyzed. The code internally calculates the dimensions of the arrays for each problem and, therefore, only the minimum amount of core memory is used. Since the dimensions of the arrays are not fixed, problem sizes can vary from very large to very small without having to change any of the common blocks.

The technique for implementing object-time dimensioning is fairly standard. All arrays are placed within the single large array, A, in blank common. The pointers of the individual arrays are calculated and stored in common block POINT. Each pointer is an integer variable whose name is the name of the corresponding array prefixed with an I for integer arrays and L for real arrays. Thus, the array P, which contains the pressures, is stored in array A beginning at location LP (i.e., A(LP). In order to have object-time dimensioning, the array along with its dimensions must be passed in the argument list of subroutines which use the array. For example, the calling subroutine would use

```
call STATE (A(LP), . . .
```

while the called subroutine would use

```
subroutine STATE (P, . . .
dimension P(M1, 1), . . .
```

where M1 is the appropriate dimension for this array. (It should be noted that the second dimension need not be explicitly specified). In this way, the array variables are passed from one subroutine to another.

A major function of the common blocks, aside from making important variables readily accessible to many subroutines, has to do with the THERMIT-2 restart option. Care has been taken so that all quantities needed to restart a transient calculation are stored in one of the common blocks. Therefore, a dump or a restart is accomplished by simply writing or reading the contents of all the common blocks.

To facilitate changes in common declaration statements, each occurrence of a common declaration is identical to the declaration in the main program. The main program also begins with comments which describe every array and every variable stored in common. If commons are altered, the corresponding read and write statements in subroutines START and DUMP must also be changed in order for the restart option to work properly.

The total array storage space required in blank common is given approximately (in storage words) by the following formula:

$$74\,(NC \cdot NZ) + 9(NZ \cdot NRODS) + 81NC + 42\,NZ + 4\,NRODS$$
$$+ (NCC + NCF + 2)[8 + 3(NZ \cdot NRODS)] + 53$$

2.3 I/O Units

Fortran unit numbers for the various input and output files are as follows:

- Unit 5 is the standard input unit (NINP)
- Unit 6 is the standard output unit (NOUT)
- Unit 8 is the dump file read for a restart (NRES)
- Unit 9 is the new dump file created at the end of the calculation (NDUMP).

Also, with a minor modification, input and output may be directed to an interactive terminal (NTTY).

3.0 DETAILED INPUT DESCRIPTION

3.1 Introduction

This section gives a detailed description of the input variable which must be specified to run THERMIT-2. The input is grouped into five parts with each part having one or more card groups. The data for each card group must begin on a new input card. However, more than one card may be required to specify all the information for a particular group. Variables are referred to by their Fortran names in the code (capitalized). Also, all input discussed below should be entered in SI units.

Three types of input formats are used in the code. The first is that associated with the standard Fortran READ statement. Both format-free and fixed format type variables are used. The format-free input is referred to as *-format consistent with IBM Fortran. All integer and real non-array variables are input via the format-free option. Only the title card is input in fixed character format.

The second type of input format is that associated with the standard Fortran NAMELIST option. This option is part of the restart feature and allows the user to selectively change the value of any of a variety of variables. The details of the NAMELIST option can be found in Fortran reference manuals and only an example will be given here. If the variable IFLASH is to be changed from 1 to 2 during a restart, then the input statement would be

```
& RESTRT IFLASH = 2 & END
```

This statement would set IFLASH equal to 2 while not affecting any other variable. Of course, if other variables are to be changed, they also can be included in the NAMELIST statement. As indicated above, this type of input format is only used for the restart option.

The third type of input format is that associated with the input processor found in subroutine NIPS. This subroutine is used to read the array data. The input processor permits relatively easy input of the values for the arrays. The key to this processor is that blocks of data may be repeatedly read. To achieve this result, a special type of format is used. Input fields are separated by blanks (no commas are allowed) with repeated fields inside parentheses preceeded by an integer multiplier. The end of a card group is marked with a dollar sign ($). An example serves to illustrate the use of this format. Suppose the array P(6,4) (6 levels, 4 channels) must be read in. There are 24 total values which are required. If these values are all the same (e.g., 6.9 MPa), then the input would be

```
24(6.9E6)$ P
```

(Everything after the $-sign is ignored so that comments can be placed here). If the four channels all have the same pressure distribution, but not axially uniform, then the input would be

```
4(69E6 6.85E6 6.8E6 6.75E6 6.7E6 6.65E6) $ P
```

It should be noted that the values for the variables can be given in any format, but will be interpreted according to the variable type. Up to 10 levels of parentheses nesting are permitted. Also no blank may appear between a left parentheses and the integer preceeding it. With this type of format the array data can be specified with a minimal amount of input.

The above information should be useful for understanding the mechanics of preparing the input for THERMIT-2. Detailed descriptions of the variables are given in the following sections. A ref. guide is included in Sec. 3.7.

3.2 Real and Integer Constants

The integer and real constants plus the title card are included in the first part of input. Altogether there are seven card groups in this section. The variables in each group are described in the following sections.

3.2.1 Card Group 1

The first group contains the varible NTC which is the number of title cards. Actually, this variable is an input flag indicating whether the job is a restart or a new problem. If NTC > 0, then a new problem is started and NTC is the actual number of title cards to be read in group 2. If NTC = 0, then execution is terminated. If NTC = -2, then the job is a restart or continuation of a previous one. Finally if NTC = -3, then the job is also a restart with the real time and time step number set to zero. If NTC < 0 then the next card to be input is the restart information found in fourth part of the input (See Section 3.6).

3.2.2 Card Group 2

For new problems (i.e., NTC > 0), the second card group to be read is the title card information. The number of cards which are read is equal to NTC. On each card 80 characters of information may be given.

3.2.3 Card Group 3

The third card group contains the variables related to the dimensions of the problem. These variables with their meaning are:

NC = Number of Channels

NR = Number of Rows

NRODS = Number of Fuel Rod Sections

NZ = Number of Axial Cells

NCF = Number of Cells in the Fuel

NCC = Number of Cells in the Clad.

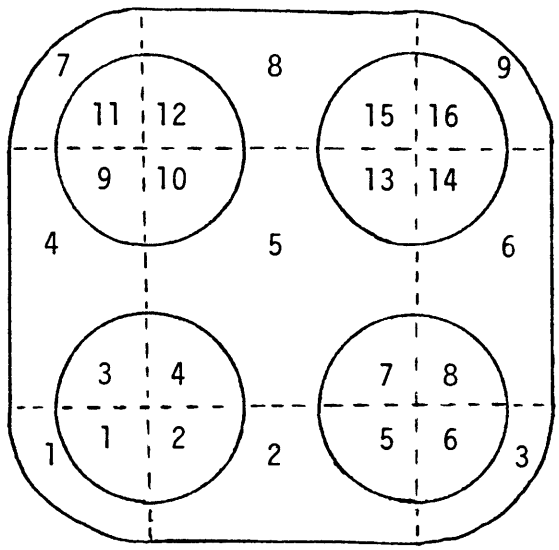
The variables NC and NZ have rather straightforward meanings. The variable NR specifies the number of rows that the channels are arranged in. The variable NRODS is used to define the appropriate fuel rod modeling. If the coolant-centered subchannel analysis method is employed, NRODS is equal to the number of fuel rod sections which are modeled. However, if coolant-centered subchannel analysis is not performed, then NRODS should equal NC (i.e., one rod per channel). For example, as shown in Figure 3.1, in the coolant-centered subchannel case, there are 9 channels and 16 rod sections. In the rod-centered case, there are 4 channels and 4 rods.

The final two variables NCF and NCC determine the number of nodes for the fuel rod modeling. It should be noted that the fuel rod is assumed to be cylindrical, so that the nodes are actual annuli.

3.2.4 Card Group 4

The fourth card group contains the thermal-hydraulic indicators and data. Both integer and real constants related to the thermal-hydraulic model are included in this group. The integer variables act as indicators for the options which the user may select.

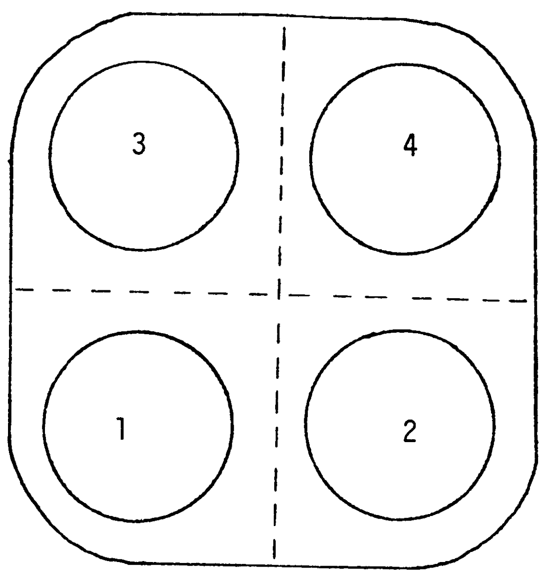
The first indicator, ITB, is used to select either a pressure or a velocity boundary condition at the top of the core. The indicator, IBB, has the same function at the bottom of the core.



NC = 9

NRODS = 16

Figure 3.1a: Coolant-Centered Subchannel Layout



NC = 4

NRODS = 4

Figure 3.1b: Rod-Centered Subchannel Layout

The next two variables are used to select the interfacial exchange models. The pre-CHF vapor generation rate is selected according to the value of the indicator IFLASH. Three options are currently included in THERMIT-2: the Nigmatulin model; suppressed mass exchange (i.e., $\Gamma = 0$); and the subcooled boiling model. For post-CHF conditions, the Saha vaporization model is used unless vaporization is suppressed. The next variable, IFINTR, is the indicator for the interfacial momentum exchange model. Currently, either the MIT model or the LASL model may be selected.

The next four variables are related to the heat transfer model. The indicator, IHT, is used to specify the fuel pin model. Three options for this model are currently available: constant rod and gap properties; constant rod, but temperature dependent gap conductance; and temperature dependent rod and gap properties. The next indicator, ISS, specifies the heat transfer calculation type. If ISS = 0, a transient calculation is performed. If ISS > 0, then the transient terms in the fuel rod conduction equations are eliminated so that the fuel and coolant will be in equilibrium (i.e., steady-state). If ISS = 2, then post-CHF wall temperatures cannot be calculated. If ISS = 1, then post-CHF wall temperatures can be calculated. The next indicator, IQSS, specifies the boundary condition at the fuel-coolant interface. If IQSS = 0, then the heat flux is held constant at the user specified value and no fuel temperatures are calculated. If IQSS = 1, then the heat flux is not held constant and the fuel temperatures are calculated. Finally, the indicator ICHF is used to select the CHF correlation. The current choices include the Biasi, W-3, CISE-4, Bowring, Barnett and Hench-Levy correlations.

The next three variables are needed to specify the transverse flow modeling. The indicator IWFT specifies whether or not transverse friction is included. The indicator IVEC determines whether the magnitude of the velocity vector or the actual transverse velocity should be used to calculate the transverse friction coefficient. Finally, the indicator ITAM specifies whether or not transverse flow is calculated. If transverse flow is not calculated, then the channels are treated as parallel unconnected channels.

The next two variables, IMIXE and IMIXM, are indicators for the turbulent mixing model. IMIXE is the indicator for turbulent energy and mass mixing while IMIXM is the indicator for turbulent momentum mixing. The next three variables specify the friction models to be used. These indicators are IAFM, for the axial friction model, ITFM, for the transverse friction model, and IGFM for the grid friction model. The user may elect to use the default values for these models or may choose to specify different models (see card group 5 description).

The last three variables are real constants which are required. The first is the gravitational constant GRAV, which, for vertical flows, should be set equal to -9.81. The second is the transverse hydraulic diameter, HDT. This hydraulic diameter should be defined as

$$\text{HDT} = \frac{\text{4 x Free Volume}}{\text{Rod Surface Area}}$$

This definition excludes the wetted perimeter associated with boundary walls. The last variable is the transverse velocity multiplier, VELX. This variable should nominally be set equal to the ratio of the maximum-to-average transverse flow area.

3.2.5 Card Group 5

The information related to the friction models is contained in the fifth card group. This card group is optional and only needs to be specified if the default friction models are not selected. The first section of this group is for the axial friction model. Four variables must be specified: A0, REX, A, B. These variables are the constants for the friction correlation where in laminar flow

$$f = A0/Re \qquad Re < REX$$

and in turbulent flow

$$f = A\ Re^{B} \qquad Re > REX$$

The variable REX is the transition Reynolds number which determines whether or not the flow is turbulent.

The second section of this group is for the transverse friction model. Again the variables A0, REX A, B need to be specified for the transverse friction correlation. The third section is for the grid friction model. The variables A and B need to be specified where

$$K_{grid} = ARe^{B}$$

3.2.6 Card Group 6

This sixth card group contains the iteration control and dump indicator variables. The variable IDUMP indicates whether or not the common blocks will be saved on a dump file at the end of the calculation. User control of the Newton and pressure iterations is limited to the specification of convergence criteria and limits on the number of iterations taken. These quantities are determined by input of the following parameters: NITMAX, the maximum number of Newton iterations, IITMAX, the maximum number of pressure or "inner" iterations per Newton iteration; EPSN, the Newton iteration convergence criterion; and EPSI, the pressure iteration convergence criterion. A relative error check on the pressure is used in THERMIT-2, so that iteration proceeds until the condition

$$\max \left| \frac{p^m - p^{m-1}}{p^m} \right| < \text{eps}$$

is met, where m designates either the Newton or pressure iteration and where eps is either EPSN or EPSI. The maximum is taken over all mesh cells, but only the pressure is checked for convergence during the Newton iteration. In no case, however, will the total iteration count be allowed to exceed the limits specified by NITMAX and IITMAX. If these limits are reached and NITMAX > 0, iteration ceases, and <u>code operation continues as if the iteration had converged</u>. If NITMAX < 0 then the calculation stops when the limits are reached.

It is important to remember that all variables in THERMIT-2 are derived from the pressure, so that, if the pressure is not converged tightly enough, errors in pressure may be amplified as other variables are computed from it. The user is therefore cautioned to be certain that his convergence criteria are sufficiently small by repeating the calculation with smaller values for these quantities, if possible. One must also remember, however, that on a finite precision machine there is a lower limit to these quantities, below which roundoff errors will prevent convergence.

3.2.7 Card Group 7

The fuel rod heat transfer information is contained in card group 7. This information is optional and is only required if IHT > 0. If IHT = 0, all heat transfer computations in THERMIT-2 are bypassed, and the heat flux from rod to coolant is set to zero. The parameter IHT may also assume the values 1, 2 or 3, providing for a selection of the heat transfer models in the code. If IHT = 1, all properties of the fuel rod, including the gap conductance, are held fixed throughout the calculations. The gap conductance is held constant at the input value, and temperature dependent models are used to compute the fuel and clad properties. Finally, if IHT = 3, all properties are allowed to vary with time, with h_{gap} computed according to the MATPRO model.

$$Q(t) = \begin{cases} Q_0 \,, & t \leq t_0 \\ Q_0 \exp \omega(t-t_0)], & t > t_0 \end{cases}$$

The three input parameters QC, TO, and OMG determine the three quantities Q_0, t_0, and ω, respectively, in the above expression. The time dependence of the power may also be given in this part of the input (see Section 3.4).

The fuel rod dimensions also need to be specified. These include the fuel rod radius, RADR, the clad thickness, THC, and the gap thickness THG. Several quantities are needed as input for the heat conduction calculation; all values mentioned here must be specified as input if IHT ≠ 0, even though some will be ignored, depending on the value of IHT.

For temperature-dependent fuel properties, the quantities FTD and FPUO2 are required; these are respectively the fraction of theoretical density of the fuel, and the fraction of PuO_2 if the fuel is mixed oxide.

If IHT = 1 or 2, the gap conductance value is given as input via HGAP.

If IHT = 3, several quantities may be needed for the gap conductance model.

The mean roughness of the clad and fuel surfaces at the fuel-clad gap is GRGH; if zero is given as input, a default value of 4.4×10^{-6}m is assumed. The gas composition in the gap is given by GMIX(1), ... GMIX(4), which are fractions of the four noble gases helium, argon, krypton, and xenon, respectively; the sum of these four numbers must be 1. This gas mixture is at pressure PGAS, which may correct the helium conductivity for small gap width. The cracked-pellet model, which accounts for partial contact of fuel against clad, is a function of burnup (in MW days/MtU) given as the input quantity BURN. Finally, if the gap conductance is to be supplemented by a term CP_f^n to represent the effect of a closed gap (GRGH > THG) with fuel pressing against clad with pressure P_f, the corresponding input data are CPR, FPRESS, and EXPR. The term may of course be suppressed by giving EPR = 0, FPRESS = 0, and EXPR = 1, for example.

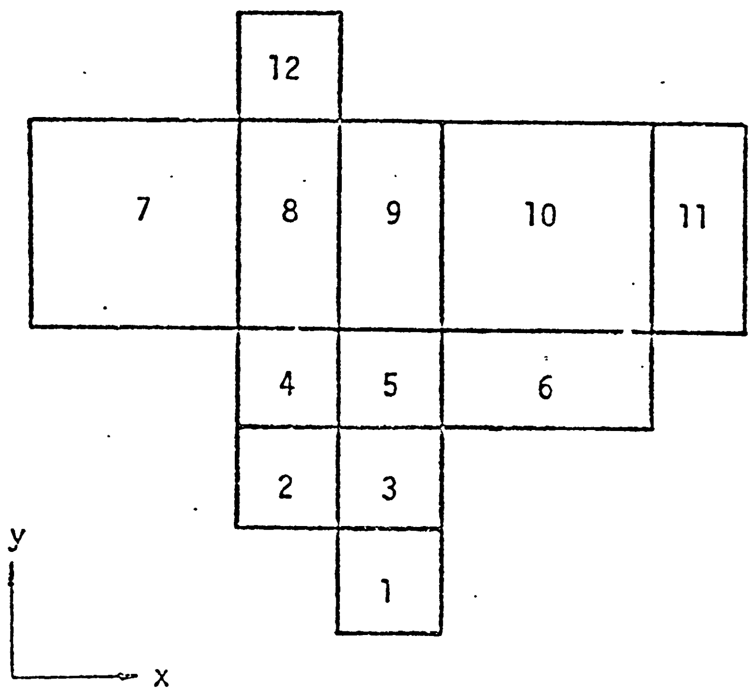
3.3 Array Data

The second part of the input is that related to the array data. This data is read in via the NIPS input processor. The array data is divided into four general sections: geometrical data; friction model; initial and boundary conditions; and heat transfer model. Each of these is discussed below.

3.3.1 Geometrical Data

Substantial flexibility is allowed in THERMIT-2 in specifying the problem geometry. The mesh is basically a regular, orthogonal, x-y-z grid, but boundaries in the x-y plane may be irregular and mesh spacings in all three dimensions can vary with location. Because of the possibility of irregular boundaries, THERMIT-2 uses a single subscript to number all mesh cells in the x-y plane. The numbering scheme assigns the index 1 to the left-most cell in the bottom row of cells, incrementing the index from left to right and bottom to top as indicated in Figure 3.2. The convention for the positive direction for the x and y axes is also indicated in this figure. This convention must be remembered in interpreting the signs of the velocities printed out by the code.

Several pieces of data must be input to THERMIT-2 to specify uniquely a mesh like that of Fig. 3.2. Two input integers, NC and NR, determine the total number of cells in the x-y plane and the number of rows into which these cells are arranged, respectively. A row of cells is a consecutive line of cells at the same y location. No gaps are allowed in a row of cells. For each row, the code user must specify the total number of cells in the row and the indentation of each row (in number of cells) from some left boundary. These quantities fill the arrays NCR (NR) and INDENT (NR), respectively. The summation of NCR over all rows must be equal to the total number of cells in the x-y plane NC. For the array INDENT, only differences in this quantity between rows are significant, so that any constant may be added to all the elements of this array and the results will be unchanged. Finally, the mesh spacings DX(NC) and DY(NC) must be input to the code. Note that, although a mesh spacing in each direction is required for every mesh cell, all DY at a given x location must be equal,



Row	Indentation
5	2
4	1
3	2
2	2
1	3

Figure 3.2: A Possible Arrangement of Channels in the Horizontal Plane, Showing THERMIT Indexing Conventions

and all DX at a given y location must be equal. This completes the input necessary to define the x-y grid used by THERMIT-2.

For the z direction, the situation is simpler because all channels (columns of cells at a given location in the x-y plane) are required to be of equal length. Only two pieces of data are required. The first is NZ, which determines the total number of cells in the z or "axial" direction. The second is the array DX(NX+2), which determines the mesh spacings in the z direction. Note that NZ+2 entries are required here; the first and last entries are required for the boundary cells at the top and bottom of the assembly that are used to set boundary conditions. Numbering of the cells in the z direction proceeds from bottom to top, with the bottom layer of cells receiving the index j = 1. It is important to remember that real mesh cells within the region of solution are assigned the indices j = 2 through j = NZ+1.

The above input to THERMIT-2 is sufficient to specify completely the mesh arrangement depicted in Fig. 3.2. Because THERMIT-2 has been developed primarily for analysis of nuclear reactor cores, there may be structural material contained within the region of interest. The presence of this structural material can have a significant effect on the volume of a mesh cell that is available to the fluid and on the flow areas of the faces of the mesh cells. For this reason, the flow areas and fluid volumes of the mesh cells are required user input. The cell fluid volumes are unambiguous quantities, and they are determined by the input array VOL(NZ,NC). For a reactor core, the areas of the cell faces normal to the z direction are also unambiguous and determined by input of the array ARZ(NZ+1, NC). For each channel index i, the quantities ARZ(j,i) for j = 1,2, ... NZ+1 represent the areas beginning with the bottom face of the first nonfictitious cell in the channel and ending with the top face of the final non-fictitious cell. The flow areas in the x and y directions should be given as the volume average areas between the two appropriate cells, which are approximately given by the following relations:

$$ARX(j,i) = \frac{VOL(j,i) + VOL(j,i+1)}{DX(i) + DX(i+1)}$$

and

$$ARY(j,i) = \frac{VOL(j,i) + VOL(j,i+1)}{DY(i) + DY(i+1)}$$

Specification of these areas is accomplished through input of the arrays ARX(NZ,NC) and ARY(NX,NC). We note that ARX(j,i) and ARY(j,i) represent the areas of the left and bottom faces of the j'th cell of the i'th channel with left and bottom taken in the sense of Fig. 3.2. With this convention, input of leftmost and bottommost boundary areas is required but not topmost or rightmost boundary areas. The leftmost and bottommost boundary areas should be set to zero by the user. Note also that any internal cell face may be given zero areas, which will close that face to any flow.

The axial hydraulic diameter for each channel HDZ(NC), must also be specified. This diameter is needed for axial wall friction calculations. The final geometrical array is SIJ(4,NC) which contains the values for the interconnecting gaps for each channel. For each channel, 4 gaps must be specified. These gaps are defined as the clearance between rods or the clearance between the rod and wall. The numbering convention for the gaps is as follows. The bottom side is the first, followed by the left-side, then the right-side and finally the top-side. For each channel the gap values must be entered in this order. If there is no gap on a particular side then a zero should be entered. Also, since the gaps are only used in the two-phase mixing model, the entire SIJ array may be set to zero if the mixing model is not used.

3.3.2 Wall Friction Model

Axial friction and form loss are specified by the array IWFZ(NZ+1), with one value associated with each axial velocity level. Form loss is attributed to a given axial velocity level if the spacer grid lies anywhere between the two neighboring pressure points. The indicator IWFZ is made up of a tens digit and a units digit, whose meanings are as follows:

- tens digit = 0 no form loss
  - 1 form loss, no funnel effect
  - 2 form loss with funnel effect
- units digit = 0 no friction
  - 1 Martinelli multiplier
  - 2 Martinelli-Nelson multiplier with mass flow effect
  - 3 Levy multiplier
  - 4 Rough tube correlation with Levy multiplier

The hydraulic diameter for axial friction is given by the input quantity HDZ.

3.3.3 Initial and Boundary Conditions

Initial conditions are required by THERMIT-2 for both transient and steady-state calculations. In the latter case, the initial conditions provide simply an initial guess of the steady state flow configuration. The final steady-state solution is, to a large degree, independent of this initial guess. An exception to this statement occurs because of the non-uniqueness of the wall temperature associated through the boiling curve with a given heat flux. Thus, if initial rod temperatures are in the stable film boiling regime, the final steady state solution may yield rod temperatures in this regime, whereas a starting guess of a lower rod temperature may yield a final steady-state solution with rod temperatures in the nucleate boiling heat transfer regime.

To determine a unique starting point for the fluid dynamics calculations, one must specify the following quantities, α, P, T_v, T_ℓ, $\vec{v}_v$ and $\vec{v}_\ell$. The remaining quantities ρ_v, ρ_ℓ, e_v and e_ℓ can be obtained from the equations of state. The input required of the code user is simplified by assuming that $T_\ell = T_v$, $v_v^x = v_v^y = v_\ell^x = v_\ell^y = 0$, and $v_\ell^z = v_v^z$ for t = 0 at all mesh locations. Therefore, the code user need only input four arrays to specify the initial condition. The first three arrays are the cell-centered quantities, P, ALP, and TV. The dimensions of each of these arrays are (NZ+2, NC), so that each quantity must be specified at all mesh cells, including the boundary cells at the top and bottom of the core. The fourth array is VVZ(NZ+1, NC). This array must contain the z velocities at all non-boundary cell faces normal to the z direction starting with the bottom face of the bottom cell of the first channel and proceeding from bottom to top and from channel 1 to channel NC in order.

The four input arrays discussed in the above paragraph also determine the boundary conditions at the top and bottom of the core. For a pressure boundary condition with flow directed into the core, fluid conditions at the boundary are set equal to those specified for the boundary cells. These conditions may change with time. The boundary velocities are then determined by solving momentum equations at the boundary. For a velocity boundary condition, the velocities are set to the input values, and no momentum equation is solved at the boundary. Again, if flow is directed into the core, fluid conditions at the boundary are obtained from the boundary cells.

3.3.4 Heat Transfer Model

If IHT > 0, then the arrays which define the heat transfer model must be specified. The first array, ICR(NRODS), contains the channel numbers which are adjacent to each fuel rod. This array is needed to define the coupling between coolant channels and the appropriate fuel rod. The array HDH(NC) contains the heated equivalent diameters for each channel. This diameter is defined as

$$HDH = \frac{4 \times \text{Flow Area}}{\text{Heat Perimeter}}$$

and is used only in heat transfer calculations. The initial wall temperature distributions are specified in TW(NZ,NRODS).

The total power must be partitioned into each mesh cell of each fuel rod. This is accomplished through input of three dimensionless power shape arrays QZ, QT, and QR and arrays RN(NRODS) and FRACP(NRODS) giving the number of fuel rods in each channel. The first array QZ(NZ) gives the axial power distribution in the reactor. The second array QT(NC) gives the transverse power shape, and the third array QR(NCC+NCF+1) gives the radial power distribution within a fuel rod. Each of these three arrays describes a power <u>shape</u> whose normalization is unimportant. The number of rods in a channel is needed to obtain the volumetric heat generation rate, q''', which is generated from the total power Q(t), the above four arrays, and other data specifying the problem geometry as:

$$q'''(i,j,k) = Q(t) \times \frac{QZ(j) \cdot QT(i) \cdot QR(k)}{N_z \, N_t \, N_r}$$

where the normalization factors are

$$N_z = \sum_{j=1}^{NZ} QZ(j) \cdot DZ(j+1)$$

$$N_t = \sum_{i=1}^{nrods} QT(i) \cdot RN(i) \cdot fracp(i)$$

$$N_r = \sum_{k=1}^{ncf+ncc+1} QR(k) \cdot a_k$$

The quantity a_k is the horizontal plane cross-sectional area of the k'th mesh cell in the fuel rod and DZ(j+1) is the mesh spacing in the z direction. The index j+1 is used here because DZ(1) refers to a boundary mesh cell.

3.4 Transient Forcing Functions

The third part of the input is the transient forcing function data. This information is used to change the boundary conditions as a function of time so that reactor transients may be simulated.

For each problem, the user must specify the time-dependent behavior of the various boundary conditions. Currently, the reactor power, the inlet temperature, the inlet pressure or velocity and the outlet pressure or velocity may vary with time. Tabular functions are used for each of these, however the reactor power may also be given as a exponential function.

The variables which define these tabular functions are described as follows. The indicators NB (bottom), NT (top), NTEMP (inlet temperature), and NQ (power) specify the number of entries in their respective forcing function tables. These variables may range from 0 to 30. Associated with each table is a time vector and a multiplier vector. At a given time, the multiplier associated with that time would be applied to appropriate boundary condition. The indicators, time vectors and multipler vectors are summarized as follows:

Indicator	Time Vector	Multiplier Vector	Boundary Condition
NB	YB	BOTFAC	Inlet Pressure or Velocity
NT	YB	TOPFAC	Outlet Pressure or Velocity
NTEMP	YTEMP	TINFAC	Inlet Temperature
NQ	YQ	QFAC	Reactor Power

If the user elects to hold a boundary condition at its initial value then the appropriate indicator should be set to zero. Otherwise, a value would need to be given for the indicator and then that number of values would be read for the appropriate time and multipler vectors. All transient forcing functions may be changed or updated during a "restart" as discussed in Section 3.6.

3.5 Time Step Control

The control of time steps in THERMIT-2 is accomplished by dividing the entire time interval of interest into several smaller time zones. For each time zone, seven parameters must be input:

TEND	end of time zone,
DTMIN	minimum time step allowed in time zone,
DTMAX	maximum time step allowed in time zone,
DTSP	time interval for short prints,
DTLP	time interval for long prints,
CLM	multiplier for convective time step limit,
IREDMX	maximum allowed number of time step redirections.

Time step sizes in a time zone are determined in the following manner. At the beginning of a time step, the z-direction vapor velocities and axial mesh spacings are used to compute the convective time step limit; the z-direction liquid velocities and transverse velocities for vapor and liquid are ignored, under the assumption that the true convective limit will normally be determined by axial vapor velocities. There are, of course, situations in which this is not the case. We next multiply the convective limit by the parameter CLM and call the result $\overline{\Delta}t$. The time step size actually used by the code is then set to the following value:

$$\Delta t = \min\ (\text{DTMAX}, \overline{\Delta}t).$$

When the user sets DTMAX = DTMIN the code bypasses the calculations of the convective limit and sets Δt = DTMIN.

Printing occurs at selected time steps as determined by the parameters DTSP and DTLP. These parameters are used to determine the times at which a print is desired. If t_0 represents the time at the beginning of the time zone, then prints should occur at the times t_0 + k*DTLP for k = 1,2,... In fact these times may not correspond to time step boundaries, so THERMIT attempts to print at the time steps nearest the above times. Computation continues in the above manner until the time exceeds TEND or until the time equals TEND within a tolerance of $1. \times 10^{-7}$s. At this point, new values of the above six quantities are input, defining a new time zone. As many time zones as desired can be used in any one problem. The code will continue the computation as long as a positive value is input for TEND. The value TEND= 0 is always taken to signify the end of the problem, and at this point the code attempts to read data for another problem from the input data file. The input of TEND < 0 is interpreted as a request for a restart. The code then requires the user to enter restart data and a new time zone card. For specific information about the restart option, see Section 3.6 below.

If at any time step the pressure problem diverges (e.g., negative void fraction), then the code automatically reduces the time step size by a factor of 10 and tries to converge using this smaller time step size. If with this smaller size the code still does not converge, the time step is again reduced. This procedure continues until $\Delta t <$ DTMIT or until the number of reductions is greater than IREDMX at which point execution is terminated. Of course, if with the smaller time step the code converges, then the calculations continue and the time step size is gradually increased.

3.6 Problem Restart

In order to facilitate the running of transient calculations, THERMIT-2 contains a restart capability. This restart option makes use of external devices to dump and read-in the common blocks. The dump file is automatically created at the end of a run when IDUMP = 1.

Request of a restart option is performed by input of a negative value for the parameter NTC, which is the first piece of data read by the code. If positive or zero, this integer specifies the number of title cards that follow immediately in the input. If NTC = -2, the code attempts to obtain the common variables from a data file. If NTC = -3, the commons are read from a dump file and the time step and real time are set to zero.

A number of code input parameters may be changed at a problem restart. This is accomplished through use of the Fortran namelist input feature. If the code encounters a negative value for NTC, it immediately attempts to obtain restart input data under namelist control from the input data file. If, however, a restart is specified by setting TEND < 0, then the code prompts the user to enter restart data under namelist control.

There are two namelist files which must be specified. The first RESTRT contains real and integer variables which may be changed during the restart. Namelist TFDATA contains the information related to the transient forcing functions. This allows the user to easily specify the desired transient boundary conditions.

Time cards are required after the namelist data is read.

3.7 Reference Guide

This section contains a reference guide for required input. Many of the options discussed above are illustrated more clearly here. With the above information understood in some detail, the following guide provides the practical information for using THERMIT-2.

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T H E R M I T - 2 INPUT DESCRIPTION (SUBCHANNEL VERSION)

****

THE INPUT REQUIRED TO RUN THERMIT IS DIVIDED INTO FIVE PARTS. EACH PART CONTAINS ONE OR MORE GROUPS WHICH ARE DESCRIBED IN MORE DETAIL BELOW. IT SHOULD BE NOTED THAT THE DATA FOR EACH GROUP MUST BEGIN ON A NEW CARD. HOWEVER, MORE THAN ONE CARD MAY BE USED FOR A PARTICULAR GROUP'S DATA.

PART I - OVERALL PROBLEM DESCRIPTION

THE FOLLOWING CARDS ARE READ VIA LIST-DIRECTED INPUT (*-FORMAT). FIELDS ARE SEPARATED BY ONE OR MORE BLANKS OR BY COMMAS. A NULL FIELD CAN BE SPECIFIED BY THE OCCURENCE OF CONSECUTIVE COMMAS. BASICALLY A CONSTANT (ENTERED AS A FIELD) IS ASSIGNED TO THE CORRESPONDING LIST ELEMENT AS IF THE CONSTANT WERE THE RIGHT SIDE OF AN ASSIGNMENT STATEMENT WHOSE LEFT SIDE WAS THE LIST ELEMENT.

FOR ADDITIONAL DETAILS ON THE USE OF LIST-DIRECTED INPUT, THE USER IS REFERRED TO THE IBM FORTRAN MANUAL.

GROUP NO.	FORMAT	CONTENTS
1	*	JOB CONTROL INDICATOR NTC NTC >0 NUMBER OF TITLE CARDS TO BE READ (SEE GROUP 2) NTC = 0 THE JOB IS ENDED NTC =-2 THE JOB IS A RESTART FROM A PREVIOUSLY CREATED DUMP FILE NTC =-3 THE JOB IS A RESTART FROM A PREVIOUSLY CREATED DUMP FILE. ADDITIONALLY, THE REAL TIME AND TIME STEP NUMBER ARE SET TO ZERO AND THE VALUES FOR THE BOUNDARY CONDITIONS ARE SAVED.
2	20A4	TITLE CARDS (THESE ARE THE ONLY CARDS IN FIXED FORMAT)
3	*	ARRAY DIMENSIONS NC,NR,NRODS,NZ,NCF,NCC NC = NUMBER OF CELLS IN X-Y PLANE NR = NUMBER OF ROWS OF CELLS IN X-Y PLANE NRODS = NUMBER OF FUEL RODS OR ROD SECTIONS TO BE MODELED IF SUBCHANNEL METHOD IS NOT USED THEN NRODS = NC NZ = NUMBER OF AXIAL CELLS NCF = NUMBER OF CELLS IN FUEL NCC = NUMBER OF CELLS IN CLAD
4	*	THERMAL-HYDRAULIC INDICATORS AND DATA ITB,IBB,IFLASH,IFINTR,IHT,ISS,IQSS,ICHF,

```
IWFT,IVEC,ITAM,IMIXM,IMIXE,IAFM,ITFM,IGFM,GRAV,HDT,VELX
ITB    = TOP BOUNDARY CONDITION INDICATOR:(0/1)
         (PRESSURE/VELOCITY)
IBB    = BOTTOM BOUNDARY CONDITION INDICATOR:(0/1)
         (PRESSURE/VELOCITY)
IFLASH = PHASE CHANGE MODEL INDICATOR:(0/1/2)
         (NIGMATULIN MODEL/SURPRESSED/SUBCOOLED MODEL)
IFINTR = INTERFACIAL MOMENTUM EXCHANGE MODEL:(0/1)
         (MIT/LASL)
IHT    = HEAT TRANSFER INDICATOR:(0/1/2/3)
         (NO HEAT TRANSFER/CONSTANT ROD PROPERTIES/
         CONSTANT GAP CONDUCTANCE/FULL CALCULATION)
ISS    = HEAT TRANSFER CALCULATION TYPE:(0/1/2)
         (TRANSIENT/STEADY-STATE/STEADY-STATE WITH
         CRITICAL HEAT FLUX CHECK SUPRESSED)
IQSS   = STEADY-STATE HEAT FLUX INDICATOR:(0/1)
         (CONSTANT HEAT FLUX/NORMAL)
ICHF   = CRITICAL HEAT FLUX INDICATOR:(1/2/3/4/5/6)
         (BIASI/W-3/CISE/BARNETT/BOWRING/HENCH-LEVY)
IWFT   = TRANSVERSE FRICTION MODEL INDICATOR:(0/1)
         (NO FRICTION/GUNTER-SHAW CORRELATION)
IVEC   = TRANSVERSE VELOCITY INDICATOR:(0/1)
         (NORMAL/MAGNITUDE OF VELOCITY USED)
ITAM   = FLUID DYNAMICS INDICATOR:(0/1)
         (NO TRANSVERSE FLOW ALLOWED/NORMAL)
IMIXM  = MOMENTUM TURBULENT MIXING INDICATOR:(0/1)
         (NO MIXING/MIXING INCLUDED)
IMIXE  = ENERGY TURBULENT MIXING INDICATOR:(0/1)
         (NO MIXING/MIXING INCLUDED)
IAFM   = AXIAL FRICTION MODEL INDICATOR:(0/1)
         (DEFAULT/USER SUPPLIED;SEE BELOW)
ITFM   = TRANSVERSE FRICTION MODEL INDICATOR:(0/1)
         (DEFAULT/USER SUPPLIED;SEE BELOW)
IGFM   = GRID FRICTION MODEL INDICATOR:(0/1)
         (DEFAULT/USER SUPPLIED;SEE BELOW)
GRAV   = GRAVITATIONAL CONSTANT (NORMALLY -9.81M/S*S)
HDT    = HYDRAULIC DIAMETER IN TRANSVERSE DIRECTION (M)
VELX   = VELOCITY MULTIPLIER FOR TRANSVERSE FRICTION
```

```
5       *      FRICTION MODEL CORRELATIONS

5A             IF IAFM=1 THEN SPECIFY A0,REX,A,B
               WHERE   IN LAMINAR FLOW          F = A0/RE
                       IN TURBULENT FLOW        F = A*RE**B
                       REX IS TRANSITION REYNOLDS NUMBER

               DEFAULT VALUES ARE  A0=64., REX=1502.11, A=.184, B= -.2

5B             IF ITFM=1 THEN SPECIFY A0,RET,A,B
               WHERE     IN LAMINAR FLOW          F = A0/RE
                         IN TURBULENT FLOW        F = A*RE**B
                         RET IS TRANSITION REYNOLDS NUMBER
```

DEFAULT VALUES ARE A0=180., RET=202.5, A=1.92, B=-.145

5C IF IGFM=1 THEN SPECIFY A,B
WHERE F = A*RE**B

DEFAULT VALUES ARE A=3., B=-.1

6 * ITERATION CONTROL AND DUMP INDICATOR
IDUMP,NITMAX,IITMAX,EPSN,EPSI
IDUMP = DUMP FILE REQUEST INDICATOR:(0/1)
(NO/YES)
NITMAX = MAXIMUM NUMBER OF NEWTON ITERATIONS
IITMAX = MAXIMUM NUMBER OF INNER ITERATIONS
EPSN = NEWTON ITERATION CONVERGENCE CRITERION
EPSI = INNER ITERATION CONVERGENCE CRITERION

THE FOLLOWING DATA IS REQUIRED ONLY WHEN THE HEAT TRANSFER CALCULATION IS REQUESTED (I.E., IHT NOT EQUAL TO 0).

7 * FUEL ROD PARAMETERS
Q0,T0,OMG,RADR,THC,THG,HGAP,FTD,FPUO2,FPRESS,
CPR,EXPR,GRGH,PGAS,(GMIX(K),K=1,4),BURN
Q0 = INITIAL TOTAL POWER (W)
(NOTE: IF Q0<0.0, Q0 IS SET EQUAL TO CURRENT POWER)
T0 = DELAY TIME (S)
OMG = INVERSE REACTOR PERIOD (1/S)
RADR = OUTER FUEL ROD RADIUS (M)
THC = CLAD THICKNESS (M)
THG = GAP WIDTH (M)
HGAP = GAP HEAT TRANSFER COEFFICIENT (W/M*M*DEG.K)
FTD = FRACTION OF THEORETICAL DENSITY OF FUEL
FPUO2 = FRACTION OF PUO2 IN FUEL
FPRESS = FUEL PRESSURE ON CLAD FOR GAP CONDUCTANCE
MODEL (PA=N/M*M)
CPR = COEFFICIENT FOR ABOVE PRESSURE
EXPR = EXPONENT FOR ABOVE PRESSURE
GRGH = GAP ROUGHNESS (M)
PGAS = GAP GAS PRESSURE (PA)
GMIX(1)= HELIUM FRACTION IN GAP GAS
GMIX(2)= ARGON FRACTION IN GAP GAS
GMIX(3)= KRYPTON FRACTION IN GAP GAS
GMIX(4)= XENON FRACTION IN GAP GAS
BURN = FUEL AVERAGE BURNUP (MWD/MTU)

PART II - ARRAY INPUT DATA

IN ORDER TO SIMPLIFY THE PROCEDURE FOR ENTERING THE DATA, THE FOLLOWING GROUPS ARE READ VIA NIPS FREE-FORMAT INPUT PROCESSOR. FIELDS ARE SEPARATED BY BLANKS. ENTRY (OR GROUP OF ENTRIES) REPETITION IS ALLOWED; FOR EXAMPLE N(A B M(C D E) F) WHERE: A,B,C,D,E,F ARE ENTRIES (INTEGER OR REAL) AND N,M ARE INTEGERS REPRESENTING THE NUMBER OF REPETITIONS; NOTE THAT NO BLANKS MUST APPEAR BETWEEN A LEFT PARANTHESIS AND THE INTEGER PRECEDING IT. UP TO 10 LEVELS OF NESTING ARE PERMITTED. NO COMMAS.

THE END OF A GROUP IS MARKED BY A &-SIGN.

GROUP NO.	CONTENTS	
	A. GEOMETRICAL DATA	
1	NCR(NR)	= NUMBER OF CELLS IN EACH ROW
2	INDENT(NR)	= INDENTATION FOR EACH ROW
3	ARX(NZ,NC)	= MESH CELL AREAS IN THE X-DIRECTION (M**2)
4	ARY(NZ,NC)	= MESH CELL AREAS IN THE Y-DIRECTION (M**2)
5	ARZ(NZ+1,NC)	= MESH CELL AREAS IN THE Z-DIRECTION (M**2)
6	VOL(NZ,NC)	= MESH CELL VOLUMES (M**3)
7	DX(NC)	= MESH SPACING IN THE X-DIRECTION (M)
8	DY(NC)	= MESH SPACING IN THE Y-DIRECTION (M)
9	DZ(NZ+2)	= MESH SPACING IN THE Z-DIRECTION (M)
10	HDZ(NC)	= HYDRAULIC DIAMETER FOR EACH CHANNEL(AXIAL) (M)
11	SIJ(4,NC)	= GAP INTERCONNECTIONS FOR EACH CHANNEL (M) (IF SUBCHANNEL METHOD IS NOT USED THESE MAY ALL BE SET TO ZERO)

B. AXIAL FRICTION MODEL

12 IFWZ(NZ+1) = INDICATOR FOR AXIAL FRICTION MODEL:

```
TENS DIGIT = 0 -> AXIAL FRICTION ONLY
             1 -> AXIAL FRICTION + FORM LOSS
             2 -> AS 1 + FUNNEL EFFECT
UNITS DIGIT = 1 MARTINELLI MODEL
              2 MARTINELLI AND JONES MODEL
              3 LEVY MODEL
              4 ROUGH TUBE CORRELATION

IFWZ  =  10   -> FORM LOSS WITHOUT AXIAL
                 FRICTION
```

C. INITIAL CONDITIONS

13	P(NZ+2,NC)	= INITIAL PRESSURES (PA)
14	ALP(NZ+2,NC)	= INITIAL VAPOR VOLUME FRACTIONS
15	TV(NZ+2,NC)	= INITIAL VAPOR TEMPERATURE (DEG.K) (NOTE: INITIAL LIQUID TEMPERATURE SET EQUAL TO TV)
16	VVZ(NZ+1,NC)	= INITIAL VAPOR AXIAL VELOCITY (M/S) (NOTE: INITIAL LIQUID VELOCITY SET EQUAL TO VVZ)

D. HEAT TRANSFER DATA

THE FOLLOWING DATA IS REQUIRED ONLY WHEN THE HEAT TRANSFER CALCULATION IS REQUESTED (I.E., IHT NOT EQUAL TO 0).

17	ICR(NRODS)	= ADJACENT CHANNEL NUMBER FOR GIVEN ROD
18	HDH(NC)	= EQUIVALENT HEATED DIAMETER FOR GIVEN CHANNEL
19	TW(NZ,NRODS)	= WALL SURFACE TEMPERATURE (DEG.K)
20	QZ(NZ)	= AXIAL POWER SHAPE
21	QT(NRODS)	= TRANSVERSE POWER SHAPE
22	QR(NCF+1+NCC)	= FUEL PIN RADIAL POWER SHAPE
23	RN(NRODS)	= NUMBER OF FUEL RODS IN EACH CHANNEL SET EQUAL TO 1.0 IF SUBCHANNEL METHOD IS BEING USED
24	FRACP(NRODS)	= FRACTION OF HEATED PERIMETER FACING ADJACENT CHANNEL (IF SUBCHANNEL METHOD IS NOT USED FRACP SHOULD BE SET TO 1.0 FOR ALL RODS)

PART III - TRANSIENT FORCING FUNCTION DATA (SEE PART I FOR *-FORMAT DESCRIPTION)

GROUP NO.	FORMAT	CONTENTS
1	*	TRANSIENT FORCING FUNCTION INDICATORS NB,NT,NTEMP,NQ NB = NUMBER OF ENTRIES IN BOTTOM BOUNDARY CONDITION FORCING FUNCTION TABLE (<=30) NT = NUMBER OF ENTRIES IN TOP BOUNDARY CONDITION FORCING FUNCTION TABLE (<=30) NTEMP= NUMBER OF ENTRIES IN INLET TEMPERATURE FORCING FUNCTION TABLE (<=30) NQ = NUMBER OF ENTRIES IN REACTOR POWER FORCING FUNCTION TABLE (<=30)
2	*	BOTTOM BOUNDARY CONDTION FORCING FUNCTION TABULAR VALUES (ONLY REQUIRED IF NB>0) (BOTFAC(I),YB(I)),I=1,NB BOTFAC(I) = BOTTOM BOUNDARY CONDITION MULTIPLIER YB(I) = TIME CORRESPONDING TO MULTIPLIER THESE ARE READ IN AS PAIRS; IE. BOTFAC(1),YB(1), BOTFAC(2),YB(2),...BOTFAC(NB),YB(NB).

3	*	TOP BOUNDARY CONDITION FORCING FUNCTION TABULAR VALUES (ONLY REQUIRED IF NT>0) (TOPFAC(I),YT(I)),I=1,NT TOPFAC(I) = TOP BOUNDARY CONDITION MULTIPLIER YT(I) = TIME CORRESPONDING TO MULTIPLIER THESE ARE READ IN AS PAIRS IE. TOPFAC(1),YT(1), TOPFAC(2),YT(2),...,TOPFAC(NT),YT(NT).
4	*	INLET TEMPERATURE FORCING FUNCTION TABULAR VALUES (ONLY REQUIRED IF NTEMP>0) (TINFAC(I),YTEMP(I)),I=1,NTEMP TINFAC(I) = INLET TEMPERATURE MULTIPLIER YTEMP(I) = TIME CORRESPONDING TO MULTIPLIER THESE ARE READ IN AS PAIRS IE. TINFAC(1),YTEMP(1), TINFAC(2),YTEMP(2),...,TINFAC(NTEMP),YT(NTEMP).
5	*	REACTOR POWER FORCING FUNCTION TABULAR VALUES (ONLY REQUIRED IF NQ>0 . ALSO IF NQ>0 THEN THE BUILT-IN EXPONENTIAL POWER FUNCTION IS DISABLED) (QFAC(I),YQ(I)),I=1,NQ QFAC(I) = REACTOR POWER MULTIPLIER YQ(I) = TIME CORRESPONDING TO MULTIPLIER THESE ARE READ IN AS PAIRS IE. QFAC(1),YQ(1), QFAC(2),YQ(2),...,QFAC(NQ),YQ(NQ).

NB THE CODE LINEARLY INTERPOLATES BETWEEN VALUES. IF ANY TIME IS LESS THAN THE FIRST ENTRY THEN A MULTIPLIER OF 1.0 IS USED. IF ANY TIME IS GREATER THAN THE LAST ENTRY, THEN LAST FACTOR IN THE TABLE IS USED. ALL OF THESE FORCING FUNCTION TABLES CAN BE CHANGED OR UPDATED IN THE TFDATA RESTART NAMELIST (SEE BELOW).

PART IV - TIME CARDS (SEE PART I FOR *-FORMAT DESCRIPTION)

GROUP NO.	FORMAT	CONTENTS
1	*	TIME ZONE CONTROL CARDS TEND,DTMIN,DTMAX,DTSP,DTLP,CLM,IREDMX TEND = END OF TIME ZONE (S) DTMIN = MINIMUM TIME STEP (S) DTMAX = MAXIMUM TIME STEP (S) DTSP = SHORT PRINT TIME INTERVAL (S)

```
DTLP   = LONG PRINT TIME INTERVAL (S)
CLM    = CONVECTIVE LIMIT MULTIPLIER
IREDMX = MAXIMUM NUMBER OF TIME STEP REDUCTIONS
(NOTE: AS MANY TIME CARDS AS NEEDED MAY BE INPUT;
IF DTMIN>=DTMAX, THEN THIS WILL BE THE TIME STEP
USED THROUGHOUT THE CURRENT TIME ZONE;
IF TEND=0.0, THE CASE IS ENDED;
IF TEND<0.0, THEN SUBSEQUENT TIME CARDS WILL BE
READ FROM THE TERMINAL; IF THIS HAS ALREADY BEEN
SIGNALED BY A PREVIOUS TIME CARD WITH TEND<0.0
THEN THE RESTART OPTION IS REQUESTED - SEE BELOW)
```

PART V - RESTART OPTION

THE FOLLOWING ITEMS (PREVIOUSLY DEFINED) ARE READ VIA "RESTRT" NAMELIST WHEN THE RESTART OPTION IS INVOKED:

```
NITMAX,IITMAX,EPSN  ,EPSI  ,IFLASH,
ITB   ,IBB   ,HDT   ,GRAV  ,
IHT   ,ISS   ,Q0    ,TO    ,OMG   ,
IWFT  ,IVEC  ,IDUMP ,ITAM  ,ISS   ,
ICHF  ,IQSS  ,IMIXM ,IMIXE ,IFINTR
```

THE FOLLOWING ITEMS (PREVIOUSLY DEFINED) ARE READ VIA THE "TFDATA" NAMELIST WHEN THE RESTART OPTION IS INVOKED:

```
NB, NT, NTEMP, NQ,
BOTFAC(I),TOPFAC(I),TINFAC(I),QFAC(I),
YB(I),YT(I),YTEMP(I),YQ(I).
```

NOTE THAT IMMEDIATELY AFTER THE RESTART INFORMATION IS SUPPLIED A TIME CARD IS REQUIRED.

```
THE INPUT SHOULD LOOK LIKE
     &RESTRT F1,F2,F3,...,FN &      FOR NAMELIST RESTRT AND
     &TFDATA   F1,F2,F3,...,FN &       FOR NAMELIST TFDATA
WHERE EACH FI IS A FIELD CONSISTING OF:
     ALL BLANKS  OR
     NAME = CONSTANT  OR
     NAME = LIST OF CONSTANTS.
```

THE ORDER OF INPUT IS IMMATERIAL; AS MANY CARDS AS NEEDED MAY BE USED; THE &-SIGN SIGNIFYING THE END OF THE NAMELIST INPUT SHOULD APPEAR ONLY ON THE LAST CARD.

FOR ADDITIONAL DETAILS ON THE USE OF NAMELIST INPUT,THE USER IS REFERRED TO A STANDARD FORTRAN MANUAL.

* * *

****

AS OF 8/10/80

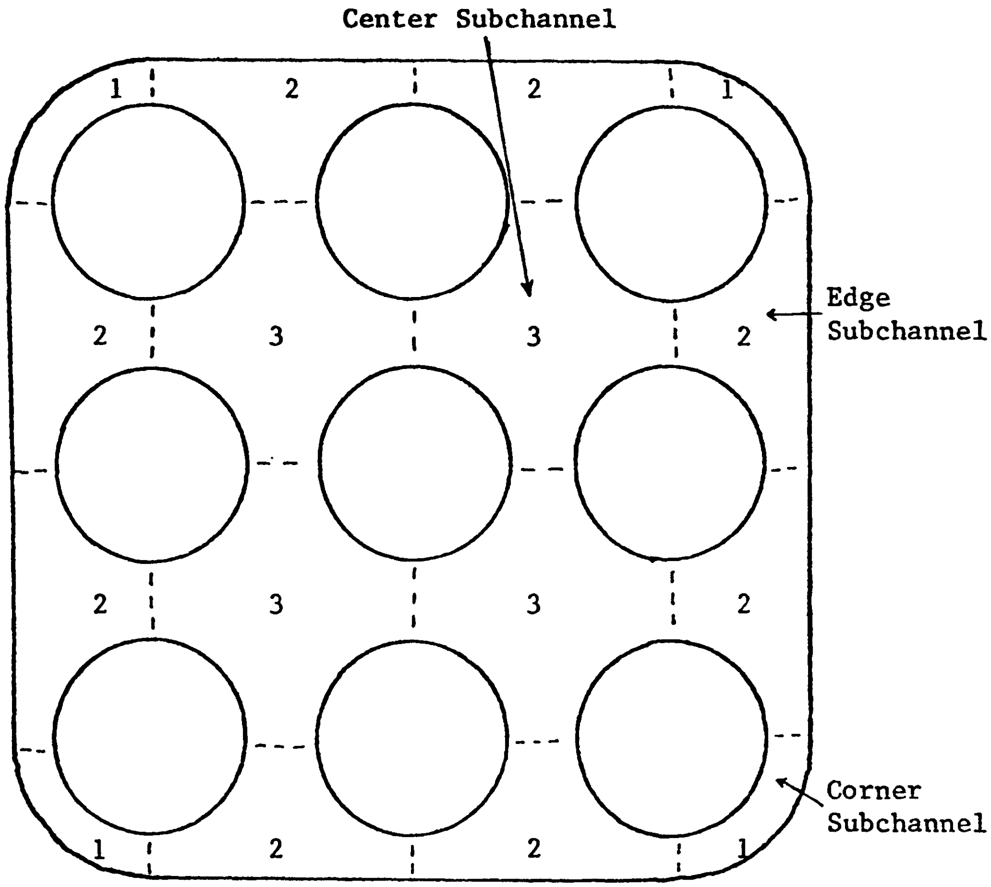
4.0 SAMPLE PROBLEMS

This section contains the descriptions of the two sample problems. The first problem is an analysis of a typical BWR 9-rod test section for steady-state conditions. The second is an analysis of 5 PWR assemblies for steady-state and transient conditions. These problems serve to illustrate many features of the modeling capability as well as serving as reference cases.

4.1 Sample Problem 1 Description

The first sample problem illustrates the use of the subchannel analysis capability of THERMIT-2. One quarter of a 9-rod BWR type bundle is modeled in this problem. Due to symmetry only the upper left-hand corner needs to be modeled. The dimensions of the test section are included in Figure 4.1.

For this problem, four coolant channels along with 9 fuel rod sections are modeled. In the axial direction 10 nodes are used. Since this problem is only a steady-state one, the fuel pin modeling is very simple. Steady-state conditions are attained at approximately 1.0 seconds. The input and output for this case are as follows:



<u>Geoemtrical Details</u>

Rod Diameter	14.478 mm
Rod-Rod Gap	4.267 mm
Rod-Wall Gap	3.429 mm
Radius of Corner	10.2 mm
Heated Length	1829. mm

Figure 4.1: Cross Section View of G.E. 9 Rod Bundle Used in Mass Velocity & Enthalpy Measurements

SAMPLE PROBLEM 1 INPUT DATA FILE

```
1
GE CHF TEST SAMPLE PROBLEM  STEADY-STATE
4 2 9 10 3 1
0 1 2 0 1 2 1 1 1 0 1 1 1 0 0 0 -9.81 18.97E-3 1.
1 2 50 2.E-7 1.E-7
273.25E3 0. 0. 7.1628E-3 7.62E-4 5.08E-5 1.E5 1. 0 0 0 0 0 0 0 0 0 0 0
2 2 $ NCR
0 0 $ IND
10(0.) 10(1.9249E-3) 10(0.) 10(1.0616E-3) $ ARX
20(0.) 10(1.0616E-3) 10(1.9249E-3) $ ARY
11(1.1938E-4) 11(1.902E-4) 11(5.1358E-5) 11(1.1938E-4) $ ARZ
10(2.1832E-5) 10(3.4783E-5) 10(9.3924E-6) 10(2.1832E-5) $ VOL
10.668E-3 .018745 10.668E-3 .018745 $ DX
0.018745 .018745 .010668 .010668 $ DY
12(.18288) $ DZ
11.577E-3 16.905E-3 9.001E-3 11.577E-3 $ HDZ
0 0 .0044196 .003505 0 .0044196 0 .0044196
0.003505 0 .003505 0 .0044196 .003505 0 0 $ SIJ
2(2) 12 2(2) 12 2 2 12 2 2 $ IFWZ
4(68.95E5 69.21E5 69.18E5 69.15E5 69.12E5 69.1E5 69.08E5
69.05E5 69.02E5 69.0E5 68.97E5 68.95E5) $ P
4(12(0.)) $ ALP
4(12(544.9)) $ TV
4(11(1.783)) $ VVZ
1 2 2 1 2 2 3 4 4 $ ICR
21.221E-3 16.905E-3 18.259E-3 21.221E-3 $ HDH
90(550.) $ TW
10(1.) $ QZ
9(1.) $ QT
1. 1. 1. 0. 1. $ QR
9(1.) $ RN
9(.25) $ FRACP
0 0 0 0
1. .0001 .01 1. 1. 1. 5
0. 1 1  1 1 1 1
0
```

THERMIT AS OF 10 JULY 1980

GE CHF TEST SAMPLE PROBLEM STEADY-STATE

ARRAY DIMENSIONS

NUMBER OF CHANNELS	= 4
NUMBER OF ROWS	= 2
NUMBER OF FUEL RODS MODELED	= 9
NUMBER OF AXIAL NODES	= 10
NUMBER OF CELLS IN FUEL	= 3
NUMBER OF CELLS IN CLAD	= 1

THERMAL-HYDRAULIC OPTIONS IN USE

PRESSURE BOUNDARY CONDITION AT CORE EXIT
VELOCITY BOUNDARY CONDITION AT CORE INLET
SUBCOOLED BOILING MODEL
MIT INTERFACIAL MOMENTUM EXCHANGE MODEL
CONSTANT PROPERTY FUEL PIN MODEL
STEADY-STATE HEAT TRANSFER CALCULATION WITHOUT CHF CHECK
COUPLED HEAT FLUX BOUNDARY CONDITION
BIASI CRITICAL HEAT FLUX CORRELATION
TRANSVERSE FRICTION MODEL - GUNTER-SHAW
TRANSVERSE VELOCITY USED IN TRANSVERSE MOMENTUM CALCULATIONS
TRANSVERSE FLOW IS CALCULATED
MIXING MODEL INCLUDED

GRAVITATIONAL CONSTANT	= -9.81000
TRANSVERSE HYDRAULIC DIAMETER	= 0.18970E-01
TRANSVERSE FRICTION MULTIPLIER	= 0.10000E+01

FRICTION MODEL

AXIAL	F =	0.184*RE**-0.200
TRANSVERSE	F =	1.920*RE**-0.145
GRID SPACER	K =	3.000*RE**-0.100

ITERATION CONTROL PARAMETERS

DUMP INDICATOR (0/1)(NO/YES)	= 1
MAX NUMBER OF NEWTON ITERATIONS	= 2
MAX NUMBER OF INNER ITERATIONS	= 50
CONVERGENCE CRIT. FOR NEWTON ITER	= 0.20000E-06
CONVERGENCE CRIT. FOR INNER ITER	= 0.10000E-06

FUEL ROD MODEL DATA

INITIAL TOTAL POWER	= 0.27325E+06
DELAY TIME	= 0.0
INVERSE REACTOR PERIOD	= 0.0
ROD RADIUS	= 0.71628E-02

```
CLAD THICKNESS                    = 0.76200E-03
GAP THICKNESS                     = 0.50800E-04
GAP CONDUCTIVITY                  = 0.10000E+06

 NCR
CARD IMAGE>2 2 $ NCR                                                                      <
 INDENT
CARD IMAGE>0 0 $ IND                                                                      <
ARX
CARD IMAGE>10(0.) 10(1.9249E-3) 10(0.) 10(1.0616E-3) $ ARX                                <
ARY
CARD IMAGE>20(0.) 10(1.0616E-3) 10(1.9249E-3) $ ARY                                       <
ARZ
CARD IMAGE>11(1.1938E-4) 11(1.902E-4) 11(5.1358E-5) 11(1.1938E-4) $ ARZ                   <
VOL
CARD IMAGE>10(2.1832E-5) 10(3.4783E-5) 10(9.3924E-6) 10(2.1832E-5) $ VOL                  <
DX
CARD IMAGE>10.668E-3 .018745 10.668E-3 .018745 $ DX                                       <
DY
CARD IMAGE>.018745 .018745 .010668 .010668 $ DY                                           <
DZ
CARD IMAGE>12(.18288) $ DZ                                                                <
HDZ
CARD IMAGE>11.577E-3 16.905E-3 9.001E-3 11.577E-3 $ HDZ                                   <
SIJ
CARD IMAGE>0 0 .0044196 .003505 0 .0044196 0 .0044196                                     <
CARD IMAGE>.003505 0 .003505 0 .0044196 .003505 0 0 $ SIJ                                 <
IND FRIC
CARD IMAGE>2(2) 12 2(2) 12 2 2 12 2 2 $ IFWZ                                              <
P
CARD IMAGE>4(68.95E5 69.21E5 69.18E5 69.15E5 69.12E5 69.1E5 69.08E5                       <
CARD IMAGE>69.05E5 69.02E5 69.0E5 68.97E5 68.95E5) $ P                                    <
ALP
CARD IMAGE>4(12(0.)) $ ALP                                                                <
TEMP
CARD IMAGE>4(12(544.9)) $ TV                                                              <
VZ
CARD IMAGE>4(11(1.783)) $ VVZ                                                             <
IND RODS
CARD IMAGE>1 2 2 1 2 2 3 4 4 $ ICR                                                        <
HDH
CARD IMAGE>21.221E-3 16.905E-3 18.259E-3 21.221E-3 $ HDH                                  <
TW
CARD IMAGE>90(550.) $ TW                                                                  <
      QZ
CARD IMAGE>10(1.) $ QZ                                                                    <
      QT
CARD IMAGE>9(1.) $ QT                                                                     <
      QR
CARD IMAGE>1. 1. 1. 0. 1. $ QR                                                            <
      RN
CARD IMAGE>9(1.) $ RN                                                                     <
FRAC PH
CARD IMAGE>9(.25) $ FRACP                                                                 <
```

< CHANNEL OVERLAY >

3	4
1	2

TIME STEP NO = 0 TIME = 0.0 SEC TIME STEP SIZE = 0.0 SEC CPU TIME = 0.0 SEC
NUMBER OF NEWTON ITERATIONS = 0
NUMBER OF INNER ITERATIONS = 0 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 273.250 KW INLET FLOW RATE = 0.656 KG/S MAXIMUM TEMPERATURES IR IZ
TOTAL HEAT TRANSFER = 0.0 KW OUTLET FLOW RATE = 0.656 KG/S WALL: 0.0 AT 0 0
FLUID ENERGY RISE = 0.003 KW ROD: 0.0 AT 0 0
MIN CHFR = 0.0 AT 0 0

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	6.89500	0.0	0.0	1193.985	1193.985	544.90	544.90	557.99	1.783	1.783	36.53	766.13	1366.0
1	2	6.92100	0.0	0.0	1193.980	1193.980	544.90	544.90	558.24	1.783	1.783	36.70	766.16	1366.1
1	3	6.91800	0.0	0.0	1193.981	1193.981	544.90	544.90	558.21	1.783	1.783	36.68	766.16	1366.1
1	4	6.91500	0.0	0.0	1193.981	1193.981	544.90	544.90	558.18	1.783	1.783	36.66	766.15	1366.0
1	5	6.91200	0.0	0.0	1193.982	1193.982	544.90	544.90	558.15	1.783	1.783	36.64	766.15	1366.0
1	6	6.91000	0.0	0.0	1193.983	1193.983	544.90	544.90	558.13	1.783	1.783	36.63	766.15	1366.0
1	7	6.90800	0.0	0.0	1193.983	1193.983	544.90	544.90	558.11	1.783	1.783	36.62	766.14	1366.0
1	8	6.90500	0.0	0.0	1193.983	1193.983	544.90	544.90	558.08	1.783	1.783	36.60	766.14	1366.0
1	9	6.90200	0.0	0.0	1193.984	1193.984	544.90	544.90	558.06	1.783	1.783	36.58	766.14	1366.0
1	10	6.90000	0.0	0.0	1193.984	1193.984	544.90	544.90	558.04	1.783	1.783	36.56	766.13	1366.0
1	11	6.89700	0.0	0.0	1193.985	1193.985	544.90	544.90	558.01	1.783	1.783	36.54	766.13	1366.0
1	12	6.89500	0.0		1193.985	1193.985	544.90	544.90	557.99			36.53	766.13	
2	1	6.89500	0.0	0.0	1193.985	1193.985	544.90	544.90	557.99	1.783	1.783	36.53	766.13	1366.0
2	2	6.92100	0.0	0.0	1193.980	1193.980	544.90	544.90	558.24	1.783	1.783	36.70	766.16	1366.1
2	3	6.91800	0.0	0.0	1193.981	1193.981	544.90	544.90	558.21	1.783	1.783	36.68	766.16	1366.1
2	4	6.91500	0.0	0.0	1193.981	1193.981	544.90	544.90	558.18	1.783	1.783	36.66	766.15	1366.0
2	5	6.91200	0.0	0.0	1193.982	1193.982	544.90	544.90	558.15	1.783	1.783	36.64	766.15	1366.0
2	6	6.91000	0.0	0.0	1193.983	1193.983	544.90	544.90	558.13	1.783	1.783	36.63	766.15	1366.0
2	7	6.90800	0.0	0.0	1193.983	1193.983	544.90	544.90	558.11	1.783	1.783	36.62	766.14	1366.0
2	8	6.90500	0.0	0.0	1193.983	1193.983	544.90	544.90	558.08	1.783	1.783	36.60	766.14	1366.0
2	9	6.90200	0.0	0.0	1193.984	1193.984	544.90	544.90	558.06	1.783	1.783	36.58	766.14	1366.0
2	10	6.90000	0.0	0.0	1193.984	1193.984	544.90	544.90	558.04	1.783	1.783	36.56	766.13	1366.0
2	11	6.89700	0.0	0.0	1193.985	1193.985	544.90	544.90	558.01	1.783	1.783	36.54	766.13	1366.0
2	12	6.89500	0.0		1193.985	1193.985	544.90	544.90	557.99			36.53	766.13	
3	1	6.89500	0.0	0.0	1193.985	1193.985	544.90	544.90	557.99	1.783	1.783	36.53	766.13	1366.0
3	2	6.92100	0.0	0.0	1193.980	1193.980	544.90	544.90	558.24	1.783	1.783	36.70	766.16	1366.1
3	3	6.91800	0.0	0.0	1193.981	1193.981	544.90	544.90	558.21	1.783	1.783	36.68	766.16	1366.1
3	4	6.91500	0.0	0.0	1193.981	1193.981	544.90	544.90	558.18	1.783	1.783	36.66	766.15	1366.0
3	5	6.91200	0.0	0.0	1193.982	1193.982	544.90	544.90	558.15	1.783	1.783	36.64	766.15	1366.0
3	6	6.91000	0.0	0.0	1193.983	1193.983	544.90	544.90	558.13	1.783	1.783	36.63	766.15	1366.0
3	7	6.90800	0.0	0.0	1193.983	1193.983	544.90	544.90	558.11	1.783	1.783	36.62	766.14	1366.0
3	8	6.90500	0.0	0.0	1193.993	1193.983	544.90	544.90	558.08	1.783	1.783	36.60	766.14	1366.0
3	9	6.90200	0.0	0.0	1193.984	1193.984	544.90	544.90	558.06	1.783	1.783	36.58	766.14	1366.0
3	10	6.90000	0.0	0.0	1193.984	1193.984	544.90	544.90	558.04	1.783	1.783	36.56	766.13	1366.0
3	11	6.89700	0.0	0.0	1193.985	1193.985	544.90	544.90	558.01	1.783	1.783	36.54	766.13	1366.0
3	12	6.89500	0.0		1193.965	1193.985	544.90	544.90	557.99			36.53	766.13	
4	1	6.89500	0.0	0.0	1193.965	1193.985	544.90	544.90	557.99	1.783	1.783	36.53	766.13	1366.0
4	2	6.92100	0.0	0.0	1193.980	1193.980	544.90	544.90	558.24	1.783	1.783	36.70	766.16	1366.1
4	3	6.91800	0.0	0.0	1193.981	1193.981	544.90	544.90	558.21	1.783	1.783	36.68	766.16	1366.1
4	4	6.91500	0.0	0.0	1193.981	1193.981	544.90	544.90	558.18	1.783	1.783	36.66	766.15	1366.0
4	5	6.91200	0.0	0.0	1193.982	1193.982	544.90	544.90	558.15	1.783	1.783	36.64	766.15	1366.0
4	6	6.91000	0.0	0.0	1193.983	1193.963	544.90	544.90	558.13	1.783	1.783	36.63	766.15	1366.0
4	7	6.90800	0.0	0.0	1193.983	1193.983	544.90	544.90	558.11	1.783	1.783	36.62	766.14	1366.0
4	8	6.90500	0.0	0.0	1193.993	1193.983	544.90	544.90	558.08	1.783	1.783	36.60	766.14	1366.0
4	9	6.90200	0.0	0.0	1193.984	1193.984	544.90	544.90	558.06	1.783	1.783	36.58	766.14	1366.0
4	10	6.90000	0.0	0.0	1193.984	1193.984	544.90	544.90	558.04	1.783	1.783	36.56	766.13	1366.0

4	11	6.89700	0.0	0.0	1193.985	1193.985	544.90	544.90	558.01	1.783	1.783	36.54	766.13	1366.0
4	12	6.89500	0.0		1193.985	1193.985	544.90	544.90	557.99			36.53	766.13	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	2	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	3	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	4	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	5	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	6	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	7	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	8	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	9	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	10	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	11	4	0.0	0.0	0.0	0.0

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
1	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
2	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0

3	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
3	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
4	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
5	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
6	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
7	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
8	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0

9	1	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	2	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	3	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	4	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	5	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	6	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	7	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	8	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	9	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0
9	10	0	0.	0.0	550.0	550.0	550.0	550.0	550.0	550.0

TIME STEP NO = 100 TIME = 0.999999 SEC TIME STEP SIZE = 0.10000E-01 SEC CPU TIME = 74.20 SEC
NUMBER OF NEWTON ITERATIONS = 2
NUMBER OF INNER ITERATIONS = 4 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 273.250 KW
TOTAL HEAT TRANSFER = 273.245 KW
FLUID ENERGY RISE = 272.624 KW

INLET FLOW RATE = 0.656 KG/S
OUTLET FLOW RATE = 0.656 KG/S

MAXIMUM TEMPERATURES		IR	IZ
WALL:	584.50 AT	2	8
ROD:	2449.67 AT	2	8
MIN CHFR =	1.758 AT	2	10

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	6.93498	0.0	0.0	1193.977	1193.977	544.90	544.90	558.38	1.783	1.783	36.79	766.18	1366.1
1	2	6.93324	0.0890	0.56	1231.906	1223.276	558.36	550.53	558.36	2.363	1.966	36.01	755.62	1361.2
1	3	6.93130	0.2033	1.79	1271.789	1244.385	558.34	554.52	558.34	3.331	2.245	35.99	747.85	1361.9
1	4	6.92773	0.3397	3.68	1311.612	1255.747	558.31	556.64	558.31	4.062	2.649	35.97	743.61	1350.3
1	5	6.92534	0.4509	6.03	1352.331	1260.939	558.28	557.61	558.28	5.000	3.100	35.96	741.65	1343.4
1	6	6.92267	0.4946	8.60	1393.076	1263.041	558.26	558.00	558.26	6.531	3.296	35.94	740.86	1350.4
1	7	6.91712	0.5859	11.09	1431.404	1263.695	558.20	558.12	558.20	7.068	3.887	35.91	740.60	1340.7
1	8	6.91394	0.6428	13.61	1469.579	1263.848	558.17	558.15	558.17	7.876	4.362	35.89	740.54	1335.4
1	9	6.91049	0.6407	16.26	1509.582	1263.796	558.14	558.13	558.14	9.540	4.246	35.88	740.56	1348.9
1	10	6.90290	0.7058	18.63	1545.171	1263.440	558.06	558.07	558.06	9.865	5.000	35.83	740.68	1339.1
1	11	6.89898	0.7410	21.08	1581.980	1263.222	558.03	558.03	558.03	10.597	5.487	35.81	740.75	1334.1
1	12	6.89500	0.7410		1581.980	1263.224	558.03	558.03	557.99			35.78	740.75	
2	1	6.93485	0.0	0.0	1193.978	1193.978	544.90	544.90	558.38	1.783	1.783	36.79	766.18	1366.1
2	2	6.93324	0.1298	0.91	1240.429	1226.303	558.36	551.11	558.36	2.720	2.104	36.01	754.52	1394.0
2	3	6.93131	0.2422	2.45	1283.802	1246.271	558.34	554.87	558.34	3.943	2.413	35.99	747.15	1400.5
2	4	6.92773	0.3846	4.74	1328.569	1256.595	558.31	556.80	558.31	4.868	2.960	35.97	743.29	1421.2
2	5	6.92534	0.4904	7.35	1372.545	1261.221	558.28	557.66	558.28	5.950	3.499	35.96	741.55	1427.3
2	6	6.92267	0.5205	10.16	1416.815	1263.112	558.26	558.01	558.26	7.653	3.563	35.94	740.83	1408.8
2	7	6.91712	0.6211	13.32	1465.117	1263.705	558.20	558.12	558.20	8.498	4.395	35.91	740.60	1422.9
2	8	6.91394	0.6821	16.48	1513.018	1263.846	558.17	558.14	558.17	9.607	5.061	35.89	740.54	1426.9
2	9	6.91049	0.6712	19.53	1558.979	1263.787	558.14	558.13	558.14	11.390	4.643	35.88	740.56	1404.6
2	10	6.90290	0.7450	22.93	1610.262	1263.436	558.06	558.07	558.06	12.258	5.822	35.83	740.68	1426.7
2	11	6.89898	0.7843	26.25	1660.231	1263.221	558.03	558.03	558.03	13.398	6.617	35.81	740.76	1433.5
2	12	6.89500	0.7843		1660.231	1263.223	558.03	558.03	557.99			35.78	740.75	
3	1	6.93512	0.0	0.0	1193.977	1193.977	544.90	544.90	558.38	1.783	1.783	36.79	766.18	1366.1
3	2	6.93324	0.0959	0.61	1234.491	1225.065	558.36	550.87	558.36	2.264	1.873	36.01	754.97	1286.1
3	3	6.93130	0.2278	2.06	1277.617	1246.162	558.34	554.85	558.34	3.161	2.139	35.99	747.19	1259.9
3	4	6.92773	0.3507	3.79	1314.254	1256.732	558.31	556.83	558.31	3.718	2.470	35.97	743.24	1238.6
3	5	6.92534	0.4476	5.85	1349.993	1261.367	558.28	557.69	558.28	4.530	2.863	35.96	741.49	1245.7
3	6	6.92267	0.4896	8.13	1386.220	1263.201	558.26	558.03	558.26	5.919	3.111	35.94	740.80	1280.5
3	7	6.91712	0.5684	10.05	1415.700	1263.742	558.20	558.13	558.20	6.259	3.578	35.91	740.59	1271.2
3	8	6.91394	0.6193	12.20	1448.277	1263.864	558.17	558.15	558.17	7.017	3.992	35.89	740.53	1279.8
3	9	6.91049	0.6217	14.57	1464.017	1263.796	558.14	558.13	558.14	8.479	3.959	35.88	740.56	1298.1
3	10	6.90290	0.6807	16.40	1511.442	1263.436	558.06	558.07	558.06	8.471	4.452	35.83	740.68	1259.7
3	11	6.89898	0.7112	18.32	1540.375	1263.219	558.03	558.03	558.03	9.049	4.802	35.81	740.75	1257.6
3	12	6.89500	0.7112		1540.375	1263.222	558.03	558.03	557.99			35.78	740.75	
4	1	6.93498	0.0	0.0	1193.977	1193.977	544.90	544.90	558.38	1.783	1.783	36.79	766.18	1366.1
4	2	6.93324	0.0890	0.56	1231.911	1223.279	558.36	550.53	558.36	2.363	1.966	36.01	755.62	1361.1
4	3	6.93130	0.2033	1.79	1271.790	1244.385	558.34	554.52	558.34	3.331	2.245	35.99	747.85	1361.9
4	4	6.92773	0.3397	3.68	1311.612	1255.748	558.31	556.64	558.31	4.062	2.649	35.97	743.61	1350.3
4	5	6.92534	0.4509	6.03	1352.326	1260.934	558.28	557.61	558.28	5.000	3.100	35.96	741.65	1343.4
4	6	6.92267	0.4946	8.60	1393.074	1263.039	558.26	558.00	558.26	6.531	3.296	35.94	740.86	1350.4
4	7	6.91712	0.5859	11.09	1431.402	1263.693	558.20	558.12	558.20	7.068	3.887	35.91	740.60	1340.7
4	8	6.91394	0.6428	13.61	1469.582	1263.849	558.17	558.15	558.17	7.876	4.362	35.89	740.54	1335.4
4	9	6.91049	0.6407	16.26	1509.578	1263.792	558.14	558.13	558.14	9.540	4.246	35.88	740.56	1348.9
4	10	6.90290	0.7058	18.63	1545.170	1263.440	558.06	558.07	558.06	9.865	5.000	35.83	740.68	1339.1

4	11	6.89898	0.7410	21.08	1581.979	1263.222	558.03	558.03	558.03	10.597	5.487	35.81	740.75	1334.1
4	12	6.89500	0.7410		1581.979	1263.224	558.03	553.03	557.99			35.78	740.75	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	4.780E-03	1.175E-03	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	-2.318E-02	-6.418E-04	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	1.359E-02	1.438E-03	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	1.445E-02	1.399E-03	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	-6.443E-03	-6.647E-05	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	-3.006E-03	8.239E-04	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	6.405E-03	1.666E-03	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	-1.196E-02	-5.975E-04	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	2.714E-02	3.001E-03	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	-4.139E-04	1.977E-03	0.0	0.0
3	0.0	0.0	-2.152E-02	-3.029E-03	2	4	2.152E-02	3.029E-03	-4.780E-03	-1.175E-03
3	0.0	0.0	-4.809E-03	-2.219E-03	3	4	4.809E-03	2.219E-03	2.318E-02	6.418E-04
3	0.0	0.0	-3.758E-03	-2.564E-03	4	4	3.758E-03	2.564E-03	-1.359E-02	-1.438E-03
3	0.0	0.0	-1.092E-02	-2.752E-03	5	4	1.092E-02	2.752E-03	-1.445E-02	-1.399E-03
3	0.0	0.0	-8.444E-03	-2.662E-03	6	4	8.444E-03	2.662E-03	6.443E-03	6.647E-05
3	0.0	0.0	-1.433E-02	-3.163E-03	7	4	1.433E-02	3.163E-03	3.005E-03	-8.239E-04
3	0.0	0.0	-1.280E-02	-2.644E-03	8	4	1.280E-02	2.644E-03	-6.405E-03	-1.666E-03
3	0.0	0.0	-5.705E-03	-2.341E-03	9	4	5.705E-03	2.341E-03	1.196E-02	5.975E-04
3	0.0	0.0	-1.548E-02	-3.948E-03	10	4	1.548E-02	3.948E-03	-2.714E-02	-3.001E-03
3	0.0	0.0	-1.854E-02	-3.110E-03	11	4	1.854E-02	3.110E-03	4.138E-04	-1.977E-03

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES,(DEG K)					
1	1	3	1475492.	2.7243	2444.7	2250.0	1665.8	692.1	678.9	579.6
1	2	3	1475500.	2.6931	2445.1	2250.4	1666.2	692.5	679.3	579.9
1	3	3	1475537.	2.6317	2445.2	2250.5	1666.2	692.6	679.4	580.0
1	4	3	1475523.	2.5382	2445.3	2250.5	1666.3	692.6	679.4	580.1
1	5	4	1475523.	2.4166	2445.5	2250.8	1666.6	692.9	679.7	580.4
1	6	4	1475530.	2.3039	2445.3	2250.5	1666.3	692.6	679.4	580.1
1	7	4	1475495.	2.1998	2445.3	2250.6	1666.4	692.7	679.5	580.1
1	8	4	1475517.	2.0982	2445.6	2250.9	1666.7	693.0	679.8	580.5
1	9	4	1475512.	1.9563	2447.6	2252.9	1668.7	695.0	681.8	582.5
1	10	4	1475491.	1.8740	2447.3	2252.6	1668.4	694.7	681.5	582.1
2	1	3	1475521.	2.9779	2448.3	2253.5	1669.3	695.6	682.4	583.1
2	2	3	1475513.	2.8975	2448.8	2254.1	1669.9	696.2	683.0	583.6
2	3	3	1475528.	2.7968	2448.9	2254.2	1670.0	696.3	683.1	583.8
2	4	3	1475504.	2.6624	2449.2	2254.4	1670.2	696.5	683.3	584.0
2	5	4	1475523.	2.5286	2449.5	2254.8	1670.6	696.9	683.7	584.3
2	6	4	1475514.	2.3727	2449.0	2254.3	1670.1	696.4	683.2	583.9
2	7	4	1475519.	2.2247	2449.2	2254.5	1670.3	696.6	683.4	584.1
2	8	4	1475512.	2.1182	2449.7	2254.9	1670.7	697.0	683.8	584.5
2	9	4	1475525.	1.8991	2447.3	2252.6	1668.4	694.7	681.5	582.1
2	10	4	1475513.	1.7582	2446.4	2251.6	1667.4	693.7	680.5	581.2
3	1	3	1475521.	2.9779	2448.3	2253.5	1669.3	695.6	692.4	583.1
3	2	3	1475513.	2.8975	2448.8	2254.1	1669.9	696.2	683.0	583.6
3	3	3	1475528.	2.7968	2448.9	2254.2	1670.0	696.3	683.1	583.8
3	4	3	1475504.	2.6624	2449.2	2254.4	1670.2	696.5	683.3	584.0
3	5	4	1475523.	2.5286	2449.5	2254.8	1670.6	696.9	683.7	584.3

3	6	4	1475514.	2.3727	2449.0	2254.3	1670.1	696.4	683.2	583.9
3	7	4	1475519.	2.2247	2449.2	2254.5	1670.3	695.6	683.4	584.1
3	8	4	1475512.	2.1182	2449.7	2254.9	1670.7	697.0	683.8	584.5
3	9	4	1475525.	1.8991	2447.3	2252.6	1668.4	694.7	681.5	582.1
3	10	4	1475513.	1.7582	2446.4	2251.6	1667.4	693.7	680.5	581.2
4	1	3	1475492.	2.7243	2444.7	2250.0	1665.8	692.1	678.9	579.6
4	2	3	1475500.	2.6931	2445.1	2250.4	1666.2	692.5	679.3	579.9
4	3	3	1475537.	2.6317	2445.2	2250.5	1666.2	692.6	679.4	580.0
4	4	3	1475523.	2.5382	2445.3	2250.5	1666.3	692.6	679.4	580.1
4	5	4	1475523.	2.4166	2445.5	2250.8	1666.6	692.9	679.7	580.4
4	6	4	1475530.	2.3039	2445.3	2250.5	1666.3	692.6	679.4	580.1
4	7	4	1475495.	2.1998	2445.3	2250.6	1666.4	692.7	679.5	580.1
4	8	4	1475517.	2.0982	2445.6	2250.9	1666.7	693.0	679.8	580.5
4	9	4	1475512.	1.9563	2447.6	2252.9	1668.7	695.0	681.8	582.5
4	10	4	1475491.	1.8740	2447.3	2252.6	1668.4	694.7	681.5	582.1
5	1	3	1475521.	2.9779	2448.3	2253.5	1669.3	695.6	682.4	583.1
5	2	3	1475513.	2.8975	2448.8	2254.1	1669.9	696.2	683.0	583.6
5	3	3	1475528.	2.7968	2448.9	2254.2	1670.0	696.3	683.1	583.8
5	4	3	1475504.	2.6624	2449.2	2254.4	1670.2	696.5	683.3	584.0
5	5	4	1475523.	2.5286	2449.5	2254.8	1670.6	696.9	683.7	584.3
5	6	4	1475514.	2.3727	2449.0	2254.3	1670.1	696.4	683.2	583.9
5	7	4	1475519.	2.2247	2449.2	2254.5	1670.3	696.6	683.4	584.1
5	8	4	1475512.	2.1182	2449.7	2254.9	1670.7	697.0	683.8	584.5
5	9	4	1475525.	1.8991	2447.3	2252.6	1668.4	694.7	681.5	582.1
5	10	4	1475513.	1.7582	2446.4	2251.6	1667.4	693.7	680.5	581.2
6	1	3	1475521.	2.9779	2448.3	2253.5	1669.3	695.6	682.4	583.1
6	2	3	1475513.	2.8975	2448.8	2254.1	1669.9	696.2	683.0	583.6
6	3	3	1475528.	2.7968	2448.9	2254.2	1670.0	696.3	683.1	583.8
6	4	3	1475504.	2.6624	2449.2	2254.4	1670.2	696.5	683.3	584.0
6	5	4	1475523.	2.5286	2449.5	2254.8	1670.6	696.9	683.7	584.3
6	6	4	1475514.	2.3727	2449.0	2254.3	1670.1	696.4	683.2	583.9
6	7	4	1475519.	2.2247	2449.2	2254.5	1670.3	696.6	683.4	584.1
6	8	4	1475512.	2.1182	2449.7	2254.9	1670.7	697.0	683.8	584.5
6	9	4	1475525.	1.8991	2447.3	2252.6	1668.4	694.7	681.5	582.1
6	10	4	1475513.	1.7582	2446.4	2251.6	1667.4	693.7	680.5	581.2
7	1	3	1475509.	2.9239	2442.8	2248.0	1663.8	690.1	676.9	577.6
7	2	3	1475501.	2.9236	2442.9	2248.2	1563.9	690.3	677.1	577.7
7	3	3	1475505.	2.8564	2443.0	2248.2	1664.0	690.3	677.1	577.8
7	4	3	1475551.	2.7628	2443.0	2248.3	1664.1	690.4	677.2	577.8
7	5	4	1475546.	2.6299	2443.2	2248.5	1664.3	690.6	677.4	578.1
7	6	4	1475526.	2.5232	2443.1	2248.4	1664.2	690.5	677.3	577.9
7	7	4	1475500.	2.4367	2443.2	2248.5	1664.2	690.6	677.4	578.0
7	8	4	1475542.	2.3256	2443.4	2248.7	1664.5	690.8	677.6	578.2
7	9	4	1475520.	2.2289	2446.4	2251.6	1667.4	693.7	680.6	581.2
7	10	4	1475498.	2.1644	2446.2	2251.5	1667.3	693.6	680.4	581.0
8	1	3	1475505.	2.7244	2444.7	2250.0	1665.8	692.1	678.9	579.6
8	2	3	1475524.	2.6930	2445.1	2250.4	1666.2	692.5	679.3	579.9
8	3	3	1475493.	2.6316	2445.2	2250.5	1666.2	692.6	679.4	580.0
8	4	3	1475522.	2.5382	2445.3	2250.5	1666.3	692.6	679.4	580.1
8	5	4	1475534.	2.4165	2445.5	2250.8	1666.6	692.9	679.7	580.4
8	6	4	1475504.	2.3041	2445.3	2250.5	1666.3	692.6	679.4	580.1
8	7	4	1475524.	2.1998	2445.3	2250.6	1666.4	692.7	679.5	580.1
8	8	4	1475549.	2.0982	2445.6	2250.9	1666.7	693.0	679.8	580.5
8	9	4	1475513.	1.9563	2447.6	2252.9	1668.7	695.0	681.8	582.5
8	10	4	1475506.	1.8741	2447.3	2252.6	1668.4	694.7	681.5	582.1

9	1	3	1475505.	2.7244	2444.7	2250.0	1665.8	692.1	678.9	579.6
9	2	3	1475524.	2.6930	2445.1	2250.4	1666.2	692.5	679.3	579.9
9	3	3	1475493.	2.6316	2445.2	2250.5	1666.2	692.6	679.4	580.0
9	4	3	1475522.	2.5382	2445.3	2250.5	1666.3	692.6	679.4	580.1
9	5	4	1475534.	2.4165	2445.5	2250.8	1666.6	692.9	679.7	580.4
9	6	4	1475504.	2.3041	2445.3	2250.5	1666.3	692.6	679.4	580.1
9	7	4	1475524.	2.1998	2445.3	2250.6	1666.4	692.7	679.5	580.1
9	8	4	1475549.	2.0982	2445.6	2250.9	1666.7	693.0	679.8	580.5
9	9	4	1475513.	1.9563	2447.6	2252.9	1668.7	695.0	681.8	582.5
9	10	4	1475506.	1.8741	2447.3	2252.6	1668.4	694.7	681.5	582.1

4.1 Sample Problem 2 Description

The second sample problem illustrates the core-wide and transient capabilities of THERMIT-2. In this problem, 5 PWR assemblies in a cross configuration are modeled (see Figure 4.2). A steady-state condition is first attained followed by a simultaneous flow decay and power increase which drive the transient.

As in the previous problem, a steady-state solution is obtained first. However, the mixing model is not included for the steady-state calculation since whole assemblies are being modeled. Once the steady-state is obtained, a restart is performed and the transient forcing function information is input. The transient is then initiated and the results are calculated for 1.0 seconds of the transient. The input and output for this problem follow.

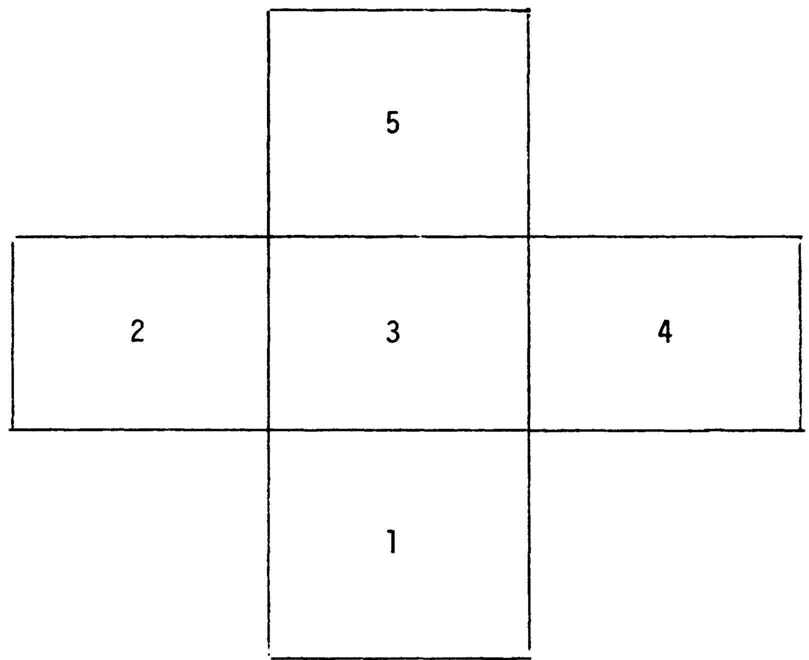


Figure 4.2: PWR 5 Assembly Test Problem Arrangement

SAMPLE PROBLEM 2 DATA FILE (STEADY-STATE)

```
1
PWR 5 ASSEMBLY TEST PROBLEM
5 3 5 10 3 1
0 1 2 0 1 2 1  1 1 0 1  0 0 1 0 0  -9.81 .01 1.25
64. 2000. .179 -.2
1 2 50 2.E-7 1.E-7
8.83E7 0. 0. .47E-2 .572E-3 .824E-4 5000. 1. 0 0 0 0 0 0 0 0 0 0 0
1 3 1 $ NCR
1 0 1 $ INDENT
10(0.) 10(0.) 20(.0445) 10(0.) $ ARX
20(0.) 10(0.0445) 10(0.) 10(.0445) $ ARY
11(5(.026169)) $ ARZ
10(5(.95779E-2)) $ VOL
5(.215) $ DX
5(.215) $ DY
12(.366) $ DZ
5(.01) $ HDZ
5(4(0.)) $ SIJ
2 2 12 2 2 12 2 2 12 2 2 $ IFWZ
5(155.9E5 155.8E5 155.75E5 155.7E5 155.65E5 155.6E5 155.5E5
155.45E5 155.35E5 155.25E5 155.1E5 155.E5) $ P
5(12(0.)) $ ALP
5(12(573.)) $ TV
5(11(4.3)) $ VVZ
1 2 3 4 5 $ ICR
5(.01) $ HDH
5(10(580.)) $ TWALL
1. 2. 3. 3.5 4. 4. 3.5  3. 2. 1. $ QZ
1. 1. 1.2 1. 1. $ QT
3(1.) 2(0) $ QR
5(264.) $ RN
5(1.) $ FRACP
0 0 0 0
6. .00001 .05 6. 6. 1. 5
0. 1 1 1 1 1 1
0
```

```
                 PWR 5 ASSEMBLY TEST PROBLEM


          ARRAY DIMENSIONS

NUMBER OF CHANNELS              =   5
NUMBER OF ROWS                  =   3
NUMBER OF FUEL RODS MODELED     =   5
NUMBER OF AXIAL NODES           =  10
NUMBER OF CELLS IN FUEL         =   3
NUMBER OF CELLS IN CLAD         =   1


       THERMAL-HYDRAULIC OPTIONS IN USE

PRESSURE BOUNDARY CONDITION AT CORE EXIT
VELOCITY BOUNDARY CONDITION AT CORE INLET
SUBCOOLED    BOILING MODEL
MIT  INTERFACIAL MOMENTUM EXCHANGE MODEL
CONSTANT PROPERTY FUEL PIN MODEL
TRANSIENT    HEAT TRANSFER CALCULATION
COUPLED  HEAT FLUX BOUNDARY CONDITION
BIASI    CRITICAL HEAT FLUX CORRELATION
TRANSVERSE FRICTION MODEL - GUNTER-SHAW
TRANSVERSE   VELOCITY USED IN TRANSVERSE MOMENTUM CALCULATIONS
TRANSVERSE FLOW IS CALCULATED
NO MIXING MODEL
GRAVITATIONAL CONSTANT          =   -9.81000
TRANSVERSE HYDRAULIC DIAMETER   =  0.10000E-01
TRANSVERSE FRICTION MULTIPLIER  =  0.12500E+01


       FRICTION MODEL

AXIAL         F =  0.179*RE**-0.200
TRANSVERSE    F =  1.920*RE**-0.145
GRID SPACER   K =  3.000*RE**-0.100


       ITERATION CONTROL PARAMETERS

DUMP INDICATOR (0/1)(NO/YES)       =   1
MAX NUMBER OF NEWTON ITERATIONS    =   5
MAX NUMBER OF INNER ITERATIONS     =  50
CONVERGENCE CRIT. FOR NEWTON ITER= 0.20000E-06
CONVERGENCE CRIT. FOR INNER ITER = 0.10000E-06


    FUEL ROD MODEL DATA

INITIAL TOTAL POWER             = 0.88300E+08
DELAY TIME                      = 0.0
INVERSE REACTOR PERIOD          = 0.0
ROD RADIUS                      = 0.47000E-02
CLAD THICKNESS                  = 0.57200E-03
GAP THICKNESS                   = 0.82400E-04
```

Sample Problem 2 Output (Steady-State)

GAP CONDUCTIVITY = 0.50000E+04

FORCING FUNCTION FOR BOTTOM BOUNDARY CONDITION

TIME	FACTOR
6.0000	1.0000
7.0000	0.8000

FORCING FUNCTION FOR REACTOR POWER

TIME	FACTOR
6.0000	0.100000E+01
7.0000	0.150000E+01

TIME STEP NO = 121 TIME = 6.049922 SEC TIME STEP SIZE = 0.50000E-01 SEC CPU TIME = 0.0 SEC
NUMBER OF NEWTON ITERATIONS = 2
NUMBER OF INNER ITERATIONS = 3 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 88299.937 KW INLET FLOW RATE = 409.018 KG/S MAXIMUM TEMPERATURES IR IZ
TOTAL HEAT TRANSFER = 88294.437 KW OUTLET FLOW RATE = 409.920 KG/S WALL: 630.73 AT 3 6
FLUID ENERGY RISE = 89785.750 KW ROD: 1970.22 AT 3 6
MIN CHFR = 2.519 AT 3 7

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	15.58588	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.01	726.97	3126.0
1	2	15.57989	0.0	0.0	1344.792	1344.792	618.35	574.43	618.35	4.322	4.322	106.70	724.15	3129.8
1	3	15.57383	0.0	0.0	1358.852	1358.852	618.32	577.01	618.32	4.368	4.368	106.62	715.36	3124.6
1	4	15.56207	0.0	0.0	1380.731	1380.731	618.26	580.98	618.26	4.431	4.431	106.48	707.45	3135.0
1	5	15.55590	0.0	0.0	1408.537	1408.537	618.22	585.81	618.22	4.497	4.497	106.40	696.60	3132.6
1	6	15.54971	0.0	0.0	1440.491	1440.491	618.19	591.13	618.19	4.582	4.582	106.32	682.81	3128.6
1	7	15.53757	0.0	0.0	1468.080	1468.080	618.13	595.92	618.13	4.665	4.665	106.18	670.01	3125.6
1	8	15.53124	0.0	0.0	1495.624	1495.624	618.10	600.23	618.10	4.755	4.755	106.10	658.24	3129.8
1	9	15.52489	0.0	0.0	1518.499	1518.499	618.06	603.60	618.06	4.835	4.835	106.02	649.44	3140.3
1	10	15.51239	0.0000	0.00	1538.169	1538.169	618.00	606.09	618.00	4.907	4.907	105.87	639.57	3138.3
1	11	15.50616	0.0000	0.00	1542.053	1542.053	617.97	606.75	617.97	4.934	4.934	105.79	637.59	3145.7
1	12	15.50000	0.0000		1542.053	1542.080	617.97	606.75	617.93			105.64	637.56	
2	1	15.58589	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.01	726.97	3126.0
2	2	15.57989	0.0	0.0	1344.785	1344.785	618.35	574.43	618.35	4.319	4.319	106.70	724.15	3127.5
2	3	15.57385	0.0	0.0	1358.314	1358.314	618.32	576.90	618.32	4.368	4.368	106.62	716.35	3128.9
2	4	15.56208	0.0	0.0	1383.255	1383.255	618.26	581.11	618.26	4.429	4.429	106.48	708.45	3137.7
2	5	15.55591	0.0	0.0	1411.653	1411.653	618.22	586.25	618.22	4.499	4.499	106.40	694.62	3124.9
2	6	15.54973	0.0	0.0	1441.224	1441.224	618.19	591.15	618.19	4.585	4.585	106.33	683.81	3135.0
2	7	15.53760	0.0	0.0	1473.905	1473.905	618.13	596.35	618.13	4.687	4.687	106.18	671.03	3145.2
2	8	15.53128	0.0	0.0	1501.265	1501.265	618.10	600.60	618.10	4.774	4.774	106.10	657.26	3137.6
2	9	15.52497	0.0000	0.00	1523.396	1523.396	618.06	604.10	618.06	4.855	4.855	106.02	647.48	3143.2
2	10	15.51242	0.0	0.0	1540.187	1540.187	618.00	606.42	618.00	4.909	4.909	105.87	639.60	3139.8
2	11	15.50618	0.0000	0.00	1545.923	1545.923	617.97	607.26	617.97	4.937	4.937	105.79	635.63	3138.1
2	12	15.50000	0.0000		1545.923	1545.951	617.97	607.26	617.93			105.64	635.60	
3	1	15.58589	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.01	726.97	3126.0
3	2	15.57989	0.0	0.0	1346.323	1346.323	618.35	574.71	618.35	4.320	4.320	106.70	723.59	3125.9
3	3	15.57336	0.0	0.0	1364.700	1364.700	618.32	578.16	618.32	4.376	4.376	106.62	715.39	3130.0
3	4	15.56207	0.0	0.0	1393.866	1393.866	618.26	582.92	618.26	4.442	4.442	106.48	702.51	3120.8
3	5	15.55591	0.0	0.0	1425.281	1425.281	618.22	588.43	618.22	4.522	4.522	106.40	689.71	3119.1
3	6	15.54973	0.0	0.0	1462.368	1462.368	618.19	594.99	618.19	4.630	4.630	106.33	673.00	3116.1
3	7	15.53758	0.0	0.0	1501.965	1501.965	618.13	600.74	618.13	4.743	4.733	106.18	658.30	3116.0
3	8	15.53128	0.0009	0.01	1526.360	1526.207	618.10	604.73	618.10	4.857	4.830	106.10	645.56	3115.4
3	9	15.52497	0.0037	0.06	1555.290	1554.646	618.06	608.60	618.06	4.969	4.920	106.02	629.85	3089.4
3	10	15.51242	0.0033	0.06	1579.700	1579.127	618.00	611.47	618.00	5.014	4.992	105.87	620.05	3086.9
3	11	15.50617	0.0006	0.01	1590.824	1590.729	617.97	612.86	617.97	5.051	5.039	105.79	615.16	3098.3
3	12	15.50000	0.0006		1590.824	1590.763	617.97	612.86	617.93			105.64	615.12	
4	1	15.58589	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.02	726.97	3126.0
4	2	15.57990	0.0	0.0	1344.785	1344.785	618.35	574.43	618.35	4.317	4.317	106.70	724.15	3126.0
4	3	15.57387	0.0	0.0	1361.657	1361.657	618.32	577.33	618.32	4.370	4.370	106.62	715.37	3126.5
4	4	15.56209	0.0	0.0	1383.537	1383.537	618.26	581.26	618.26	4.431	4.431	106.48	707.46	3134.9
4	5	15.55593	0.0	0.0	1412.677	1412.677	618.22	586.24	618.22	4.494	4.494	106.40	694.62	3121.7
4	6	15.54975	0.0	0.0	1445.107	1445.107	618.19	591.58	618.19	4.591	4.591	106.33	681.83	3130.1
4	7	15.53757	0.0	0.0	1469.330	1469.330	618.13	595.84	618.13	4.685	4.685	106.18	671.00	3143.3
4	8	15.53124	0.0000	0.00	1495.803	1495.803	618.10	599.81	618.10	4.771	4.771	106.10	661.21	3154.6
4	9	15.52497	0.0000	0.00	1522.901	1522.901	618.06	603.90	618.06	4.860	4.860	106.02	647.46	3146.5
4	10	15.51243	0.0000	0.00	1540.969	1540.969	618.00	606.69	618.00	4.914	4.914	105.87	638.62	3138.2

4	11	15.50618	0.0000	0.00	1544.349	1544.349	617.97	607.26	617.97	4.936	4.936	105.79	636.63	3142.5
4	12	15.50000	0.0000		1544.349	1544.377	617.97	607.26	617.93			105.64	636.60	
5	1	15.58590	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.02	726.97	3126.0
5	2	15.57990	0.0	0.0	1344.789	1344.789	618.35	574.43	618.35	4.313	4.313	106.70	724.15	3123.1
5	3	15.57363	0.0	0.0	1361.937	1361.937	618.32	577.50	618.32	4.370	4.370	106.62	714.37	3121.9
5	4	15.56202	0.0	0.0	1382.004	1382.004	618.26	581.17	618.26	4.428	4.428	106.48	707.46	3132.6
5	5	15.55585	0.0	0.0	1409.083	1409.083	618.22	585.78	618.22	4.495	4.495	106.40	695.60	3127.1
5	6	15.54939	0.0	0.0	1438.931	1438.931	618.19	590.97	618.19	4.585	4.585	106.32	683.80	3135.1
5	7	15.53757	0.0	0.0	1467.320	1467.320	618.13	595.79	618.13	4.673	4.673	106.18	670.00	3131.0
5	8	15.53129	0.0000	0.00	1497.643	1497.643	618.10	600.14	618.10	4.760	4.760	106.10	659.23	3138.1
5	9	15.52499	0.0000	0.00	1519.581	1519.582	618.06	603.77	618.06	4.848	4.848	106.02	647.45	3138.6
5	10	15.51245	0.0	0.0	1540.190	1540.190	618.00	606.39	618.00	4.911	4.911	105.87	639.59	3141.2
5	11	15.50618	0.0000	0.00	1543.363	1543.363	617.97	606.84	617.97	4.932	4.932	105.79	636.60	3139.7
5	12	15.50000	0.0000		1543.363	1543.390	617.97	606.84	617.93			105.64	636.57	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	-2.529E-03	-2.529E-03	-5.674E-03	-5.674E-03	2	4	2.431E-04	2.431E-04	0.0	0.0
3	-6.771E-03	-6.771E-03	-1.662E-02	-1.662E-02	3	4	5.909E-05	5.909E-05	0.0	0.0
3	-6.384E-04	-6.384E-04	-7.933E-03	-7.933E-03	4	4	2.335E-04	2.335E-04	0.0	0.0
3	-6.471E-04	-6.471E-04	-9.235E-03	-9.235E-03	5	4	-1.023E-03	-1.023E-03	0.0	0.0
3	-6.316E-03	-6.316E-03	-1.197E-02	-1.197E-02	6	4	-6.217E-03	-6.217E-03	0.0	0.0
3	3.437E-03	3.437E-03	-1.088E-03	-1.098E-03	7	4	5.491E-03	5.491E-03	0.0	0.0
3	3.252E-03	3.[illegible]	3.1[illegible]E-03	3.639E-03	8	4	1.5[illegible]E-02	1.476E-02	0.0	0.0
3	5.462E-03	5.305E-03	-7.549E-03	-5.612E-03	9	4	8.734E-04	1.042E-03	0.0	0.0
3	1.477E-03	1.713E-03	-2.795E-04	1.378E-03	10	4	-2.405E-04	2.120E-04	0.0	0.0
3	2.578E-03	2.465E-03	-4.277E-03	-4.153E-03	11	4	-2.672E-03	-2.555E-03	0.0	0.0
5	0.0	0.0	-1.587E-03	-1.597E-03	2					
5	0.0	0.0	-4.388E-03	-4.388E-03	3					
5	0.0	0.0	7.718E-03	7.718E-03	4					
5	0.0	0.0	1.399E-02	1.399E-02	5					
5	0.0	0.0	1.771E-02	1.771E-02	6					
5	0.0	0.0	1.182E-02	1.182E-02	7					
5	0.0	0.0	.2.845E-03	2.906E-03	8					
5	0.0	0.0	-9.786E-03	-7.965E-03	9					
5	0.0	0.0	-1.191E-02	-9.871E-03	10					
5	0.0	0.0	-1.888E-03	-1.808E-03	11					

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	1	220355.	99.0000	860.0	836.0	764.1	644.2	593.5	581.0
1	2	1	440776.	99.0000	1148.0	1100.1	956.2	716.4	615.0	589.9
1	3	1	661189.	99.0000	1437.4	1365.5	1149.6	790.0	637.9	600.2
1	4	1	771395.	99.0000	1584.9	1501.0	1249.2	829.5	652.1	608.2

1	5	1	881613.	99.0000	1732.8	1636.9	1349.1	869.5	666.8	616.6
1	6	1	881610.	99.0000	1737.3	1641.4	1353.7	874.1	671.3	621.1
1	7	1	771395.	99.0000	1598.7	1514.8	1263.0	843.4	666.0	622.0
1	8	3	661207.	3.4835	1458.6	1386.7	1170.9	811.2	659.1	621.4
1	9	1	440784.	99.0000	1176.4	1128.4	984.5	744.7	643.3	618.3
1	10	1	220360.	99.0000	891.9	867.9	796.0	676.1	625.4	612.8
2	1	1	220368.	99.0000	860.0	836.0	764.1	644.2	593.5	581.0
2	2	1	440789.	99.0000	1147.9	1099.9	956.1	716.3	614.9	589.8
2	3	1	661200.	99.0000	1437.5	1365.6	1149.8	790.1	638.0	600.4
2	4	1	771389.	99.0000	1585.3	1501.4	1249.6	829.9	652.5	608.6
2	5	1	881612.	99.0000	1732.8	1636.8	1349.1	869.5	666.7	616.5
2	6	1	881612.	99.0000	1737.7	1641.8	1354.0	874.4	671.6	621.5
2	7	1	771396.	99.0000	1599.1	1515.2	1263.4	843.7	666.3	622.4
2	8	3	661188.	3.4908	1459.0	1387.1	1171.2	811.6	659.5	621.8
2	9	3	440782.	5.2327	1176.7	1128.7	984.9	745.1	643.7	618.6
2	10	1	220367.	99.0000	892.4	868.4	796.5	676.6	625.9	613.3
3	1	1	264442.	99.0000	917.4	888.7	802.3	658.4	597.6	582.6
3	2	1	528947.	99.0000	1263.4	1205.8	1033.1	745.4	623.7	593.6
3	3	1	793435.	99.0000	1610.6	1524.2	1265.3	833.6	651.1	606.0
3	4	1	925679.	99.0000	1787.3	1686.5	1384.4	880.8	667.9	615.2
3	5	1	1057931.	99.0000	1964.9	1849.8	1504.5	928.9	685.6	625.4
3	6	1	1057925.	99.0000	1970.2	1855.[illegible]	1509.8	934.3	691.0	630.7
3	7	3	925658.	2.5189	1798.7	1698.0	1395.8	892.3	679.3	626.7
3	8	3	793500.	2.9234	1630.9	1544.6	1285.6	854.0	671.5	626.3
3	9	3	528937.	4.3497	1293.5	1235.9	1063.3	775.5	653.8	623.7
3	10	3	264445.	8.8452	954.6	925.9	839.5	695.6	634.8	619.8
4	1	1	220372.	99.0000	860.0	836.0	764.1	644.2	593.5	581.0
4	2	1	440777.	99.0000	1148.3	1100.4	956.5	716.7	615.3	590.2
4	3	1	661188.	99.0000	1437.7	1365.7	1149.9	790.2	638.1	600.5
4	4	1	771401.	99.0000	1585.3	1501.4	1249.6	829.9	652.5	608.6
4	5	1	881598.	99.0000	1733.2	1637.3	1349.6	870.0	667.2	617.0
4	6	1	881619.	99.0000	1737.2	1641.3	1353.5	873.9	671.1	621.0
4	7	3	771383.	3.0138	1598.0	1514.0	1262.3	842.6	665.2	621.3
4	8	3	661161.	3.4849	1458.8	1386.9	1171.0	811.3	659.2	621.6
4	9	3	440808.	5.2208	1176.9	1129.0	985.1	745.3	643.9	618.8
4	10	1	220370.	99.0000	892.4	868.4	796.5	676.6	625.9	613.3
5	1	1	220375.	99.0000	860.0	836.1	764.1	644.2	593.5	581.0
5	2	1	440792.	99.0000	1148.5	1100.6	956.7	716.9	615.5	590.4
5	3	1	661190.	99.0000	1437.6	1365.7	1149.9	790.2	639.1	600.4
5	4	1	771401.	99.0000	1584.9	1500.9	1249.1	829.5	652.1	608.1
5	5	1	881596.	99.0000	1732.7	1636.7	1349.0	869.4	666.6	616.4
5	6	1	881603.	99.0000	1737.3	1641.3	1353.6	874.0	671.2	621.0
5	7	1	771397.	99.0000	1598.7	1514.7	1263.0	843.3	665.9	622.0
5	8	1	661189.	99.0000	1459.4	1387.4	1171.6	811.9	659.8	622.2
5	9	3	440784.	5.2398	1176.7	1128.7	984.8	745.0	643.7	618.6
5	10	1	220368.	99.0000	892.0	868.0	796.1	676.2	625.5	612.9

TIME STEP NO = 125 TIME = 6.249919 SEC TIME STEP SIZE = 0.50000E-01 SEC CPU TIME = 3.57 SEC
NUMBER OF NEWTON ITERATIONS = 5
NUMBER OF INNER ITERATIONS = 15 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 99333.812 KW
TOTAL HEAT TRANSFER = 82588.125 KW
FLUID ENERGY RISE = 114332.375 KW

INLET FLOW RATE = 388.571 KG/S
OUTLET FLOW RATE = 408.589 KG/S

MAXIMUM TEMPERATURES			IR	IZ
WALL:	631.11	AT	3	6
ROD:	1973.33	AT	3	6
MIN CHFR =	2.510	AT	3	7

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	15.58371	0.0	0.0	1337.111	1337.111	573.00	573.00	618.37	4.085	4.085	132.96	726.97	2969.7
1	2	15.57802	0.0	0.0	1345.115	1345.115	618.34	574.49	618.34	4.140	4.140	106.68	724.03	2997.8
1	3	15.57218	0.0	0.0	1363.189	1363.189	618.31	577.52	618.31	4.228	4.228	106.60	715.37	3024.5
1	4	15.56095	0.0	0.0	1386.121	1386.121	618.25	581.48	618.25	4.320	4.320	106.46	706.46	3051.8
1	5	15.55494	0.0	0.0	1412.875	1412.875	618.22	586.16	618.22	4.414	4.414	106.39	696.61	3075.2
1	6	15.54836	0.0	0.0	1442.469	1442.469	618.19	591.24	618.19	4.507	4.507	106.31	684.81	3086.4
1	7	15.53700	0.0	0.0	1470.109	1470.109	618.13	596.23	618.13	4.611	4.611	106.17	670.02	3089.3
1	8	15.53084	0.0000	0.00	1495.092	1495.092	618.09	600.04	618.09	4.711	4.711	106.09	659.22	3105.6
1	9	15.52465	0.0000	0.00	1519.537	1519.537	618.06	603.44	618.06	4.799	4.799	106.02	649.43	3116.5
1	10	15.51223	0.0000	0.00	1534.047	1534.047	618.00	605.53	618.00	4.864	4.864	105.86	641.52	3120.1
1	11	15.50603	0.0	0.0	1541.238	1541.238	617.97	606.43	617.96	4.886	4.886	105.79	639.56	3125.2
1	12	15.50000	0.0		1541.238	1541.265	617.97	606.43	617.93			105.64	639.53	
2	1	15.58332	0.0	0.0	1337.111	1337.111	573.00	573.00	618.37	4.085	4.085	132.96	726.97	2969.7
2	2	15.57812	0.0	0.0	1345.104	1345.104	618.34	574.49	618.34	4.139	4.139	106.68	724.03	2996.6
2	3	15.57223	0.0	0.0	1361.607	1361.607	618.31	577.09	618.31	4.217	4.217	106.60	717.35	3025.2
2	4	15.56100	0.0	0.0	1385.635	1385.635	618.25	581.59	618.25	4.306	4.306	106.46	705.47	3037.4
2	5	15.55501	0.0	0.0	1410.607	1410.607	618.22	586.05	618.22	4.402	4.402	106.39	695.61	3061.7
2	6	15.54893	0.0	0.0	1443.262	1443.262	618.19	591.39	618.19	4.514	4.514	106.31	683.82	3087.0
2	7	15.53713	0.0	0.0	1472.921	1472.921	618.13	596.29	618.13	4.614	4.614	106.17	670.03	3091.7
2	8	15.53097	0.0	0.0	1497.365	1497.365	618.09	600.46	618.09	4.724	4.724	106.09	659.25	3114.5
2	9	15.52472	0.0	0.0	1523.120	1523.120	618.06	603.89	618.06	4.825	4.825	106.02	648.46	3129.1
2	10	15.51227	0.0	0.0	1541.004	1541.004	618.00	606.73	618.00	4.888	4.888	105.86	637.62	3116.9
2	11	15.50610	0.0	0.0	1546.498	1546.498	617.97	607.43	617.96	4.919	4.919	105.79	633.65	3116.7
2	12	15.50000	0.0		1546.498	1546.525	617.97	607.43	617.93			105.64	633.61	
3	1	15.58385	0.0	0.0	1337.111	1337.111	573.00	573.00	618.37	4.085	4.085	132.96	726.97	2969.7
3	2	15.57816	0.0	0.0	1346.681	1346.681	618.34	574.78	618.34	4.148	4.148	106.68	723.46	3000.8
3	3	15.57231	0.0	0.0	1362.953	1362.953	618.31	577.80	618.31	4.238	4.238	106.60	714.38	3027.2
3	4	15.56110	0.0	0.0	1389.243	1389.243	618.25	582.59	618.25	4.338	4.338	106.47	703.50	3052.1
3	5	15.55516	0.0	0.0	1427.347	1427.347	618.22	588.75	618.22	4.449	4.449	106.39	688.72	3063.9
3	6	15.54913	0.0	0.0	1462.310	1462.310	618.19	594.84	618.19	4.563	4.563	106.32	674.99	3080.1
3	7	15.53728	0.0	0.0	1500.452	1500.452	618.13	600.93	618.13	4.693	4.679	106.17	657.31	3075.6
3	8	15.53113	0.0021	0.03	1535.863	1536.507	618.10	605.76	618.10	4.830	4.799	106.10	641.64	3073.9
3	9	15.52488	0.0052	0.09	1562.732	1561.819	618.06	609.34	618.06	4.960	4.907	106.02	627.92	3067.8
3	10	15.51238	0.0028	0.05	1576.579	1576.089	618.00	611.16	618.00	4.998	4.975	105.87	620.02	3077.2
3	11	15.50617	0.0004	0.01	1584.644	1584.579	617.96	612.18	617.97	5.035	5.026	105.79	617.09	3100.3
3	12	15.50000	0.0004		1584.644	1584.613	617.96	612.18	617.93			105.64	617.05	
4	1	15.58381	0.0	0.0	1337.111	1337.111	573.00	573.00	618.37	4.085	4.085	132.96	726.97	2969.7
4	2	15.57812	0.0	0.0	1345.115	1345.115	618.34	574.49	618.34	4.139	4.139	106.68	724.03	2997.0
4	3	15.57230	0.0	0.0	1362.395	1362.395	618.31	577.38	618.31	4.229	4.229	106.60	716.36	3029.3
4	4	15.56110	0.0	0.0	1384.834	1384.834	618.25	581.66	618.25	4.330	4.330	106.47	706.47	3058.7
4	5	15.55514	0.0	0.0	1410.099	1410.099	618.22	585.97	618.22	4.423	4.423	106.39	695.61	3076.3
4	6	15.54911	0.0	0.0	1440.180	1440.180	618.19	590.95	618.19	4.521	4.521	106.32	684.80	3095.9
4	7	15.53726	0.0	0.0	1469.827	1469.827	618.13	596.09	618.13	4.630	4.630	106.17	671.02	3106.6
4	8	15.53112	0.0000	0.00	1501.512	1501.512	618.10	600.73	618.10	4.743	4.743	106.10	657.27	3117.2
4	9	15.52498	0.0000	0.00	1520.859	1520.860	618.06	603.81	618.06	4.836	4.835	106.02	647.46	3130.6
4	10	15.51238	0.0000	0.00	1534.351	1534.352	618.00	605.82	618.00	4.889	4.889	105.87	639.55	3126.7

4	11	15.50620	0.0000	0.00	1544.857	1544.857	617.97	606.84	617.97	4.934	4.934	105.79	637.60	3145.8
4	12	15.50000	0.0000		1544.857	1544.885	617.97	606.88	617.93			105.64	637.57	
5	1	15.58392	0.0	0.0	1337.111	1337.111	573.00	573.00	618.37	4.085	4.085	132.96	726.97	2969.7
5	2	15.57812	0.0	0.0	1345.101	1345.101	618.34	574.49	618.34	4.138	4.138	106.68	724.04	2996.2
5	3	15.57224	0.0	0.0	1363.696	1363.696	618.31	577.97	618.31	4.224	4.224	106.60	715.37	3021.6
5	4	15.56093	0.0	0.0	1383.312	1383.312	618.25	581.29	618.25	4.310	4.310	106.46	706.46	3044.6
5	5	15.55501	0.0	0.0	1413.189	1413.189	618.22	586.29	618.22	4.399	4.399	106.39	694.62	3055.8
5	6	15.54898	0.0	0.0	1441.219	1441.219	618.19	591.29	618.19	4.503	4.503	106.31	683.81	3079.3
5	7	15.53710	0.0	0.0	1473.742	1473.742	618.13	596.56	618.13	4.612	4.612	106.17	668.04	3080.9
5	8	15.53093	0.0000	0.00	1498.700	1498.700	618.09	600.19	618.09	4.725	4.725	106.09	658.23	3110.2
5	9	15.52471	0.0000	0.00	1517.021	1517.021	618.06	603.35	618.06	4.814	4.814	106.02	648.42	3121.7
5	10	15.51227	0.0	0.0	1532.482	1532.482	618.00	605.42	618.00	4.873	4.873	105.86	642.52	3131.3
5	11	15.50607	0.0	0.0	1540.547	1540.547	617.97	606.41	617.96	4.902	4.902	105.79	637.56	3125.4
5	12	15.50000	0.0		1540.547	1540.574	617.97	606.41	617.93			105.64	637.53	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	-6.350E-03	-6.350E-03	-4.830E-02	-4.830E-02	2	4	2.187E-02	2.187E-02	0.0	0.0
3	-1.056E-02	-1.056E-02	-4.815E-02	-4.815E-02	3	4	2.393E-02	2.393E-02	0.0	0.0
3	-1.305E-02	-1.305E-02	-5.108E-02	-5.108E-02	4	4	2.237E-02	2.237E-02	0.0	0.0
3	-2.589E-02	-2.589E-02	-6.058E-02	-6.058E-02	5	4	2.820E-02	2.820E-02	0.0	0.0
3	-2.823E-02	-2.823E-02	-7.459E-02	-7.459E-02	6	4	2.066E-02	2.066E-02	0.0	0.0
3	-3.728E-02	-3.728E-02	-7.819E-02	-7.819E-02	7	4	1.099E-02	1.099E-02	0.0	0.0
3	-4.329E-02	-3.971E-02	-8.656E-02	-8.144E-02	8	4	6.613E-03	6.469E-03	0.0	0.0
3	-4.251E-02	-3.728E-02	-7.281E-02	-6.341E-02	9	4	4.492E-03	5.103E-03	0.0	0.0
3	-2.808E-02	-2.424E-02	-3.789E-02	-3.360E-02	10	4	7.894E-03	7.911E-03	0.0	0.0
3	-1.766E-02	-1.720E-02	-3.346E-02	-3.240E-02	11	4	-2.703E-03	-2.416E-03	0.0	0.0
5	0.0	0.0	6.007E-03	6.007E-03	2					
5	0.0	0.0	7.878E-03	7.669E-03	3					
5	0.0	0.0	2.172E-02	2.172E-02	4					
5	0.0	0.0	3.121E-02	3.121E-02	5					
5	0.0	0.0	2.903E-02	2.903E-02	6					
5	0.0	0.0	3.492E-02	3.492E-02	7					
5	0.0	0.0	4.996E-02	4.648E-02	8					
5	0.0	0.0	5.139E-02	4.582E-02	9					
5	0.0	0.0	3.039E-02	2.723E-02	10					
5	0.0	0.0	2.258E-02	2.194E-02	11					

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	1	219684.	99.0000	860.7	836.7	764.8	644.8	593.8	581.2
1	2	1	436814.	99.0000	1149.3	1101.4	957.5	717.5	615.6	590.6
1	3	1	656968.	99.0000	1439.4	1367.4	1151.6	791.6	638.5	600.9
1	4	1	769647.	99.0000	1587.2	1503.2	1251.4	831.5	652.7	608.7

1	5	1	[illegible]1216.	99.0000	1735.4	1639.5	1351.7	871.7	667.2	616.9
1	6	1	881695.	99.0000	1739.9	1644.0	1356.2	876.3	671.9	621.5
1	7	3	781723.	2.9059	1601.0	1517.1	1265.3	845.2	666.0	621.7
1	8	3	664352.	3.4758	1460.6	1388.6	1172.8	812.8	659.4	621.5
1	9	1	443750.	99.0000	1177.7	1129.7	985.8	745.7	643.1	617.8
1	10	1	226490.	99.0000	892.5	868.5	796.6	676.6	625.4	612.7
2	1	1	219751.	99.0000	860.7	836.7	764.8	644.8	593.8	581.2
2	2	1	441722.	99.0000	1149.2	1101.2	957.4	717.4	615.5	590.3
2	3	1	658337.	99.0000	1439.5	1367.5	1151.7	791.8	638.8	601.1
2	4	1	775814.	99.0000	1587.6	1503.6	1251.8	831.8	653.0	608.8
2	5	1	885565.	99.0000	1735.4	1639.4	1351.7	871.7	667.5	617.1
2	6	1	885516.	99.0000	1740.3	1644.4	1356.6	876.6	672.1	621.7
2	7	1	778002.	99.0000	1601.4	1517.4	1265.6	845.6	666.7	622.4
2	8	1	667134.	99.0000	1460.9	1389.0	1173.2	813.3	660.4	622.5
2	9	1	441301.	99.0000	1178.0	1130.0	986.1	746.2	644.1	618.9
2	10	1	223453.	99.0000	893.0	869.0	797.1	677.2	626.2	613.6
3	1	1	263741.	99.0000	918.2	869.4	803.1	659.1	597.9	582.9
3	2	1	532531.	99.0000	1264.9	1207.4	1034.7	746.7	624.0	593.7
3	3	1	799734.	99.0000	1612.9	1526.6	1267.6	835.6	651.6	606.2
3	4	1	925562.	99.0000	1790.0	1689.3	1387.1	883.2	668.7	615.8
3	5	1	1062321.	99.0000	1968.0	1852.9	1507.6	931.5	686.2	625.6
3	6	1	1060514.	99.0000	1973.3	1858.2	1512.9	936.9	691.6	631.1
3	7	3	926900.	2.5099	1801.4	1700.7	1398.6	894.6	680.1	627.2
3	8	3	796867.	2.9210	1633.3	1546.9	1287.9	856.0	672.1	626.8
3	9	3	532537.	4.3557	1295.0	1237.5	1064.8	776.8	654.0	623.6
3	10	3	271596.	8.6802	955.4	926.6	840.3	696.2	634.6	619.3
4	1	1	219730.	99.0000	860.7	836.7	764.8	644.8	593.8	581.2
4	2	1	442105.	99.0000	1149.6	1101.7	957.8	717.8	615.8	590.6
4	3	1	657038.	99.0000	1439.6	1367.7	1151.9	791.9	638.8	601.1
4	4	1	774178.	99.0000	1587.6	1503.6	1251.8	831.8	652.9	608.7
4	5	1	889272.	99.0000	1735.8	1639.9	1352.1	872.1	667.4	616.8
4	6	1	887165.	99.0000	1739.8	1643.9	1356.1	876.2	672.0	621.5
4	7	3	770027.	3.0019	1600.2	1516.3	1264.5	844.6	666.0	622.0
4	8	3	664335.	3.4841	1460.7	1388.8	1173.0	813.0	659.6	621.7
4	9	3	446338.	5.1523	1178.2	1130.3	986.4	746.3	643.6	618.1
4	10	1	225153.	99.0000	893.0	869.1	797.1	677.1	625.8	613.1
5	1	1	219753.	99.0000	860.7	836.7	764.8	644.8	593.8	581.2
5	2	1	439335.	99.0000	1149.8	1101.8	958.0	718.0	615.9	590.8
5	3	1	662063.	99.0000	1439.6	1367.6	1151.8	791.8	638.7	600.9
5	4	1	767651.	99.0000	1587.1	1503.2	1251.4	831.4	652.8	608.8
5	5	1	880651.	99.0000	1735.2	1639.3	1351.6	871.6	667.2	616.9
5	6	1	877178.	99.0000	1739.8	1643.9	1356.2	876.2	672.0	621.7
5	7	3	776905.	2.9962	1600.9	1517.0	1265.2	845.1	666.0	621.7
5	8	1	660811.	99.0000	1461.3	1389.4	1173.5	813.4	659.7	621.8
5	9	1	448210.	99.0000	1178.0	1130.0	986.1	746.0	643.3	617.8
5	10	1	226496.	99.0000	892.6	868.6	796.7	676.7	625.4	612.6

TIME STEP NO = 129 TIME = 6.449916 SEC TIME STEP SIZE = 0.50000E-01 SEC CPU TIME = 7.37 SEC
NUMBER OF NEWTON ITERATIONS = 5
NUMBER OF INNER ITERATIONS = 18 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 108163.667 KW
TOTAL HEAT TRANSFER = 88908.937 KW
FLUID ENERGY RISE = 116711.875 KW

INLET FLOW RATE = 372.208 KG/S
OUTLET FLOW RATE = 394.999 KG/S

MAXIMUM TEMPERATURES		IR	IZ
WALL:	632.00 AT	3	6
ROD:	1980.00 AT	3	6
MIN CHFR =	2.490 AT	3	7

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	15.58084	0.0	0.0	1337.114	1337.114	573.00	573.00	618.35	3.913	3.913	132.89	726.96	2844.6
1	2	15.57538	0.0	0.0	1345.499	1345.499	618.33	574.56	618.33	3.954	3.954	106.64	723.88	2862.1
1	3	15.56946	0.0	0.0	1360.896	1360.896	618.30	577.30	618.30	4.010	4.010	106.57	715.35	2868.3
1	4	15.55869	0.0	0.0	1388.466	1388.466	618.24	582.11	618.24	4.083	4.083	106.43	704.48	2876.1
1	5	15.55271	0.0	0.0	1412.139	1412.139	618.21	586.26	618.21	4.165	4.165	106.36	695.61	2897.4
1	6	15.54664	0.0	0.0	1447.163	1447.163	618.18	592.21	618.18	4.257	4.257	106.28	680.85	2898.4
1	7	15.53521	0.0	0.0	1480.655	1480.655	618.12	597.70	618.12	4.351	4.351	106.14	666.10	2898.4
1	8	15.52901	0.0	0.0	1502.290	1502.290	618.09	601.18	618.08	4.447	4.447	106.07	656.29	2918.8
1	9	15.52280	0.0	0.0	1524.193	1524.193	618.06	604.30	618.05	4.545	4.545	105.99	646.48	2938.5
1	10	15.51092	0.0	0.0	1539.989	1539.989	617.99	606.26	617.99	4.591	4.591	105.84	638.58	2932.0
1	11	15.50517	0.0	0.0	1539.763	1539.763	617.96	606.64	617.96	4.624	4.624	105.77	637.58	2948.2
1	12	15.50000	0.0		1539.763	1539.786	617.96	606.64	617.93			105.65	637.55	
2	1	15.58128	0.0	0.0	1337.114	1337.114	573.00	573.00	618.36	3.913	3.913	132.90	726.96	2844.7
2	2	15.57581	0.0	0.0	1345.504	1345.504	618.33	574.56	618.33	3.956	3.956	106.65	723.88	2864.0
2	3	15.56995	0.0	0.0	1364.752	1364.752	618.30	577.72	618.30	4.028	4.028	106.57	714.37	2877.5
2	4	15.55919	0.0	0.0	1386.871	1386.871	618.24	582.01	618.24	4.109	4.109	106.44	706.48	2903.0
2	5	15.55332	0.0	0.0	1418.853	1418.853	618.21	587.06	618.21	4.203	4.203	106.37	692.65	2911.5
2	6	15.54734	0.0	0.0	1444.614	1444.614	618.18	591.97	618.18	4.311	4.311	106.29	680.84	2934.9
2	7	15.53592	0.0	0.0	1480.339	1480.339	618.12	597.52	618.12	4.428	4.428	106.15	668.09	2958.4
2	8	15.52975	0.0	0.0	1505.378	1505.378	618.09	601.41	618.09	4.532	4.532	106.08	655.31	2970.1
2	9	15.52359	0.0	0.0	1526.226	1526.226	618.06	604.43	618.06	4.641	4.641	106.00	646.50	3000.4
2	10	15.51159	0.0	0.0	1539.665	1539.665	618.00	606.57	617.99	4.711	4.711	105.85	639.60	3013.0
2	11	15.50565	0.0	0.0	1548.755	1548.755	617.96	607.54	617.96	4.757	4.757	105.78	634.65	3018.9
2	12	15.50000	0.0		1548.755	1548.780	617.96	607.54	617.93			105.65	634.62	
3	1	15.58167	0.0	0.0	1337.113	1337.113	573.00	573.00	618.36	3.913	3.913	132.91	726.96	2844.7
3	2	15.57620	0.0	0.0	1347.213	1347.213	618.33	574.88	618.33	3.994	3.994	106.65	723.26	2888.9
3	3	15.57052	0.0	0.0	1366.491	1366.491	618.30	578.32	618.30	4.094	4.094	106.58	715.39	2929.1
3	4	15.55964	0.0	0.0	1395.958	1395.958	618.24	583.50	618.24	4.206	4.206	106.45	700.53	2946.3
3	5	15.55405	0.0	0.0	1431.439	1431.439	618.21	589.52	618.22	4.328	4.328	106.38	687.75	2976.7
3	6	15.54816	0.0	0.0	1463.363	1463.363	618.18	594.97	618.18	4.448	4.448	106.31	673.99	2998.0
3	7	15.53675	0.0	0.0	1501.982	1501.982	618.12	601.03	618.12	4.615	4.599	106.17	657.31	3022.8
3	8	15.53063	0.0028	0.05	1539.862	1539.368	618.09	606.13	618.09	4.761	4.725	106.09	639.66	3015.2
3	9	15.52444	0.0068	0.12	1566.550	1565.394	618.06	609.83	618.06	4.898	4.831	106.02	626.96	3011.6
3	10	15.51229	0.0061	0.11	1584.628	1583.565	618.00	612.18	618.00	4.949	4.915	105.87	616.12	3013.0
3	11	15.50613	0.0012	0.02	1596.698	1596.475	617.96	613.65	617.96	4.989	4.969	105.79	610.24	3029.2
3	12	15.50000	0.0012		1596.668	1596.511	617.96	613.65	617.93			105.65	610.21	
4	1	15.58161	0.0	0.0	1337.113	1337.113	573.00	573.00	618.36	3.913	3.913	132.91	726.96	2844.7
4	2	15.57614	0.0	0.0	1345.527	1345.527	618.33	574.56	618.33	3.980	3.980	106.65	723.88	2881.3
4	3	15.57051	0.0	0.0	1361.920	1361.920	618.30	577.27	618.30	4.082	4.082	106.58	715.36	2920.4
4	4	15.55933	0.0	0.0	1385.601	1385.601	618.25	581.73	618.24	4.192	4.192	106.45	706.47	2961.7
4	5	15.55403	0.0	0.0	1416.234	1416.234	618.21	586.92	618.22	4.302	4.302	106.38	694.64	2988.0
4	6	15.54816	0.0	0.0	1447.952	1447.952	618.18	592.35	618.18	4.418	4.418	106.31	679.86	3003.4
4	7.	15.53672	0.0	0.0	1475.539	1475.539	618.12	597.05	618.12	4.555	4.555	106.17	667.07	3038.7
4	8	15.53061	0.0000	0.00	1504.336	1504.337	618.09	601.12	618.09	4.673	4.673	106.09	656.29	3066.7
4	9	15.52443	0.0000	0.00	1521.624	1521.624	618.06	603.88	618.06	4.759	4.759	106.01	647.46	3081.5
4	10	15.51225	0.0	0.0	1538.701	1538.701	618.00	606.30	618.00	4.826	4.826	105.86	638.59	3082.1

4	11	15.50510	0.0	0.0	1549.306	1549.306	617.96	607.51	617.96	4.859	4.859	105.79	633.65	3078.6
4	12	15.50000	0.0		1549.336	1549.334	617.96	607.51	617.93			105.64	633.62	
5	1	15.58123	0.0	0.0	1337.114	1337.114	573.00	573.00	618.36	3.913	3.913	132.90	726.96	2844.7
5	2	15.57582	0.0	0.0	1345.506	1345.506	618.33	574.56	618.33	3.955	3.955	106.65	723.88	2862.7
5	3	15.56336	0.0	0.0	1362.166	1362.166	618.30	577.58	618.30	4.026	4.026	106.57	715.36	2880.2
5	4	15.55922	0.0	0.0	1389.996	1289.996	618.24	582.23	618.24	4.116	4.116	106.44	704.48	2899.4
5	5	15.55333	0.0	0.0	1417.256	1417.256	618.21	587.01	618.21	4.213	4.213	106.37	694.64	2926.3
5	6	15.54735	0.0	0.0	1444.841	1444.841	618.18	591.90	618.18	4.318	4.318	106.29	681.84	2943.9
5	7	15.53523	0.0	0.0	1476.025	1476.025	618.12	596.95	618.12	4.434	4.434	106.15	668.06	2961.9
5	8	15.52979	0.0	0.0	1500.714	1500.714	618.09	600.72	618.09	4.539	4.539	106.08	658.26	2987.5
5	9	15.52360	0.0	0.0	1525.194	1525.194	618.06	604.08	618.06	4.633	4.633	106.00	647.47	2999.5
5	10	15.51162	0.0	0.0	1541.183	1541.183	618.00	606.35	617.99	4.700	4.700	105.85	640.59	3011.1
5	11	15.50562	0.0	0.0	1542.299	1542.299	617.96	606.89	617.96	4.735	4.735	105.78	637.60	3019.2
5	12	15.50000	0.0		1542.299	1542.324	617.96	606.89	617.93			105.65	637.57	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	-8.478E-02	-8.478E-02	-1.972E-01	-1.972E-01	2	4	3.154E-02	3.154E-02	0.0	0.0
3	-9.930E-02	-9.930E-02	-2.263E-01	-2.263E-01	3	4	3.103E-02	3.103E-02	0.0	0.0
3	-1.111E-01	-1.111E-01	-2.283E-01	-2.283E-01	4	4	3.075E-02	3.075E-02	0.0	0.0
3	-1.271E-01	-1.271E-01	-2.504E-01	-2.504E-01	5	4	2.641E-02	2.641E-02	0.0	0.0
3	-1.456E-01	-1.456E-01	-2.781E-01	-2.781E-01	6	4	1.108E-02	1.108E-02	0.0	0.0
3	-1.433E-01	-1.433E-01	-2.686E-01	-2.686E-01	7	4	2.161E-02	2.161E-02	0.0	0.0
3	-1.656E-01	-1.565E-01	-2.984E-01	-2.852E-01	8	4	2.282E-02	2.186E-02	0.0	0.0
3	-1.732E-01	-1.576E-01	-3.281E-01	-3.017E-01	9	4	1.766E-02	1.719E-02	0.0	0.0
3	-1.452E-01	-1.316E-01	-2.629E-01	-2.460E-01	10	4	1.355E-02	1.195E-02	0.0	0.0
3	-9.153E-02	-8.671E-02	-1.695E-01	-1.622E-01	11	4	4.468E-03	3.937E-03	0.0	0.0
5	0.0	0.0	8.374E-02	8.374E-02	2					
5	0.0	0.0	9.660E-02	9.666E-02	3					
5	0.0	0.0	1.052E-01	1.052E-01	4					
5	0.0	0.0	1.265E-01	1.265E-01	5					
5	0.0	0.0	1.496E-01	1.496E-01	6					
5	0.0	0.0	1.494E-01	1.494E-01	7					
5	0.0	0.0	1.656E-01	1.563E-01	8					
5	0.0	0.0	1.745E-01	1.590E-01	9					
5	0.0	0.0	1.294E-01	1.194E-01	10					
5	0.0	0.0	8.986E-02	8.495E-02	11					

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	1	221562.	99.0000	862.1	838.1	766.1	645.9	594.3	581.6
1	2	1	446018.	99.0000	1152.1	1104.1	960.2	719.8	616.5	591.1
1	3	1	660473.	99.0000	1443.5	1371.6	1155.7	795.0	640.2	602.3
1	4	1	780524.	99.0000	1592.0	1508.1	1256.2	835.3	654.4	609.9

1	5	1	687383.	99.0000	1741.0	1645.0	1357.2	876.0	659.5	618.7
1	6	1	879428.	99.0000	1745.5	1649.6	1361.7	880.6	674.2	623.6
1	7	1	773543.	99.0000	1605.9	1521.9	1270.1	848.9	669.0	623.6
1	8	1	661607.	99.0000	1464.7	1392.8	1176.9	816.0	661.1	623.2
1	9	1	441393.	99.0000	1180.5	1132.5	988.5	747.7	644.1	618.7
1	10	1	224993.	99.0000	893.9	869.9	798.0	677.6	625.7	612.9
2	1	1	221700.	99.0000	862.1	838.1	766.1	645.9	594.3	581.6
2	2	1	440937.	99.0000	1152.0	1104.0	960.1	719.7	616.6	591.3
2	3	1	603722.	99.0000	1443.7	1371.7	1155.8	795.1	640.3	602.3
2	4	1	775499.	99.0000	1592.4	1508.5	1256.6	835.6	654.9	610.5
2	5	1	892615.	99.0000	1740.9	1645.0	1357.1	876.1	669.4	618.5
2	6	1	886522.	99.0000	1745.9	1649.9	1362.1	880.9	674.3	623.5
2	7	1	775834.	99.0000	1606.2	1522.3	1270.4	849.3	668.3	623.8
2	8	1	665913.	99.0000	1465.1	1393.2	1177.3	816.5	661.4	623.3
2	9	1	443069.	99.0000	1180.8	1132.8	988.9	748.2	644.5	619.0
2	10	1	223275.	99.0000	894.4	870.4	798.5	678.3	626.5	613.7
3	1	1	266032.	99.0000	919.9	891.1	804.7	660.5	599.5	583.3
3	2	1	534142.	99.0000	1268.2	1210.7	1038.0	749.3	625.2	594.7
3	3	1	798136.	99.0000	1617.9	1531.6	1272.5	839.4	653.4	607.7
3	4	1	925871.	99.0000	1795.8	1695.1	1392.8	887.6	670.4	617.2
3	5	1	1072219.	99.0000	1974.7	1859.5	1514.1	936.5	687.8	626.8
3	6	1	1070466.	99.0000	1980.0	1864.9	1519.4	941.8	693.2	632.0
3	7	3	939677.	2.4698	1807.3	1706.5	1404.3	898.9	681.3	627.6
3	8	3	806761.	2.9105	1638.3	1551.9	1292.9	859.7	673.2	627.2
3	9	3	539084.	4.3765	1298.4	1240.8	1008.1	779.3	655.0	624.3
3	10	3	259322.	8.8872	957.1	928.3	841.9	697.4	635.5	620.4
4	1	1	221701.	99.0000	862.1	838.1	766.1	645.9	594.3	581.6
4	2	1	443714.	99.0000	1152.4	1104.4	960.5	720.0	616.6	591.1
4	3	1	668573.	99.0000	1443.8	1371.8	1156.0	795.2	640.2	602.0
4	4	1	774908.	99.0000	1592.4	1508.5	1256.6	835.5	654.6	610.2
4	5	1	885548.	99.0000	1741.4	1645.5	1357.6	876.3	669.4	618.5
4	6	1	887130.	99.0000	1745.4	1649.4	1361.6	880.5	673.7	622.9
4	7	3	776341.	3.0001	1605.1	1521.2	1269.3	848.3	667.2	622.6
4	8	1	664824.	99.0000	1464.9	1393.0	1177.1	816.1	660.8	622.7
4	9	1	449371.	99.0000	1181.0	1133.1	939.1	748.2	644.4	618.9
4	10	1	220915.	99.0000	894.4	870.4	798.5	678.1	626.3	613.6
5	1	1	221638.	99.0000	862.1	838.1	766.1	645.9	594.3	581.6
5	2	1	445485.	99.0000	1152.6	1104.6	960.7	720.2	616.8	591.3
5	3	1	661476.	99.0000	1443.7	1371.8	1155.9	795.1	640.4	602.4
5	4	1	773356.	99.0000	1592.0	1508.0	1256.2	835.3	654.7	610.3
5	5	1	886128.	99.0000	1740.8	1644.9	1357.0	875.8	669.1	618.3
5	6	1	885769.	99.0000	1745.4	1649.5	1361.6	880.5	673.7	622.9
5	7	1	781347.	99.0000	1605.8	1521.9	1270.0	848.8	667.8	623.3
5	8	1	664765.	99.0000	1465.5	1393.5	1177.6	816.4	661.1	623.0
5	9	1	440987.	99.0000	1180.8	1132.8	988.8	747.9	644.1	618.7
5	10	1	220037.	99.0000	894.0	870.0	798.1	677.6	625.7	613.0

TIME STEP NO = 133 TIME = 6.649913 SEC TIME STEP SIZE = 0.50000E-01 SEC CPU TIME = 11.22 SEC
NUMBER OF NEWTON ITERATIONS = 5
NUMBER OF INNER ITERATIONS = 20 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 116993.562 KW INLET FLOW RATE = 355.845 KG/S
TOTAL HEAT TRANSFER = 90429.062 KW OUTLET FLOW RATE = 377.680 KG/S
FLUID ENERGY RISE = 113305.812 KW

MAXIMUM TEMPERATURES			IR	IZ
WALL:	629.24	AT	3	5
ROD:	1990.23	AT	3	6
MIN CHFR =	2.194	AT	3	6

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HV (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	15.57769	0.0	0.0	1337.118	1337.118	573.00	573.00	618.34	3.741	3.741	132.81	726.95	2719.6
1	2	15.57244	0.0	0.0	1345.964	1345.964	618.32	574.65	618.31	3.706	3.706	106.59	723.71	2681.7
1	3	15.56308	0.0	0.0	1363.754	1363.754	618.28	578.00	618.28	3.720	3.720	106.51	713.37	2653.8
1	4	15.55563	0.0	0.0	1390.514	1390.514	618.23	582.24	618.22	3.754	3.754	106.39	704.47	2644.4
1	5	15.54972	0.0	0.0	1416.028	1416.028	618.20	586.74	618.19	3.820	3.820	106.31	693.62	2649.9
1	6	15.54087	0.0	0.0	1449.208	1449.208	618.17	592.39	618.16	3.950	3.950	106.24	680.85	2689.5
1	7	15.53311	0.0	0.0	1484.229	1484.229	618.11	597.95	618.11	4.044	4.044	106.11	666.10	2693.5
1	8	15.52701	0.0	0.0	1507.975	1507.975	618.03	602.00	618.07	4.145	4.145	106.04	653.34	2708.4
1	9	15.52104	0.0	0.0	1532.459	1532.459	618.05	605.27	618.04	4.260	4.260	105.96	642.55	2737.6
1	10	15.50990	0.0	0.0	1547.474	1547.474	617.99	607.34	617.98	4.313	4.313	105.83	634.66	2737.0
1	11	15.50443	0.0	0.0	1552.663	1552.663	617.96	608.13	617.96	4.330	4.330	105.76	631.70	2735.4
1	12	15.50000	0.0		1552.663	1552.683	617.96	608.13	617.93			105.66	631.67	
2	1	15.57859	0.0	0.0	1337.117	1337.117	573.00	573.00	618.34	3.741	3.741	132.84	726.96	2719.6
2	2	15.57335	0.0	0.0	1345.984	1345.984	618.32	574.65	618.32	3.754	3.754	106.61	723.70	2716.5
2	3	15.56730	0.0	0.0	1363.246	1363.246	618.29	577.84	618.28	3.809	3.809	106.54	713.36	2716.9
2	4	15.55693	0.0	0.0	1387.417	1387.417	618.23	582.03	618.23	3.870	3.870	106.41	705.47	2730.3
2	5	15.55113	0.0	0.0	1417.793	1417.793	618.20	587.25	618.20	3.960	3.960	106.34	693.65	2747.1
2	6	15.54533	0.0	0.0	1453.644	1453.644	618.17	593.21	618.17	4.094	4.094	106.27	676.89	2771.0
2	7	15.53445	0.0	0.0	1482.947	1482.947	618.12	597.92	618.11	4.206	4.206	106.13	666.11	2802.0
2	8	15.52841	0.0	0.0	1511.089	1511.089	618.08	602.33	618.08	4.322	4.322	106.06	651.37	2815.5
2	9	15.52238	0.0	0.0	1534.229	1534.229	618.05	605.46	618.05	4.435	4.435	105.98	642.57	2849.7
2	10	15.51096	0.0	0.0	1544.881	1544.881	617.99	607.23	617.99	4.505	4.505	105.84	635.66	2863.7
2	11	15.50518	0.0	0.0	1552.140	1552.140	617.96	608.19	617.96	4.528	4.528	105.77	631.71	2860.6
2	12	15.50000	0.0		1552.140	1552.164	617.96	608.19	617.93			105.65	631.68	
3	1	15.57959	0.0	0.0	1337.116	1337.116	573.00	573.00	618.35	3.741	3.741	132.86	726.96	2719.6
3	2	15.57435	0.0	0.0	1347.871	1347.871	618.32	575.00	618.32	3.860	3.860	106.63	723.01	2791.2
3	3	15.56574	0.0	0.0	1370.893	1370.893	618.29	578.72	618.29	3.976	3.976	106.56	713.39	2836.8
3	4	15.55845	0.0	0.0	1397.679	1397.679	618.23	583.75	618.24	4.102	4.102	106.44	702.53	2881.6
3	5	15.55270	0.0	0.0	1434.040	1434.040	618.20	590.08	618.21	4.232	4.232	106.36	685.77	2902.3
3	6	15.54689	0.0	0.0	1474.465	1474.465	618.17	596.60	618.18	4.345	4.339	106.29	668.09	2898.5
3	7	15.53593	0.0020	0.03	1515.721	1515.374	618.12	602.82	618.12	4.526	4.498	106.16	651.43	2925.0
3	8	15.52989	0.0055	0.09	1549.578	1547.614	618.09	607.61	618.09	4.672	4.629	106.08	634.79	2924.8
3	9	15.52381	0.0094	0.16	1572.803	1571.147	618.05	610.60	618.06	4.799	4.724	106.01	622.03	2915.9
3	10	15.51210	0.0101	0.18	1592.491	1590.742	617.99	613.17	618.00	4.863	4.823	105.86	613.23	2932.9
3	11	15.50900	0.0025	0.04	1597.760	1597.321	617.96	614.06	617.96	4.897	4.867	105.79	607.29	2949.4
3	12	15.50000	0.0025		1597.760	1597.355	617.96	614.06	617.93			105.65	607.25	
4	1	15.57950	0.0	0.0	1337.116	1337.116	573.00	573.00	618.35	3.741	3.741	132.86	726.96	2719.6
4	2	15.57425	0.0	0.0	1346.039	1346.039	618.32	574.65	618.32	3.840	3.840	106.63	723.69	2778.9
4	3	15.56573	0.0	0.0	1362.706	1362.706	618.29	577.69	618.29	3.959	3.959	106.56	714.36	2828.0
4	4	15.55944	0.0	0.0	1386.653	1386.653	618.24	581.88	618.24	4.081	4.081	106.43	705.47	2879.1
4	5	15.55274	0.0	0.0	1415.534	1415.534	618.21	586.91	618.21	4.206	4.206	106.36	692.64	2913.3
4	6	15.54694	0.0	0.0	1449.449	1449.449	618.18	592.52	618.18	4.312	4.312	106.29	680.87	2936.1
4	7	15.53590	0.0000	0.00	1482.433	1482.434	618.12	597.88	618.12	4.463	4.462	106.16	666.11	2972.5
4	8	15.52989	0.0000	0.00	1510.468	1510.469	618.09	602.24	618.09	4.589	4.589	106.08	654.37	3002.8
4	9	15.52383	0.0000	0.00	1531.190	1531.190	618.06	605.44	618.06	4.666	4.666	106.01	641.58	2993.3
4	10	15.51207	0.0000	0.00	1546.953	1546.953	618.00	607.34	618.00	4.734	4.734	105.86	634.67	3004.2

4	11	15.50593	0.0000	0.00	1548.204	1548.204	617.96	607.53	617.96	4.750	4.750	105.79	635.65	3019.1
4	12	15.50000	0.0000		1548.204	1548.231	617.96	607.53	617.93			105.65	635.62	
5	1	15.57862	0.0	0.0	1337.117	1337.117	573.00	573.00	618.34	3.741	3.741	132.84	726.96	2719.6
5	2	15.57337	0.0	0.0	1345.991	1345.991	618.32	574.65	618.32	3.747	3.747	106.61	723.70	2712.0
5	3	15.56736	0.0	0.0	1364.976	1364.976	618.29	577.87	618.23	3.801	3.801	106.54	715.37	2719.0
5	4	15.55701	0.0	0.0	1393.109	1393.109	618.23	582.84	618.23	3.872	3.872	106.41	702.50	2719.9
5	5	15.55118	0.0	0.0	1420.166	1420.166	618.20	587.66	618.20	3.967	3.967	106.34	690.67	2740.0
5	6	15.54535	0.0	0.0	1450.212	1450.212	618.17	592.68	618.17	4.098	4.098	106.27	680.87	2790.0
5	7	15.53446	0.0	0.0	1480.117	1480.117	618.12	597.61	618.11	4.203	4.203	106.13	667.09	2803.9
5	8	15.52841	0.0	0.0	1509.739	1509.739	618.08	601.83	618.08	4.305	4.305	106.06	654.33	2817.0
5	9	15.52240	0.0	0.0	1528.583	1528.583	618.05	605.19	618.06	4.427	4.427	105.98	643.55	2848.7
5	10	15.51095	0.0	0.0	1541.931	1541.991	617.99	606.79	617.99	4.491	4.491	105.84	638.62	2868.0
5	11	15.50520	0.0	0.0	1547.498	1547.498	617.96	607.31	617.96	4.519	4.519	105.78	634.63	2867.9
5	12	15.50000	0.0		1547.498	1547.521	617.96	607.31	617.93			105.65	634.60	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	-1.740E-01	-1.740E-01	-3.146E-01	-3.146E-01	2	4	4.900E-02	4.900E-02	0.0	0.0
3	-2.028E-01	-2.028E-01	-3.774E-01	-3.774E-01	3	4	4.326E-02	4.326E-02	0.0	0.0
3	-2.206E-01	-2.206E-01	-4.063E-01	-4.063E-01	4	4	4.024E-02	4.024E-02	0.0	0.0
3	-2.332E-01	-2.332E-01	-4.375E-01	-4.375E-01	5	4	2.645E-02	2.645E-02	0.0	0.0
3	-2.477E-01	-2.477E-01	-4.692E-01	-4.692E-01	6	4	8.002E-03	8.002E-03	0.0	0.0
3	-2.393E-01	-2.329E-01	-4.309E-01	-4.243E-01	7	4	2.603E-02	2.426E-02	0.0	0.0
3	-2.546E-01	-2.398E-01	-4.657E-01	-4.435E-01	8	4	2.280E-02	2.252E-02	0.0	0.0
3	-2.763E-01	-2.504E-01	-5.081E-01	-4.627E-01	9	4	-3.390E-04	1.219E-03	0.0	0.0
3	-2.104E-01	-1.935E-01	-3.756E-01	-3.543E-01	10	4	1.077E-02	7.022E-03	0.0	0.0
3	-1.420E-01	-1.337E-01	-2.614E-01	-2.435E-01	11	4	1.482E-04	-1.885E-04	0.0	0.0
5	0.0	0.0	1.703E-01	1.705E-01	2					
5	0.0	0.0	1.912E-01	1.912E-01	3					
5	0.0	0.0	2.007E-01	2.007E-01	4					
5	0.0	0.0	2.224E-01	2.224E-01	5					
5	0.0	0.0	2.462E-01	2.482E-01	6					
5	0.0	0.0	2.444E-01	2.379E-01	7					
5	0.0	0.0	2.574E-01	2.419E-01	8					
5	0.0	0.0	2.658E-01	2.400E-01	9					
5	0.0	0.0	2.073E-01	1.929E-01	10					
5	0.0	0.0	1.343E-01	1.259E-01	11					

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	1	224798.	99.0000	864.2	840.2	768.2	647.4	594.9	582.1
1	2	1	446858.	99.0000	1156.4	1108.4	964.4	722.9	618.1	592.4
1	3	1	671911.	99.0000	1449.9	1377.9	1161.9	799.6	642.1	603.6
1	4	1	791924.	99.0000	1599.5	1515.5	1263.5	840.6	656.9	611.7

1	5	1	905335.	99.0000	1749.5	1653.5	1365.4	882.2	672.1	620.5
1	6	1	902722.	99.0000	1754.0	1659.1	1370.0	886.8	677.1	625.5
1	7	1	790187.	99.0000	1613.3	1529.4	1277.3	854.4	670.8	625.7
1	8	1	677267.	99.0000	1471.1	1399.2	1183.1	820.8	663.8	625.2
1	9	1	449275.	99.0000	1184.7	1136.7	992.7	750.8	646.0	620.4
1	10	1	220281.	99.0000	896.0	872.1	800.0	679.2	627.1	614.4
2	1	1	224972.	99.0000	864.2	840.2	768.2	647.4	594.9	582.0
2	2	1	449104.	99.0000	1156.2	1109.3	964.2	722.8	617.9	592.2
2	3	1	673509.	99.0000	1450.0	1378.1	1162.0	799.7	642.2	603.4
2	4	1	792375.	99.0000	1599.9	1515.9	1263.9	841.0	657.2	612.0
2	5	1	900060.	99.0000	1749.4	1653.5	1365.4	882.2	672.4	620.8
2	6	1	905659.	99.0000	1754.4	1658.4	1370.3	887.0	676.9	625.3
2	7	1	789485.	99.0000	1613.7	1529.7	1277.6	854.7	670.9	625.8
2	8	1	671944.	99.0000	1471.5	1399.5	1183.5	821.1	663.7	625.1
2	9	1	449994.	99.0000	1185.0	1137.0	993.0	751.1	646.0	620.2
2	10	1	219128.	99.0000	896.5	872.6	800.6	679.7	627.2	614.5
3	1	1	270087.	99.0000	922.4	893.6	807.2	662.3	599.3	583.8
3	2	1	541751.	99.0000	1273.4	1215.8	1042.9	752.9	626.8	595.8
3	3	1	813631.	99.0000	1625.6	1539.2	1279.9	844.8	655.5	609.0
3	4	1	945003.	99.0000	1804.8	1704.0	1401.5	893.9	673.2	619.0
3	5	1	1078331.	99.0000	1984.9	1869.7	1524.0	943.6	691.1	629.2
3	6	3	1103564.	2.1943	1990.2	1875.1	1529.3	948.2	692.4	629.1
3	7	3	949170.	2.4694	1816.2	1715.5	1412.9	904.9	683.1	628.6
3	8	3	820311.	2.8792	1645.9	1559.6	1300.3	864.8	674.6	627.8
3	9	3	541979.	4.3675	1303.5	1245.9	1073.0	782.7	656.2	625.1
3	10	3	272080.	8.9469	959.6	930.8	844.4	699.3	636.4	620.9
4	1	1	225012.	99.0000	864.2	840.2	768.2	647.4	594.9	582.0
4	2	1	449148.	99.0000	1156.7	1108.7	964.7	722.9	617.7	591.9
4	3	1	678101.	99.0000	1450.2	1378.2	1162.2	799.6	641.8	603.0
4	4	1	792832.	99.0000	1599.9	1515.9	1263.8	840.7	656.5	611.2
4	5	1	903611.	99.0000	1749.9	1654.0	1365.9	882.2	671.7	619.9
4	6	3	922714.	2.4632	1753.9	1657.9	1369.9	886.5	675.8	623.7
4	7	3	791875.	2.9834	1612.6	1528.6	1276.5	853.4	669.1	623.8
4	8	3	679498.	3.4583	1471.3	1399.3	1183.2	820.5	662.3	623.4
4	9	3	446424.	5.2351	1185.3	1137.3	993.2	751.1	645.6	619.9
4	10	1	225097.	99.0000	896.6	872.6	800.5	679.5	626.9	613.9
5	1	1	225002.	99.0000	864.2	840.2	768.2	647.4	594.9	582.1
5	2	1	450984.	99.0000	1156.8	1108.9	964.8	723.2	618.1	592.3
5	3	1	671530.	99.0000	1450.1	1378.2	1162.1	799.8	642.6	604.0
5	4	1	781510.	99.0000	1599.4	1515.5	1263.4	840.7	657.2	612.2
5	5	1	902408.	99.0000	1749.3	1653.4	1365.3	882.0	672.0	620.4
5	6	1	904299.	99.0000	1753.9	1658.0	1369.9	886.6	676.6	625.0
5	7	1	783955.	99.0000	1613.3	1529.3	1277.2	854.1	670.4	625.3
5	8	1	674854.	99.0000	1471.9	1399.9	1183.8	821.0	663.5	624.9
5	9	1	449524.	99.0000	1185.0	1137.0	992.9	750.9	645.6	619.8
5	10	1	225701.	99.0000	896.1	872.1	800.1	679.2	626.7	613.8

TIME STEP NO = 137 TIME = 6.849910 SEC TIME STEP SIZE = 0.50000E-01 SEC CPU TIME = 15.00 SEC
NUMBER OF NEWTON ITERATIONS = 5
NUMBER OF INNER ITERATIONS = 20 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 125823.437 KW INLET FLOW RATE = 339.482 KG/S
TOTAL HEAT TRANSFER = 92027.875 KW OUTLET FLOW RATE = 364.692 KG/S
FLUID ENERGY RISE = 118342.750 KW

MAXIMUM TEMPERATURES		IR	IZ
WALL:	631.93 AT	3	5
ROD:	2004.00 AT	3	6
MIN CHFR =	2.129 AT	3	6

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	15.57460	0.0	0.0	1337.122	1337.122	573.00	573.00	618.32	3.569	3.569	132.74	726.95	2594.5
1	2	15.56957	0.0	0.0	1346.531	1346.531	618.30	574.75	618.30	3.516	3.516	106.55	723.50	2543.9
1	3	15.56323	0.0	0.0	1365.003	1365.003	618.27	578.14	618.26	3.518	3.518	106.48	714.36	2513.5
1	4	15.55532	0.0	0.0	1391.547	1391.547	618.22	582.89	618.21	3.543	3.543	106.36	703.49	2492.4
1	5	15.54758	0.0	0.0	1422.965	1422.965	618.19	588.35	618.18	3.622	3.622	106.29	690.68	2501.4
1	6	15.54192	0.0	0.0	1455.698	1455.698	618.16	593.85	618.15	3.759	3.759	106.22	675.91	2541.0
1	7	15.53175	0.0	0.0	1489.965	1489.965	618.10	599.08	618.10	3.847	3.847	106.09	661.17	2543.6
1	8	15.52568	0.0	0.0	1519.507	1519.507	618.07	603.30	618.07	3.957	3.957	106.02	650.42	2573.6
1	9	15.52012	0.0	0.0	1537.362	1537.362	618.04	606.16	618.04	4.098	4.098	105.95	639.61	2621.2
1	10	15.50955	0.0	0.0	1551.337	1551.337	617.99	607.93	617.98	4.156	4.156	105.82	632.71	[illegible]
1	11	15.50426	0.0	0.0	1554.979	1554.979	617.96	608.40	617.96	4.174	4.174	105.76	630.72	2632.7
1	12	15.50000	0.0		1554.979	1555.000	617.96	608.40	617.93			105.66	630.70	
2	1	15.57562	0.0	0.0	1337.121	1337.121	573.00	573.00	618.33	3.569	3.569	132.76	726.95	2594.5
2	2	15.57059	0.0	0.0	1346.563	1346.563	618.30	574.76	618.30	3.577	3.577	106.58	723.49	2588.0
2	3	15.56466	0.0	0.0	1363.282	1365.282	618.27	578.09	618.27	3.630	3.630	106.50	714.37	2593.3
2	4	15.55462	0.0	0.0	1394.101	1394.101	618.22	582.99	618.22	3.695	3.695	106.38	703.50	2599.6
2	5	15.54918	0.0	0.0	1421.448	1421.448	618.19	587.90	618.19	3.789	3.789	106.31	690.67	2616.7
2	6	15.54355	0.0	0.0	1455.161	1455.161	618.16	593.63	618.16	3.924	3.924	106.24	676.91	2656.1
2	7	15.53323	0.0	0.0	1489.449	1489.449	618.11	599.07	618.11	4.047	4.047	106.12	661.17	2675.6
2	8	15.52737	0.0	0.0	1520.634	1520.634	618.08	603.77	618.08	4.169	4.169	106.05	646.46	2695.1
2	9	15.52158	0.0	0.0	1544.247	1544.247	618.05	607.21	618.05	4.300	4.300	105.98	637.71	2742.5
2	10	15.51070	0.0	0.0	1555.428	1555.428	617.99	608.75	617.99	4.381	4.381	105.84	630.79	2763.2
2	11	15.50508	0.0	0.0	1558.290	1558.290	617.96	608.96	617.96	4.408	4.408	105.77	629.77	2775.9
2	12	15.50000	0.0		1558.290	1553.314	617.96	608.96	617.93			105.65	629.74	
3	1	15.57679	0.0	0.0	1337.119	1337.119	573.00	573.00	618.33	3.569	3.569	132.79	726.95	2594.5
3	2	15.57176	0.0	0.0	1348.591	1348.591	618.30	575.13	618.31	3.709	3.709	106.60	722.75	2680.8
3	3	15.56631	0.0	0.0	1370.184	1370.184	618.27	578.88	618.28	3.833	3.833	106.53	711.39	2727.1
3	4	15.55652	0.0	0.0	1404.935	1404.935	618.22	584.74	618.23	3.974	3.974	106.41	698.56	2776.3
3	5	15.55093	0.0	0.0	1440.458	1440.458	618.19	591.06	618.20	4.115	4.115	106.34	683.81	2814.1
3	6	15.54529	0.0	0.0	1480.928	1480.928	618.17	598.03	618.17	4.232	4.219	106.27	664.16	2802.2
3	7	15.53484	0.0040	0.07	1522.012	1521.310	618.11	604.09	618.12	4.426	4.382	106.14	647.52	2828.0
3	8	15.52897	0.0107	0.18	1564.904	1563.025	618.08	609.48	618.08	4.577	4.509	106.07	628.95	2810.8
3	9	15.52309	0.0215	0.39	1595.496	1591.672	618.05	613.10	618.05	4.735	4.621	106.00	614.29	2788.3
3	10	15.51186	0.0254	0.46	1613.574	1609.090	617.99	615.21	618.00	4.774	4.708	105.86	603.46	2781.7
3	11	15.50593	0.0143	0.27	1617.996	1615.399	617.96	615.87	617.96	4.831	4.766	105.79	598.50	2617.7
3	12	15.50000	0.0148		1617.996	1615.436	617.96	615.87	617.93			105.65	598.46	
4	1	15.57668	0.0	0.0	1337.119	1337.119	573.00	573.00	618.33	3.569	3.569	132.79	726.95	2594.5
4	2	15.57165	0.0	0.0	1346.637	1346.637	618.31	574.77	618.31	3.685	3.685	106.60	723.46	2666.1
4	3	15.56630	0.0	0.0	1364.462	1364.462	618.28	577.94	618.28	3.816	3.816	106.53	715.37	2729.8
4	4	15.55662	0.0	0.0	1390.758	1390.758	618.23	582.51	618.23	3.952	3.952	106.41	704.49	2784.1
4	5	15.55097	0.0	0.0	1421.407	1421.407	618.20	588.00	618.20	4.086	4.086	106.34	691.68	2825.9
4	6	15.54533	0.0	0.0	1451.030	1451.030	618.17	592.97	618.17	4.196	4.195	106.27	678.88	2848.1
4	7	15.53481	0.0000	0.00	1487.307	1487.308	618.12	598.82	618.12	4.354	4.353	106.14	664.16	2891.4
4	8	15.52894	0.0000	0.00	1511.608	1511.607	618.08	602.71	618.08	4.471	4.471	106.07	650.39	2907.9
4	9	15.52309	0.0000	0.00	1539.637	1539.637	618.05	606.34	618.05	4.558	4.557	106.00	639.64	2914.8
4	10	15.51182	0.0000	0.00	1551.538	1551.538	617.99	608.01	618.00	4.634	4.634	105.86	633.73	2936.5

4	11	15.50503	0.0000	0.00	1560.050	1560.059	617.95	609.15	617.96	4.667	4.667	105.79	629.79	2939.2
4	12	15.50000	0.0000		1560.058	1560.088	617.93	609.15	617.93			105.65	629.76	
5	1	15.57536	0.0	0.0	1337.121	1337.121	573.00	573.00	618.33	3.569	3.569	132.77	726.95	2594.5
5	2	15.57063	0.0	0.0	1346.566	1346.566	618.30	574.76	618.30	3.571	3.571	106.58	723.49	2583.8
5	3	15.56470	0.0	0.0	1365.287	1365.287	618.27	578.12	618.27	3.630	3.630	106.51	713.37	2589.2
5	4	15.55485	0.0	0.0	1392.313	1392.313	618.22	582.87	618.22	3.704	3.704	106.38	703.49	2606.1
5	5	15.54921	0.0	0.0	1420.937	1420.937	618.19	587.87	618.19	3.794	3.794	106.31	690.67	2620.5
5	6	15.54302	0.0	0.0	1459.041	1459.041	618.16	594.09	618.16	3.935	3.935	106.24	674.93	2655.8
5	7	15.53326	0.0	0.0	1493.549	1493.549	618.11	599.52	618.11	4.050	4.050	106.12	660.20	2673.6
5	8	15.52742	0.0	0.0	1516.703	1516.703	618.08	603.08	618.08	4.160	4.160	106.04	650.41	2705.9
5	9	15.52159	0.0	0.0	1535.541	1535.541	618.05	605.90	618.05	4.283	4.283	105.98	640.61	2743.8
5	10	15.51069	0.0	0.0	1547.741	1547.741	617.99	607.60	617.99	4.355	4.355	105.84	633.68	2759.7
5	11	15.50507	0.0	0.0	1553.659	1553.659	617.96	608.39	617.96	4.386	4.386	105.77	631.72	2770.5
5	12	15.50000	0.0		1553.659	1553.682	617.96	608.39	617.93			105.65	631.70	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	-1.855E-01	-1.855E-01	-3.271E-01	-3.271E-01	2	4	5.904E-02	5.904E-02	0.0	0.0
3	-2.151E-01	-2.151E-01	-3.956E-01	-3.950E-01	3	4	5.039E-02	5.039E-02	0.0	0.0
3	-2.295E-01	-2.295E-01	-4.213E-01	-4.213E-01	4	4	4.365E-02	4.365E-02	0.0	0.0
3	-2.519E-01	-2.519E-01	-4.669E-01	-4.669E-01	5	4	2.686E-02	2.686E-02	0.0	0.0
3	-2.793E-01	-2.793E-01	-5.233E-01	-5.233E-01	6	4	5.226E-03	5.226E-03	0.0	0.0
3	-2.060E-01	-2.542E-01	-4.770E-01	-4.639E-01	7	4	3.115E-02	2.986E-02	0.0	0.0
3	-2.855E-01	-2.610E-01	-5.118E-01	-4.737E-01	8	4	3.953E-02	3.566E-02	0.0	0.0
3	-3.187E-01	-2.717E-01	-5.911E-01	-5.022E-01	9	4	9.826E-03	1.012E-02	0.0	0.0
3	-2.269E-01	-2.047E-01	-4.094E-01	-3.781E-01	10	4	1.496E-02	1.053E-02	0.0	0.0
3	-1.605E-01	-1.438E-01	-2.959E-01	-2.700E-01	11	4	-3.286E-03	-3.497E-03	0.0	0.0
5	0.0	0.0	1.813E-01	1.819E-01	2					
5	0.0	0.0	2.055E-01	2.055E-01	3					
5	0.0	0.0	2.245E-01	2.245E-01	4					
5	0.0	0.0	2.527E-01	2.527E-01	5					
5	0.0	0.0	2.715E-01	2.715E-01	6					
5	0.0	0.0	2.649E-01	2.522E-01	7					
5	0.0	0.0	2.856E-01	2.564E-01	8					
5	0.0	0.0	3.216E-01	2.693E-01	9					
5	0.0	0.0	2.251E-01	2.024E-01	10					
5	0.0	0.0	1.542E-01	1.378E-01	11					

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	1	229276.	99.0000	867.1	843.1	770.9	649.3	595.7	582.6
1	2	1	459307.	99.0000	1162.1	1114.1	969.9	726.7	619.7	593.5
1	3	1	688431.	99.0000	1458.5	1386.5	1170.2	805.4	645.0	605.7
1	4	1	797444.	99.0000	1609.5	1525.5	1273.1	847.4	660.4	614.6

1	5	1	91647[illegible].	99.0000	1761.0	[illegible]	1376.4	889.9	676.0	623.6
1	6	1	916560.	99.0000	1765.5	1669.5	1381.0	894.6	680.7	628.2
1	7	1	800614.	99.0000	1623.4	1539.4	1286.9	861.2	674.1	628.2
1	8	1	687778.	99.0000	1479.7	1407.7	1191.4	826.7	666.4	627.1
1	9	1	458379.	99.0000	1190.4	1142.4	998.1	754.8	647.9	621.6
1	10	1	230731.	99.0000	893.9	874.9	802.8	681.3	628.2	615.2
2	1	1	229329.	99.0000	867.1	843.1	770.9	649.3	595.7	582.6
2	2	1	458775.	99.0000	1162.0	1114.0	969.8	726.6	619.5	593.3
2	3	1	684167.	99.0000	1458.7	1386.7	1170.3	805.4	644.6	605.3
2	4	1	800439.	99.0000	1609.9	1525.9	1273.5	847.5	659.8	613.8
2	5	1	920345.	99.0000	1760.9	1664.9	1376.4	889.8	675.5	623.0
2	6	1	921650.	99.0000	1765.9	1669.8	1381.3	894.6	680.4	627.8
2	7	1	800016.	99.0000	1623.7	1539.7	1287.2	861.4	674.1	628.3
2	8	1	680587.	99.0000	1480.1	1408.1	1191.8	826.9	666.7	627.6
2	9	1	454002.	99.0000	1190.8	1142.8	998.5	755.1	648.2	622.1
2	10	1	226655.	99.0000	899.4	875.4	803.3	681.7	628.6	615.6
3	1	1	275120.	99.0000	925.9	897.1	810.5	664.5	600.2	584.4
3	2	1	551773.	99.0000	1280.2	1222.6	1049.5	757.3	628.4	596.8
3	3	1	826128.	99.0000	1635.9	1549.5	1289.8	851.6	658.5	611.1
3	4	1	962791.	99.0000	1816.8	1716.0	1413.0	901.8	676.5	621.3
3	5	1	1099380.	99.0000	1998.7	1883.4	1537.1	952.6	695.0	631.9
3	6	3	1131016.	2.1293	2004.0	1888.8	1542.3	955.6	694.2	629.7
3	7	3	976546.	2.4332	1828.3	1727.5	1424.4	912.2	685.3	629.5
3	8	3	837966.	2.8155	1656.3	1569.9	1310.1	871.1	676.7	628.9
3	9	3	552476.	4.2609	1310.4	1252.7	1079.6	787.0	657.9	626.2
3	10	3	266454.	8.8218	963.1	934.3	847.7	701.7	637.7	622.2
4	1	1	229242.	99.0000	867.1	843.1	770.9	649.3	595.7	582.5
4	2	1	457304.	99.0000	1162.4	1114.4	970.1	726.6	619.2	592.9
4	3	1	682554.	99.0000	1458.8	1386.8	1170.4	805.1	644.0	604.5
4	4	1	798464.	99.0000	1609.9	1525.9	1273.4	847.1	659.0	613.0
4	5	1	927499.	99.0000	1761.4	1665.4	1376.8	889.6	674.4	621.6
4	6	3	926715.	2.5896	1765.4	1669.4	1380.8	893.5	677.8	624.8
4	7	3	812665.	2.9442	1622.6	1538.6	1286.1	859.7	671.0	624.6
4	8	3	696270.	3.4254	1479.9	1407.9	1191.4	825.8	664.1	624.3
4	9	3	463153.	5.1653	1191.0	1143.0	998.6	754.8	647.3	620.9
4	10	1	220557.	99.0000	899.4	875.4	803.3	681.6	628.4	615.5
5	1	1	229373.	99.0000	867.1	843.1	770.9	649.3	595.7	582.6
5	2	1	456638.	99.0000	1162.6	1114.6	970.3	726.9	619.6	593.3
5	3	1	682872.	99.0000	1458.7	1386.7	1170.4	805.5	644.8	605.4
5	4	1	802282.	99.0000	1609.5	1525.5	1273.1	847.4	660.0	613.9
5	5	1	917786.	99.0000	1760.8	1664.8	1376.3	889.7	675.7	623.3
5	6	1	911099.	99.0000	1765.4	1669.4	1380.9	894.3	680.3	628.0
5	7	1	801262.	99.0000	1623.3	1539.3	1286.8	860.9	673.5	627.7
5	8	1	688304.	99.0000	1480.5	1408.5	1192.0	826.7	666.0	626.6
5	9	1	458870.	99.0000	1190.8	1142.7	998.4	754.7	647.4	621.2
5	10	1	225913.	99.0000	899.0	875.0	802.9	681.2	628.0	615.0

TIME STEP NO = 141 TIME = 7.049907 SEC TIME STEP SIZE = 0.50000E-01 SEC CPU TIME = 18.84 SEC
NUMBER OF NEWTON ITERATIONS = 5
NUMBER OF INNER ITERATIONS = 20 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 132449.937 KW INLET FLOW RATE = 327.201 KG/S
TOTAL HEAT TRANSFER = 94108.000 KW OUTLET FLOW RATE = 351.503 KG/S
FLUID ENERGY RISE = 118050.812 KW

MAXIMUM TEMPERATURES			IR	IZ
WALL:	635.50	AT	3	5
ROD:	2021.03	AT	3	6
MIN CHFR =	2.096	AT	3	6

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	15.57176	0.0	0.0	1337.125	1337.125	573.00	573.00	618.31	3.440	3.440	132.67	726.94	2500.7
1	2	15.56883	0.0	0.0	1347.148	1347.148	618.29	574.86	618.28	3.369	3.369	106.52	723.27	2436.8
1	3	15.56073	0.0	0.0	1367.332	1367.332	618.26	578.40	613.25	3.373	3.373	106.45	713.37	2406.3
1	4	15.55121	0.0	0.0	1394.120	1394.120	618.21	583.43	618.20	3.394	3.394	106.33	702.50	2384.2
1	5	15.54537	0.0	0.0	1428.921	1428.921	618.18	589.07	618.17	3.472	3.472	106.26	687.70	2387.7
1	6	15.54011	0.0	0.0	1464.143	1464.143	618.15	595.14	618.14	3.613	3.613	106.19	673.97	2435.2
1	7	15.53056	0.0	0.0	1501.759	1501.759	618.10	600.88	618.09	3.704	3.704	106.08	657.28	2434.8
1	8	15.52495	0.0003	0.00	1528.374	1528.330	618.07	604.59	618.06	3.819	3.815	106.01	644.51	2458.2
1	9	15.51943	0.0024	0.04	1552.423	1552.018	618.04	607.98	618.03	3.978	3.974	105.94	633.76	2513.6
1	10	15.50937	0.0002	0.00	1566.523	1566.485	617.99	609.90	617.98	4.071	4.071	105.82	626.88	2551.6
1	11	15.50423	0.0	0.0	1566.330	1566.330	617.96	609.93	617.95	4.098	4.098	105.76	624.86	2560.5
1	12	15.50000	0.0		1566.330	1566.351	617.96	609.93	617.93			105.66	624.83	
2	1	15.57275	0.0	0.0	1337.124	1337.124	573.00	573.00	618.31	3.440	3.440	132.69	726.94	2500.7
2	2	15.56787	0.0	0.0	1347.180	1347.180	618.29	574.87	618.29	3.436	3.436	106.54	723.26	2485.4
2	3	15.56209	0.0	0.0	1366.021	1366.021	618.26	578.35	618.26	3.484	3.484	106.47	714.37	2489.0
2	4	15.55268	0.0	0.0	1396.[illegible]	1396.739	618.21	583.49	618.21	3.549	3.549	106.36	700.51	2486.2
2	5	15.54714	0.0	0.0	1432.960	1432.960	618.18	589.47	618.18	3.641	3.641	106.29	688.73	2507.4
2	6	15.54174	0.0	0.0	1467.743	1467.743	618.15	595.36	618.15	3.781	3.781	106.22	672.99	2544.7
2	7	15.53204	0.0	0.0	1497.410	1497.410	618.10	600.28	618.10	3.906	3.906	106.10	658.24	2571.2
2	8	15.52643	0.0	0.0	1525.523	1525.523	618.07	604.41	618.07	4.048	4.035	106.03	644.51	2600.8
2	9	15.52085	0.0018	0.03	1549.522	1549.216	618.04	607.76	618.04	4.206	4.181	105.97	633.75	2646.1
2	10	15.51046	0.0001	0.00	1564.444	1564.426	617.99	609.95	617.99	4.267	4.285	105.84	626.89	2685.8
2	11	15.50493	0.0000	0.00	1567.367	1567.367	617.96	610.16	617.96	4.323	4.323	105.77	623.88	2697.1
2	12	15.50000	0.0000		1567.367	1567.392	617.96	610.16	617.93			105.65	623.85	
3	1	15.57397	0.0	0.0	1337.122	1337.122	573.00	573.00	618.32	3.440	3.440	132.72	726.95	2500.7
3	2	15.56910	0.0	0.0	1349.353	1349.353	618.29	575.27	618.29	3.569	3.569	106.57	722.46	2578.4
3	3	15.56381	0.0	0.0	1372.447	1372.447	618.26	579.27	618.27	3.695	3.695	106.50	712.40	2632.1
3	4	15.55441	0.0	0.0	1408.520	1408.520	618.21	585.54	618.22	3.841	3.841	106.39	697.59	2679.7
3	5	15.54893	0.0	0.0	1451.007	1451.007	618.18	592.63	618.19	3.980	3.980	106.32	679.88	2705.8
3	6	15.54351	0.0004	0.01	1496.878	1496.800	618.16	600.10	618.16	4.096	4.077	106.25	660.28	2690.6
3	7	15.53364	0.0074	0.13	1540.151	1538.844	618.10	606.11	618.11	4.293	4.238	106.13	639.68	2694.4
3	8	15.52602	0.0172	0.30	1578.244	1575.198	618.08	611.18	618.08	4.468	4.385	106.06	621.12	2685.0
3	9	15.52227	0.0309	0.57	1603.106	1597.497	618.05	613.95	618.05	4.642	4.469	105.99	607.38	2657.5
3	10	15.51158	0.0559	1.07	1630.467	1620.217	617.99	616.61	617.99	4.693	4.568	105.86	596.63	2601.1
3	11	15.50579	0.0581	1.13	1637.733	1626.986	617.96	617.34	617.96	4.787	4.618	105.79	592.69	2607.6
3	12	15.50000	0.0581		1637.733	1627.024	617.96	617.34	617.93			105.65	592.64	
4	1	15.57388	0.0	0.0	1337.122	1337.122	573.00	573.00	618.32	3.440	3.440	132.72	726.94	2500.7
4	2	15.56901	0.0	0.0	1347.262	1347.262	618.29	574.88	618.29	3.549	3.549	106.56	723.23	2566.7
4	3	15.56381	0.0	0.0	1365.257	1365.257	618.27	578.14	618.27	3.685	3.695	106.50	714.37	2632.1
4	4	15.55440	0.0	0.0	1395.691	1395.691	618.22	583.22	618.22	3.821	3.821	106.38	701.50	2680.6
4	5	15.54896	0.0	0.0	1428.341	1428.341	618.19	588.98	618.19	3.947	3.947	106.32	689.71	2722.6
4	6	15.54356	0.0	0.0	1460.550	1460.550	618.16	594.50	618.16	4.048	4.047	106.25	674.96	2731.7
4	7	15.53362	0.0000	0.00	1495.603	1495.603	618.11	599.92	618.11	4.206	4.205	106.13	659.23	2772.3
4	8	15.52803	0.0000	0.00	1523.692	1523.692	618.08	603.91	618.08	4.369	4.351	106.06	646.48	2813.0
4	9	15.52231	0.0003	0.01	1542.538	1542.480	618.05	606.91	618.05	4.444	4.425	105.99	637.69	2821.1
4	10	15.51155	0.0001	0.00	1558.739	1558.731	617.99	608.96	617.99	4.533	4.531	105.86	630.81	2858.3

4	11	15.50577	0.0000	0.00	1565.760	1565.761	617.93	609.63	617.96	4.577	4.577	105.78	626.84	2869.1
4	12	15.50000	0.0000		1565.760	1565.790	617.96	609.63	617.93			105.65	626.81	
5	1	15.57278	0.0	0.0	1337.124	1337.124	573.00	573.00	618.31	3.440	3.440	132.70	726.94	2500.7
5	2	15.56791	0.0	0.0	1347.183	1347.183	618.29	574.87	618.29	3.432	3.432	106.54	723.25	2482.5
5	3	15.56214	0.0	0.0	1363.249	1363.249	618.26	577.95	618.26	3.480	3.480	106.47	713.36	2482.3
5	4	15.55272	0.0	0.0	1395.969	1395.969	618.21	583.52	618.21	3.558	3.558	106.35	700.51	2492.5
5	5	15.54715	0.0	0.0	1429.945	1429.945	618.18	589.00	618.18	3.641	3.641	106.29	687.71	2504.0
5	6	15.54177	0.0	0.0	1463.629	1463.629	618.15	595.03	618.15	3.772	3.772	106.22	673.98	2542.2
5	7	15.53210	0.0	0.0	1493.021	1493.021	618.10	600.73	618.10	3.898	3.898	106.10	659.27	2570.1
5	8	15.52650	0.0005	0.01	1531.478	1531.339	618.07	605.10	618.07	4.034	4.028	106.04	643.56	2591.2
5	9	15.52085	0.0032	0.05	1556.200	1555.644	618.04	608.67	618.04	4.171	4.165	105.97	630.83	2620.4
5	10	15.51045	0.0003	0.01	1570.891	1570.838	617.99	610.61	617.99	4.262	4.262	105.84	624.96	2662.9
5	11	15.50501	0.0	0.0	1567.557	1567.557	617.96	610.41	617.96	4.317	4.317	105.77	624.91	2697.7
5	12	15.50000	0.0		1567.557	1567.583	617.96	610.41	617.93			105.65	624.88	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	-1.879E-01	-1.879E-01	-3.169E-01	-3.169E-01	2	4	5.467E-02	5.467E-02	0.0	0.0
3	-2.206E-01	-2.206E-01	-3.825E-01	-3.825E-01	3	4	5.108E-02	5.108E-02	0.0	0.0
3	-2.267E-01	-2.267E-01	-4.079E-01	-4.079E-01	4	4	4.682E-02	4.682E-02	0.0	0.0
3	-2.503E-01	-2.503E-01	-4.600E-01	-4.600E-01	5	4	2.786E-02	2.786E-02	0.0	0.0
3	-2.861E-01	-2.861E-01	-5.322E-01	-5.322E-01	6	4	3.231E-03	3.231E-03	0.0	0.0
3	-2.785E-01	-2.621E-01	-4.801E-01	-4.698E-01	7	4	2.697E-02	2.558E-02	0.0	0.0
3	-2.985E-01	-2.673E-01	-5.239E-01	-4.750E-01	8	4	1.901E-02	2.153E-02	0.0	0.0
3	-3.182E-01	-2.608E-01	-6.003E-01	-4.770E-01	9	4	-4.674E-03	-2.999E-03	0.0	0.0
3	-2.427E-01	-2.076E-01	-4.108E-01	-3.652E-01	10	4	1.913E-02	1.263E-02	0.0	0.0
3	-1.928E-01	-1.543E-01	-3.300E-01	-2.691E-01	11	4	1.167E-02	1.095E-02	0.0	0.0
5	0.0	0.0	1.855E-01	1.855E-01	2					
5	0.0	0.0	2.138E-01	2.138E-01	3					
5	0.0	0.0	2.196E-01	2.196E-01	4					
5	0.0	0.0	2.505E-01	2.505E-01	5					
5	0.0	0.0	2.787E-01	2.787E-01	6					
5	0.0	0.0	2.605E-01	2.429E-01	7					
5	0.0	0.0	2.767E-01	2.431E-01	8					
5	0.0	0.0	3.141E-01	2.427E-01	9					
5	0.0	0.0	2.251E-01	1.898E-01	10					
5	0.0	0.0	1.755E-01	1.357E-01	11					

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	1	234933.	99.0000	870.6	846.6	774.3	651.5	596.6	583.2
1	2	1	469089.	99.0000	1169.2	1121.2	976.6	731.1	621.5	594.7
1	3	1	704162.	99.0000	1469.2	1397.1	1160.2	812.0	647.9	607.7
1	4	1	819656.	99.0000	1622.0	1537.9	1284.8	855.2	663.9	617.0

1	5	1	936393.	99.0000	1775.2	1679.1	1389.9	898.8	680.1	626.5
1	6	1	935143.	99.0000	1779.7	1683.6	1394.4	903.5	685.0	631.5
1	7	1	819121.	99.0000	1635.8	1551.8	1295.6	869.0	677.7	630.9
1	8	3	720523.	3.3715	1490.4	1418.3	1201.4	833.0	667.1	626.0
1	9	1	460143.	99.0000	1197.6	1149.5	1004.8	759.4	650.5	623.9
1	10	1	225474.	99.0000	902.5	878.4	806.2	683.8	629.8	616.7
2	1	1	234037.	99.0000	870.6	846.6	774.3	651.5	596.6	583.2
2	2	1	468243.	99.0000	1169.1	1121.1	976.5	730.9	621.3	594.4
2	3	1	706235.	99.0000	1469.3	1397.3	1180.3	812.0	647.7	607.4
2	4	1	817311.	99.0000	1622.4	1538.3	1285.2	855.2	663.7	616.9
2	5	1	933449.	99.0000	1775.2	1679.1	1389.8	898.6	679.5	626.0
2	6	1	933220.	99.0000	1780.1	1684.0	1394.7	903.3	684.1	630.4
2	7	1	815875.	99.0000	1636.2	1552.1	1209.0	869.0	677.2	630.2
2	8	3	717571.	3.3449	1490.8	1418.7	1201.8	833.0	666.7	625.8
2	9	3	471673.	5.0397	1197.9	1143.8	1005.2	759.4	649.6	622.6
2	10	1	226711.	99.0000	903.0	878.9	806.7	684.1	630.1	616.9
3	1	1	281739.	99.0000	930.1	901.3	814.5	667.1	601.2	585.1
3	2	1	563530.	99.0000	1288.8	1231.1	1057.5	762.4	630.5	598.2
3	3	1	845034.	99.0000	1648.7	1562.2	1301.8	859.3	661.8	613.4
3	4	1	982291.	99.0000	1831.8	1730.9	1427.1	910.9	680.7	624.3
3	5	1	1117831.	99.0000	2015.7	1900.4	1553.2	963.0	699.8	635.5
3	6	3	1153396.	2.0358	2021.1	1905.7	1558.1	964.4	696.7	630.9
3	7	3	999372.	2.4065	1843.2	1742.3	1438.3	920.4	687.6	630.5
3	8	3	860372.	2.8038	1669.1	1532.6	1322.0	878.2	678.6	629.5
3	9	3	567833.	4.2225	1318.9	1261.2	1087.5	792.0	659.5	627.0
3	10	3	277695.	8.6554	967.3	938.5	851.7	704.5	639.2	623.3
4	1	1	234767.	99.0000	870.6	846.6	774.3	651.4	596.6	583.1
4	2	1	469185.	99.0000	1169.5	1121.5	976.8	730.9	620.9	594.0
4	3	1	705104.	99.0000	1469.5	1397.4	1180.4	811.6	646.9	606.5
4	4	1	818091.	99.0000	1622.4	1538.3	1285.1	854.6	662.4	615.4
4	5	1	936278.	99.0000	1775.6	1679.5	1390.1	898.0	678.1	624.3
4	6	3	949076.	2.5449	1779.6	1683.5	1394.1	901.5	680.3	626.0
4	7	3	831693.	2.9004	1635.1	1551.0	1297.7	866.7	673.2	625.7
4	8	3	712792.	3.3755	1490.6	1418.5	1201.4	831.9	666.0	625.1
4	9	3	469763.	5.1030	1198.1	1150.1	1005.3	759.0	648.9	621.9
4	10	1	231893.	99.0000	903.0	878.9	806.6	684.0	629.7	616.4
5	1	1	234914.	99.0000	870.6	846.6	774.3	651.5	596.6	583.2
5	2	1	472785.	99.0000	1169.7	1121.7	977.0	731.1	621.2	594.2
5	3	1	705539.	99.0000	1469.4	1397.3	1180.4	812.1	647.7	607.4
5	4	1	822669.	99.0000	1622.0	1537.9	1284.8	855.1	663.5	616.5
5	5	1	939206.	99.0000	1775.0	1679.0	1389.7	898.5	679.5	625.8
5	6	1	937817.	99.0000	1779.6	1683.6	1394.3	903.2	684.4	630.8
5	7	1	815288.	99.0000	1635.8	1551.7	1298.5	868.7	677.5	630.7
5	8	3	716695.	3.3996	1491.1	1419.1	1202.0	833.1	667.2	626.2
5	9	1	452153.	99.0000	1197.9	1149.8	1005.1	759.2	650.5	624.2
5	10	1	215628.	99.0000	902.6	878.5	806.2	683.6	629.7	616.9

SAMPLE PROBLEM 2 DATA FILE (TRANSIENT RESTART)

```
-2
 &RESTRT ISS=0,NITMAX=5   &END
 &TFDATA NQ=2,YQ(1)=6.,7.,QFAC(1)=1.,1.5,NB=2,YB(1)=6.,7.,
 BOTFAC(1)=1.,.8 &END
7. .0001 .05 .2 .2 1. 5
0. 0 0 0 0 0 0
0
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                         THERMIT   AS OF   10 JULY   1980

          PWR 5 ASSEMBLY TEST PROBLEM


      ARRAY DIMENSIONS

NUMBER OF CHANNELS               =   5
NUMBER OF ROWS                   =   3
NUMBER OF FUEL RODS MODELED      =   5
NUMBER OF AXIAL NODES            =  10
NUMBER OF CELLS IN FUEL          =   3
NUMBER OF CELLS IN CLAD          =   1


    THERMAL-HYDRAULIC OPTIONS IN USE

PRESSURE BOUNDARY CONDITION AT CORE EXIT
VELOCITY BOUNDARY CONDITION AT CORE INLET
SUBCOOLED   BOILING MODEL
MIT  INTERFACIAL MOMENTUM EXCHANGE MODEL
CONSTANT PROPERTY FUEL PIN MODEL
STEADY-STATE HEAT TRANSFER CALCULATION WITHOUT CHF CHECK
COUPLED  HEAT FLUX BOUNDARY CONDITION
BIASI    CRITICAL HEAT FLUX CORRELATION
TRANSVERSE FRICTION MODEL - GUNTER-SHAW
TRANSVERSE   VELOCITY USED IN TRANSVERSE MOMENTUM CALCULATIONS
TRANSVERSE FLOW IS CALCULATED
NO MIXING MODEL
GRAVITATIONAL CONSTANT          =   -9.81000
TRANSVERSE HYDRAULIC DIAMETER   =  0.10000E-01
TRANSVERSE FRICTION MULTIPLIER  =  0.12500E+01


    FRICTION MODEL

AXIAL          F =  0.179*RE**-0.200
TRANSVERSE     F =  1.920*RE**-0.145
GRID SPACER    K =  3.000*RE**-0.100


    ITERATION CONTROL PARAMETERS

DUMP INDICATOR (0/1)(NO/YES)      =   1
MAX NUMBER OF NEWTON ITERATIONS   =   2
MAX NUMBER OF INNER ITERATIONS    =  50
CONVERGENCE CRIT. FOR NEWTON ITER= 0.20000E-06
CONVERGENCE CRIT. FOR INNER ITER = 0.10000E-06


   FUEL ROD MODEL DATA

INITIAL TOTAL POWER               = 0.68300E+08
DELAY TIME                        = 0.0
INVERSE REACTOR PERIOD            = 0.0
ROD RADIUS                        = 0.47000E-02
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CLAD THICKNESS                    = 0.57200E-03
GAP THICKNESS                     = 0.82400E-04
GAP CONDUCTIVITY                  = 0.50000E+04

 NCR
CARD IMAGE>1  3  1 $ NCR                                                  <
 INDENT
CARD IMAGE>1  0  1 $ INDENT                                               <
ARX
CARD IMAGE>10(0.)  10(0.)  20(.0445)  10(0.) $ ARX                        <
ARY
CARD IMAGE>20(0.)  10(0.0445)  10(0.)  10(.0445) $ ARY                    <
ARZ
CARD IMAGE>11(5(.026169)) $ ARZ                                           <
VOL
CARD IMAGE>10(5(.95779E-2)) $ VOL                                         <
DX
CARD IMAGE>5(.215)  $ DX                                                  <
DY
CARD IMAGE>5(.215)  $ DY                                                  <
DZ
CARD IMAGE>12(.366) $ DZ                                                  <
HDZ
CARD IMAGE>5(.01) $ HDZ                                                   <
SIJ
CARD IMAGE>5(4(0.)) $ SIJ                                                 <
IND FRIC
CARD IMAGE>2  2  12  2  2  12  2  2  12  2  2  $ IFRZ                     <
P
CARD IMAGE>5(155.9E5 155.8E5 155.75E5 155.7E5 155.65E5 155.6E5 155.5E5    <
CARD IMAGE>155.45E5 155.35E5 155.25E5 155.1E5 155.E5) $ P                 <
ALP
CARD IMAGE>5(12(0.)) $ ALP                                                <
TEMP
CARD IMAGE>5(12(573.)) $ TV                                               <
VZ
CARD IMAGE>5(11(4.3)) $ VVZ                                               <
IND RODS
CARD IMAGE>1  2 3 4 5 $ ICR                                               <
HDH
CARD IMAGE>5(.01) $ HDH                                                   <
TW
CARD IMAGE>5(10(580.)) $ TWALL                                            <
      QZ
CARD IMAGE>1. 2. 3. 3.5 4. 4. 3.5  3. 2. 1. $ QZ                          <
      QT
CARD IMAGE>1. 1. 1.2 1. 1. $ QT                                           <
      QR
CARD IMAGE>3(1.) 2(0) $ QR                                                <
      RN
CARD IMAGE>5(264.) $ RN                                                   <
FRAC PH
CARD IMAGE>5(1.) $ FRACP                                                  <
```

< CHANNEL OVERLAY >

5

2 3 4

1

TIME STEP NO = 0 TIME = 0.0 SEC TIME STEP SIZE = 0.0 SEC CPU TIME = 0.0 SEC
NUMBER OF NEWTON ITERATIONS = 0
NUMBER OF INNER ITERATIONS = 0 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 88299.937 KW INLET FLOW RATE = 409.023 KG/S
TOTAL HEAT TRANSFER = 0.0 KW OUTLET FLOW RATE = 408.925 KG/S
FLUID ENERGY RISE = -93.200 KW

MAXIMUM TEMPERATURES			IR	IZ
WALL:	0.0	AT	0	0
ROD:	0.0	AT	0	0
MIN CHFR =	0.0	AT	0	0

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	15.59000	0.0	0.0	1337.104	1337.104	573.00	573.00	618.40	4.300	4.300	133.12	726.98	3126,0
1	2	15.58000	0.0	0.0	1337.115	1337.115	573.00	573.00	618.35	4.300	4.300	132.87	726.96	3125.9
1	3	15.57500	0.0	0.0	1337.122	1337.122	573.00	573.00	618.32	4.300	4.300	132.75	726.95	3125.9
1	4	15.57000	0.0	0.0	1337.127	1337.127	573.00	573.00	618.30	4.300	4.300	132.63	726.94	3125.8
1	5	15.56500	0.0	0.0	1337.133	1337.133	573.00	573.00	618.27	4.300	4.300	132.50	726.93	3125.8
1	6	15.56000	0.0	0.0	1337.139	1337.139	573.00	573.00	618.25	4.300	4.300	132.38	726.91	3125.7
1	7	15.55000	0.0	0.0	1337.150	1337.150	573.00	573.00	618.19	4.300	4.300	132.14	726.89	3125.6
1	8	15.54500	0.0	0.0	1337.156	1337.156	573.00	573.00	618.17	4.300	4.300	132.02	726.88	3125.6
1	9	15.53500	0.0	0.0	1337.167	1337.167	573.00	573.00	618.12	4.300	4.300	131.77	726.86	3125.5
1	10	15.52500	0.0	0.0	1337.179	1337.179	573.00	573.00	618.06	4.300	4.300	131.53	726.84	3125.4
1	11	15.51000	0.0	0.0	1337.196	1337.196	573.00	573.00	617.99	4.300	4.300	131.17	726.81	3125.3
1	12	15.50000	0.0		1337.196	1337.208	573.00	573.00	617.93			130.93	726.78	
2	1	15.59000	0.0	0.0	1337.104	1337.104	573.00	573.00	618.40	4.300	4.300	133.12	726.98	3126.0
2	2	15.58000	0.0	0.0	1337.115	1337.115	573.00	573.00	618.35	4.300	4.300	132.87	726.96	3125.9
2	3	15.57500	0.0	0.0	1337.122	1337.122	573.00	573.00	618.32	4.300	4.300	132.75	726.95	3125.9
2	4	15.57000	0.0	0.0	1337.127	1337.127	573.00	573.00	618.30	4.300	4.300	132.63	726.94	3125.8
2	5	15.56500	0.0	0.0	1337.133	1337.133	573.00	573.00	618.27	4.300	4.300	132.50	726.93	3125.8
2	6	15.56000	0.0	0.0	1337.139	1337.139	573.00	573.00	618.25	4.300	4.300	132.38	726.91	3125.7
2	7	15.55000	0.0	0.0	1337.150	1337.150	573.00	573.00	618.19	4.300	4.300	132.14	726.89	3125.6
2	8	15.54500	0.0	0.0	1337.156	1337.156	573.00	573.00	618.17	4.300	4.300	132.02	726.88	3125.6
2	9	15.53500	0.0	0.0	1337.167	1337.167	573.00	573.00	618.12	4.300	4.300	131.77	726.86	3125.5
2	10	15.52500	0.0	0.0	1337.179	1337.179	573.00	573.00	618.06	4.300	4.300	131.53	726.84	3125.4
2	11	15.51000	0.0	0.0	1337.196	1337.196	573.00	573.00	617.99	4.300	4.300	131.17	726.81	3125.3
2	12	15.50000	0.0		1337.196	1337.208	573.00	573.00	617.93			130.93	726.78	
3	1	15.59000	0.0	0.0	1337.104	1337.104	573.00	573.00	618.40	4.300	4.300	133.12	726.98	3126.0
3	2	15.58000	0.0	0.0	1337.115	1337.115	573.00	573.00	618.35	4.300	4.300	132.87	726.96	3125.9
3	3	15.57500	0.0	0.0	1337.122	1337.122	573.00	573.00	618.32	4.300	4.300	132.75	726.95	3125.9
3	4	15.57000	0.0	0.0	1337.127	1337.127	573.00	573.00	618.30	4.300	4.300	132.63	726.94	3125.8
3	5	15.56500	0.0	0.0	1337.133	1337.133	573.00	573.00	618.27	4.300	4.300	132.50	726.93	3125.8
3	6	15.56000	0.0	0.0	1337.139	1337.139	573.00	573.00	618.25	4.300	4.300	132.38	726.91	3125.7
3	7	15.55000	0.0	0.0	1337.150	1337.150	573.00	573.00	618.19	4.300	4.300	132.14	726.89	3125.6
3	8	15.54500	0.0	0.0	1337.156	1337.156	573.00	573.00	618.17	4.300	4.300	132.02	726.88	3125.6
3	9	15.53500	0.0	0.0	1337.167	1337.167	573.00	573.00	618.12	4.300	4.300	131.77	726.86	3125.5
3	10	15.52500	0.0	0.0	1337.179	1337.179	573.00	573.00	618.06	4.300	4.300	131.53	726.84	3125.4
3	11	15.51000	0.0	0.0	1337.196	1337.196	573.00	573.00	617.99	4.300	4.300	131.17	726.81	3125.3
3	12	15.50000	0.0		1337.196	1337.208	573.00	573.00	617.93			130.93	726.78	
4	1	15.59000	0.0	0.0	1337.104	1337.104	573.00	573.00	618.40	4.300	4.300	133.12	726.98	3126.0
4	2	15.58000	0.0	0.0	1337.115	1337.115	573.00	573.00	618.35	4.300	4.300	132.87	726.96	3125.9
4	3	15.57500	0.0	0.0	1337.122	1337.122	573.00	573.00	618.32	4.300	4.300	132.75	726.95	3125.9
4	4	15.57000	0.0	0.0	1337.127	1337.127	573.00	573.00	618.30	4.300	4.300	132.63	726.94	3125.8
4	5	15.56500	0.0	0.0	1337.133	1337.133	573.00	573.00	618.27	4.300	4.300	132.50	726.93	3125.8
4	6	15.56000	0.0	0.0	1337.139	1337.139	573.00	573.00	618.25	4.300	4.300	132.38	726.91	3125.7
4	7	15.55000	0.0	0.0	1337.150	1337.150	573.00	573.00	618.19	4.300	4.300	132.14	726.89	3125.6
4	8	15.54500	0.0	0.0	1337.156	1337.156	573.00	573.00	618.17	4.300	4.300	132.02	726.88	3125.6
4	9	15.53500	0.0	0.0	1337.167	1337.167	573.00	573.00	618.12	4.300	4.300	131.77	726.86	3125.5
4	10	15.52500	0.0	0.0	1337.179	1337.179	573.00	573.00	618.06	4.300	4.300	131.53	726.84	3125.4

4	11	15.51000	0.0	0.0	1337.196	1337.196	573.00	573.00	617.99	4.300	4.300	131.17	726.81	3125.3
4	12	15.50000	0.0		1337.196	1337.208	573.00	573.00	617.93			130.93	726.78	
5	1	15.59000	0.0	0.0	1337.104	1337.104	573.00	573.00	618.40	4.300	4.300	133.12	726.98	3126.0
5	2	15.58000	0.0	0.0	1337.115	1337.115	573.00	573.00	618.35	4.300	4.300	132.87	726.96	3125.9
5	3	15.57500	0.0	0.0	1337.122	1337.122	573.00	573.00	618.32	4.300	4.300	132.75	726.95	3125.9
5	4	15.57000	0.0	0.0	1337.127	1337.127	573.00	573.00	618.30	4.300	4.300	132.63	726.94	3125.8
5	5	15.56500	0.0	0.0	1337.133	1337.133	573.00	573.00	618.27	4.300	4.300	132.50	726.93	3125.8
5	6	15.56000	0.0	0.0	1337.139	1337.139	573.00	573.00	618.25	4.300	4.300	132.38	726.91	3125.7
5	7	15.55000	0.0	0.0	1337.150	1337.150	573.00	573.00	618.19	4.300	4.300	132.14	726.89	3125.6
5	8	15.54500	0.0	0.0	1337.156	1337.156	573.00	573.00	618.17	4.300	4.300	132.02	726.88	3125.6
5	9	15.53500	0.0	0.0	1337.167	1337.167	573.00	573.00	618.12	4.300	4.300	131.77	726.86	3125.5
5	10	15.52500	0.0	0.0	1337.179	1337.179	573.00	573.00	618.06	4.300	4.300	131.53	726.84	3125.4
5	11	15.51000	0.0	0.0	1337.196	1337.196	573.00	573.00	617.99	4.300	4.300	131.17	726.81	3125.3
5	12	15.50000	0.0		1337.196	1337.208	573.00	573.00	617.93			130.93	726.78	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	2	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	3	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	4	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	5	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	6	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	7	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	8	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	9	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	10	4	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	11	4	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	2					
5	0.0	0.0	0.0	0.0	3					
5	0.0	0.0	0.0	0.0	4					
5	0.0	0.0	0.0	0.0	5					
5	0.0	0.0	0.0	0.0	6					
5	0.0	0.0	0.0	0.0	7					
5	0.0	0.0	0.0	0.0	8					
5	0.0	0.0	0.0	0.0	9					
5	0.0	0.0	0.0	0.0	10					
5	0.0	0.0	0.0	0.0	11					

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
1	2	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
1	3	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
1	4	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0

1	5	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
1	6	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
1	7	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
1	8	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
1	9	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
1	10	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	1	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	2	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	3	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	4	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	5	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	6	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	7	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	8	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	9	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
2	10	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	1	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	2	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	3	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	4	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	5	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	6	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	7	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	8	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	9	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
3	10	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	1	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	2	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	3	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	4	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	5	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	6	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	7	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	8	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	9	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
4	10	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	1	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	2	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	3	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	4	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	5	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	6	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	7	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	8	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	9	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0
5	10	0	0.	0.0	580.0	580.0	580.0	580.0	580.0	580.0

TIME STEP NO = 120 TIME = 5.999923 SEC TIME STEP SIZE = 0.50000E-01 SEC CPU TIME = 51.71 SEC
NUMBER OF NEWTON ITERATIONS = 2
NUMBER OF INNER ITERATIONS = 4 0 REDUCED TIME STEPS SINCE LAST PRINT

TOTAL REACTOR POWER = 88299.937 KW INLET FLOW RATE = 409.018 KG/S
TOTAL HEAT TRANSFER = 88294.937 KW OUTLET FLOW RATE = 409.549 KG/S
FLUID ENERGY RISE = 88716.562 KW

MAXIMUM TEMPERATURES			IR	IZ
WALL:	630.37	AT	3	6
ROD:	1969.85	AT	3	6
MIN CHFR =	2.510	AT	3	7

IC	IZ	PRESSURE (MPA)	VOID	% QUAL	HM (KJ/KG)	HL (KJ/KG)	T VAP (K)	T LIQ (K)	T SAT (K)	VVZ (M/S)	VLZ (M/S)	ROV (KG/M3)	ROL (KG/M3)	MASS FLUX (KG/M2-S)
1	1	15.58589	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.01	726.97	3126.0
1	2	15.57969	0.0	0.0	1344.792	1344.792	618.35	574.43	618.35	4.321	4.321	106.70	724.15	3128.9
1	3	15.57364	0.0	0.0	1359.617	1359.617	618.32	577.11	618.32	4.368	4.368	106.62	715.36	3124.9
1	4	15.56207	0.0	0.0	1384.337	1384.337	618.26	581.23	618.26	4.426	4.426	106.48	706.46	3127.0
1	5	15.55590	0.0	0.0	1409.851	1409.851	618.22	585.77	618.22	4.495	4.495	106.40	695.60	3126.8
1	6	15.54972	0.0	0.0	1439.217	1439.217	618.19	591.01	618.19	4.579	4.579	106.33	682.80	3126.5
1	7	15.53763	0.0	0.0	1469.320	1469.320	618.13	596.00	618.13	4.671	4.671	106.18	671.01	3134.3
1	8	15.53135	0.0	0.0	1498.986	1498.986	618.10	600.75	618.10	4.763	4.763	106.10	656.27	3126.1
1	9	15.52503	0.0000	0.00	1521.876	1521.876	618.06	603.90	618.06	4.856	4.856	106.02	647.46	3144.3
1	10	15.51244	0.0	0.0	1536.881	1536.881	618.00	606.18	618.00	4.912	4.912	105.87	639.58	3141.8
1	11	15.50617	0.0000	0.00	1542.598	1542.598	617.97	606.80	617.97	4.933	4.933	105.79	636.60	3140.5
1	12	15.50000	0.0000		1542.598	1542.626	617.97	606.80	617.93			105.64	636.56	
2	1	15.58589	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.02	726.97	3126.0
2	2	15.57990	0.0	0.0	1344.789	1344.789	618.35	574.43	618.35	4.319	4.319	106.70	724.15	3127.9
2	3	15.57385	0.0	0.0	1359.846	1359.846	618.32	577,01	618.32	4.366	4.366	106.62	716.36	3127.7
2	4	15.56208	0.0	0.0	1383.564	1383.564	618.26	581.35	618.26	4.431	4.431	106.48	706.46	3130.4
2	5	15.55590	0.0	0.0	1412.875	1412.875	618.22	586.11	618.22	4.499	4.499	106.40	696.61	3134.0
2	6	15.54972	0.0	0.0	1439.690	1439.690	618.19	591.11	618.19	4.589	4.589	106.33	683.81	3138.3
2	7	15.53759	0.0	0.0	1472.116	1472.116	618.13	596.32	618.13	4.683	4.683	106.18	671.03	3142.6
2	8	15.53129	0.0	0.0	1500.269	1500.269	618.10	600.71	618.10	4.771	4.771	106.10	656.27	3131.2
2	9	15.52500	0.0000	0.00	1524.490	1524.490	618.06	604.14	618.06	4.859	4.859	106.02	645.48	3136.5
2	10	15.51242	0.0000	0.00	1537.628	1537.628	618.00	605.98	618.00	4.913	4.913	105.87	640.56	3146.8
2	11	15.50616	0.0	0.0	1543.600	1543.600	617.97	607.06	617.97	4.938	4.938	105.79	636.62	3143.3
2	12	15.50000	0.0		1543.600	1543.627	617.97	607.06	617.93			105.64	636.58	
3	1	15.58589	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.02	726.97	3126.0
3	2	15.57990	0.0	0.0	1346.320	1346.320	618.35	574.71	618.35	4.321	4.321	106.70	723.59	3126.6
3	3	15.57386	0.0	0.0	1366.012	1366.012	618.32	578.11	618.32	4.375	4.375	106.62	714.39	3125.7
3	4	15.56207	0.0	0.0	1390.744	1390.744	618.26	582.62	618.26	4.442	4.442	106.48	704.50	3129.4
3	5	15.55592	0.0	0.0	1425.752	1425.752	618.22	588.58	618.22	4.525	4.525	106.40	690.72	3125.2
3	6	15.54973	0.0	0.0	1464.415	1464.415	618.19	595.01	618.19	4.623	4.623	106.33	673.00	3111.3
3	7	15.53759	0.0	0.0	1497.672	1497.672	618.13	600.43	618.13	4.746	4.731	106.18	657.28	3109.9
3	8	15.53128	0.0009	0.01	1529.506	1529.353	618.10	604.74	618.10	4.858	4.826	106.10	643.56	3103.5
3	9	15.52499	0.0042	0.07	1557.144	1556.411	618.06	608.87	618.06	4.976	4.925	106.02	629.87	3091.5
3	10	15.51242	0.0033	0.06	1579.402	1578.832	618.00	611.46	618.00	5.027	4.999	105.87	621.05	3096.2
3	11	15.50615	0.0005	0.01	1588.330	1588.241	617.97	612.59	617.97	5.051	5.038	105.79	614.13	3092.9
3	12	15.50000	0.0005		1588.330	1588.275	617.97	612.59	617.93			105.64	614.09	
4	1	15.58589	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.01	726.97	3126.0
4	2	15.57989	0.0	0.0	1344.789	1344.789	618.35	574.43	618.35	4.322	4.322	106.70	724.15	3129.5
4	3	15.57385	0.0	0.0	1361.888	1361.888	618.32	577.20	618.32	4.373	4.373	106.62	716.36	3132.3
4	4	15.56206	0.0	0.0	1383.811	1383.811	618.26	581.57	618.26	4.424	4.424	106.48	706.47	3125.6
4	5	15.55593	0.0	0.0	1411.334	1411.334	618.22	586.21	618.22	4.497	4.497	106.40	696.62	3132.7
4	6	15.54972	0.0	0.0	1442.030	1442.030	618.19	591.08	618.19	4.584	4.584	106.33	682.81	3129.8
4	7	15.53759	0.0	0.0	1467.764	1467.764	618.13	595.77	618.13	4.683	4.683	106.18	672.00	3147.1
4	8	15.53131	0.0000	0.00	1495.892	1495.892	618.10	600.06	618.10	4.777	4.776	106.10	658.23	3144.0
4	9	15.52501	0.0000	0.00	1526.043	1526.043	618.06	604.38	618.06	4.863	4.863	106.02	644.50	3134.1
4	10	15.51244	0.0000	0.00	1536.884	1536.884	618.00	606.15	618.00	4.912	4.912	105.87	639.57	3141.7

4	11	15.50615	0.0	0.0	1544.913	1544.913	617.97	607.12	617.97	4.927	4.927	105.79	635.62	3131.8
4	12	15.50000	0.0		1544.913	1544.940	617.97	607.12	617.93			105.64	635.59	
5	1	15.58590	0.0	0.0	1337.109	1337.109	573.00	573.00	618.38	4.300	4.300	133.02	726.97	3126.0
5	2	15.57990	0.0	0.0	1344.789	1344.789	618.35	574.43	618.35	4.315	4.315	106.70	724.15	3124.4
5	3	15.57389	0.0	0.0	1360.600	1360.600	618.32	577.43	618.32	4.368	4.368	106.62	716.37	3128.8
5	4	15.56209	0.0	0.0	1382.318	1382.318	618.26	581.29	618.26	4.429	4.429	106.48	705.46	3124.8
5	5	15.55591	0.0	0.0	1410.346	110.346	618.22	586.13	618.22	4.499	4.499	106.40	695.62	3129.3
5	6	15.54969	0.0	0.0	1437.695	1437.695	618.19	590.75	618.19	4.576	4.576	106.33	682.79	3124.5
5	7	15.53756	0.0	0.0	1469.873	1469.873	618.13	595.91	618.13	4.669	4.669	106.18	670.01	3128.5
5	8	15.53126	0.0	0.0	1497.168	1497.168	618.10	600.12	618.10	4.758	4.758	106.10	658.23	3132.0
5	9	15.52497	0.0	0.0	1525.690	1525.690	618.06	604.22	618.06	4.852	4.852	106.02	647.49	3141.9
5	10	15.51241	0.0000	0.00	1536.637	1536.638	618.00	606.03	618.00	4.906	4.906	105.87	639.57	3137.7
5	11	15.50618	0.0	0.0	1541.065	1541.065	617.97	606.78	617.97	4.935	4.935	105.79	636.59	3141.6
5	12	15.50000	0.0		1541.065	1541.092	617.97	606.78	617.93			105.64	636.56	

IC	VVX	VLX	VVY	VLY	IZ	IC	VVX	VLX	VVY	VLY
1	0.0	0.0	0.0	0.0	2	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	3	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	4	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	5	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	6	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	7	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	8	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	9	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	10	2	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	11	2	0.0	0.0	0.0	0.0
3	-1.506E-03	-1.506E-03	-4.630E-03	-4.630E-03	2	4	2.166E-03	2.166E-03	0.0	0.0
3	-4.322E-03	-4.322E-03	-9.599E-03	-9.599E-03	3	4	5.851E-03	5.851E-03	0.0	0.0
3	7.774E-04	7.774E-04	-4.005E-03	-4.005E-03	4	4	7.541E-03	7.541E-03	0.0	0.0
3	-7.267E-03	-7.267E-03	-5.810E-03	-5.810E-03	5	4	-7.032E-04	-7.032E-04	0.0	0.0
3	-5.977E-03	-5.977E-03	-4.437E-03	-4.437E-03	6	4	3.102E-05	3.102E-05	0.0	0.0
3	-2.514E-04	-2.514E-04	1.244E-02	1.244E-02	7	4	2.690E-03	2.690E-03	0.0	0.0
3	4.737E-03	4.469E-03	2.769E-02	2.622E-02	8	4	9.316E-04	1.724E-03	0.0	0.0
3	6.203E-03	5.054E-03	2.221E-02	1.681E-02	9	4	6.528E-04	2.998E-03	0.0	0.0
3	-1.841E-03	-1.740E-03	3.237E-03	2.431E-03	10	4	5.628E-04	1.269E-03	0.0	0.0
3	2.363E-03	2.157E-03	-6.420E-03	-6.767E-03	11	4	-2.634E-03	-2.609E-03	0.0	0.0
5	0.0	0.0	-7.612E-04	-7.612E-04	2					
5	0.0	0.0	-9.212E-03	-9.212E-03	3					
5	0.0	0.0	-8.545E-03	-8.545E-03	4					
5	0.0	0.0	4.644E-04	4.644E-04	5					
5	0.0	0.0	1.134E-02	1.134E-02	6					
5	0.0	0.0	5.483E-03	5.483E-03	7					
5	0.0	0.0	3.156E-03	2.253E-03	8					
5	0.0	0.0	2.076E-03	9.958E-04	9					
5	0.0	0.0	3.176E-03	2.528E-03	10					
5	0.0	0.0	-3.459E-03	-2.928E-03	11					

IR	IZ	IHTR	HEAT FLUX(W/M**2)	CHFR OR CPR	ROD TEMPERATURES (DEG K)					
1	1	1	220380.	99.0000	860.0	836.0	764.1	644.2	593.5	581.0
1	2	1	440786.	99.0000	1148.1	1100.2	956.3	716.5	615.1	590.0
1	3	1	661187.	99.0000	1437.7	1365.7	1149.9	790.2	638.1	600.5
1	4	1	771402.	99.0000	1584.8	1500.9	1249.1	829.5	652.0	608.1

1	5	1	881614.	99.0000	1732.6	1636.7	1348.9	869.3	666.5	616.3
1	6	1	881619.	99.0000	1737.4	1641.5	1353.7	874.1	671.3	621.2
1	7	1	771393.	99.0000	1599.2	1515.3	1263.5	843.8	666.4	622.5
1	8	3	661198.	3.5076	1456.9	1387.0	1171.2	811.5	659.4	621.7
1	9	3	440777.	5.2467	1176.5	1128.5	984.6	744.8	643.4	618.4
1	10	1	220374.	99.0000	891.9	867.9	796.0	676.1	625.4	612.9
2	1	1	220392.	99.0000	860.0	836.0	764.1	644.2	593.5	581.0
2	2	1	440783.	99.0000	1148.0	1100.0	956.2	716.4	615.0	589.9
2	3	1	661201.	99.0000	1437.8	1365.8	1150.0	790.3	638.2	600.6
2	4	1	771396.	99.0000	1585.2	1501.2	1249.4	829.8	652.4	608.5
2	5	1	881603.	99.0000	1732.7	1636.8	1349.1	869.5	666.7	616.5
2	6	1	881603.	99.0000	1737.7	1641.8	1354.0	874.4	671.7	621.5
2	7	3	771387.	2.9978	1598.6	1514.7	1262.9	843.2	665.8	621.9
2	8	3	661191.	3.4685	1459.0	1387.1	1171.3	811.6	659.5	621.9
2	9	1	440772.	99.0000	1176.3	1128.3	984.4	744.6	643.2	618.1
2	10	1	220370.	99.0000	892.2	868.2	796.2	676.3	625.6	613.1
3	1	1	264452.	99.0000	917.4	888.7	802.3	658.4	597.6	582.6
3	2	1	528950.	99.0000	1263.3	1205.7	1033.1	745.3	623.7	593.5
3	3	1	793439.	99.0000	1610.3	1524.0	1265.0	833.3	650.8	605.7
3	4	1	925681.	99.0000	1787.4	1686.7	1384.5	881.0	668.0	615.3
3	5	1	1057932.	99.0000	1964.8	1849.7	1504.4	928.9	685.6	625.3
3	6	1	1057930.	99.0000	1969.9	1854.8	1509.4	933.9	690.6	630.4
3	7	3	925700.	2.5099	1798.6	1697.9	1395.8	892.2	679.3	626.6
3	8	3	793496.	2.9257	1631.1	1544.8	1285.8	854.2	671.7	626.5
3	9	3	528945.	4.4351	1293.5	1236.0	1063.3	775.6	653.9	623.8
3	10	3	264451.	8.8168	954.3	925.5	839.2	695.3	634.5	619.5
4	1	1	220374.	99.0000	860.0	836.0	764.1	644.2	593.5	581.0
4	2	1	440777.	99.0000	1148.2	1100.3	956.4	716.6	615.2	590.1
4	3	1	661203.	99.0000	1438.0	1366.1	1150.2	790.5	638.5	600.8
4	4	1	771395.	99.0000	1585.3	1501.4	1249.6	829.9	652.5	608.6
4	5	1	881607.	99.0000	1732.7	1636.7	1349.0	869.4	666.6	616.4
4	6	1	881605.	99.0000	1737.1	1641.2	1353.4	873.8	671.1	620.9
4	7	3	771415.	3.0125	1598.1	1514.1	1262.4	842.7	665.3	621.4
4	8	3	661178.	3.5135	1459.2	1387.3	1171.5	811.8	659.7	622.1
4	9	1	440774.	99.0000	1176.5	1128.5	984.6	744.8	643.4	618.3
4	10	1	220383.	99.0000	892.2	868.3	796.3	676.4	625.7	613.2
5	1	1	220366.	99.0000	860.0	836.0	764.1	644.2	593.5	581.0
5	2	1	440792.	99.0000	1148.4	1100.5	956.6	716.8	615.4	590.3
5	3	1	661200.	99.0000	1437.7	1365.8	1149.9	790.2	638.2	600.5
5	4	1	771393.	99.0000	1585.2	1501.3	1249.5	829.9	652.4	608.5
5	5	1	881621.	99.0000	1732.4	1636.5	1348.7	869.1	666.3	616.1
5	6	1	881622.	99.0000	1737.4	1641.4	1353.7	874.1	671.3	621.1
5	7	3	771413.	2.9872	1598.2	1514.2	1262.4	842.8	665.4	621.4
5	8	1	661196.	99.0000	1459.8	1387.9	1172.1	812.4	660.3	622.7
5	9	1	440788.	99.0000	1176.3	1128.4	984.5	744.7	643.3	618.2
5	10	1	220364.	99.0000	891.9	867.9	796.0	676.1	625.4	612.8

REFERENCES

1. W. H. Reed and H. B. Stewart, "THERMIT: A Computer Program for Three-Dimensional Thermal-Hydraulic Analyses of Light Water Reactors," M.I.T. report prepared for EPRI (1978).

2. J. E. Kelly and M. S. Kazimi, "Development and Testing of the Three-Dimensional Two-Fluid Computer Code THERMIT for LWR Transient Analysis," MIT-EL-79-046 (1979).

3. J. E. Kelly, "Development of a Two-Fluid Two-Phase Model for Light Water Reactor Subchannel Analysis," Ph.D. Thesis, Department of Nuclear Engineering, M.I.T. (1980).

THERMIT-2 CODE LISTING

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C         THERMIT     VERSION OF JULY 1, 1981
C
C  CHANGES AND ADDITIONS SINCE VERSION 2.0 (DATED SEPTEMBER 1979):
C
C  1. ADDED TWO-PHASE MIXING MODEL.
C     AFFECTED: EXPLICIT, JACOB; ADDED: MIXING,THETA
C
C  2. CHANGED HEAT TRANSFER LOGIC TO ALLOW STEADY-STATE CHF.
C     AFFECTED: HTCOR
C
C  3. ADDED CISE-4 CRITICAL POWER CORRELATION.
C     ADDED: CPR
C
C  4. ADDED POST-CHF GAMMA MODEL OF SAHA
C     AFFECTED: JACOB; ADDED: GAMSUP,QISUP
C
C  5. INCLUDED ENERGY TRANSFER DUE TO MASS TRANSFER
C     AFFECTED: JACOB
C
C  CHANGES AND ADDITIONS SINCE VERSION THERMIT-2(JULY 10, 1980):
C
C  1.  ADDED BOWRING CHF CORRELATION (ICHF=5)
C
C  2.  ADDED BARNETT CHF CORRELATION (ICHF=4)
C
C  3.  CHANGES MADE IN SUBROUTINE EDIT:
C
C      A)  PRINT OUT HEAT FLUX (QPP) INSTEAD OF LINEAR HEAT FLOW (QP)
C      B)  CHECK ONSET OF CHF IN TRANSIET
C
C  4.  CHANGES MADE IN SUBROUTINE HTCOR:
C
C      A)  NEW HEAT TRANSFER LOGIC
C
C  5.  CHANGES MADE IN SUBROUTINE CPR
C
C      A)  RENAME TO CISE
C      B)  XCRIT(NEW)=(HDZ/HDH)*XCRIT(OLD)
C
C  6.  MODEFIED SUBROUTINE QINTER
C
C      A)  INCORPORATE SUBROUTINE QISUB
C      B)  INCORPORATE SUBROUTINE QISUP
C
C  7.  CHANGES MADE IN SUBROUTINE HCONV
C
C      A)  SUPRESS HEAT TRANSFER WHEN QW(J)=0
C      B)  CHANGE LOGIC FOR COMPUTING F FACTOR
C      C)  CHANGE C IN THE F FACTOR
C          FROM C=.44*POW((1.-XEQUIL),4.31)*POW(GBRIT,-.478)
C          TO   C=.44*POW((1.-XEQUIL),7.9)*POW(GBRIT,-1.72)
C
C  8.  ADD SUBROUTINE INNGBS(WRITTEN BY ANDREI SCHOR)
C
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C  9.  ADD SUBROUTINE INNXYB(WRITTEN BY ANDREI SCHOR)
C
C
C  MAIN PROGRAM
C
C ***********************************************************************
C
C                  DESCRIPTION OF DATA BASE FOR CODE
C
C
C COMMON /IC/     INTEGER CONSTANTS
C
C NSTEP   TIME STEP NUMBER
C NITMAX  MAXIMUM NUMBER OF NEWTON ITERATIONS
C NITNO   COUNTER FOR NEWTON ITERATIONS
C IITMAX  MAXIMUM NUMBER OF INNER ITERATIONS
C IITOT   TOTAL INNER ITERATIONS FOR TIME STEP
C IIC     INNER ITERATION COUNT FOR ONE NEWTON ITERATION
C KRED    COUNTER FOR REDUCED TIME STEPS
C NM      TOTAL NUMBER OF BASIC UNKNOWNS
C NTC     NUMBER OF TITLE CARDS
C NC      NUMBER OF CELLS IN X-Y PLANE
C NRODS   NUMBER OF FUEL RODS OR FUEL ROD SECTIONS TO BE MODELED
C          (IE: FOR SUBCHANNEL ANALYSIS EACH ROD IS
C           DIVIDED INTO FOUR SECTIONS)
C NZ      NUMBER OF AXIAL CELLS
C NR      NUMBER OF ROWS OF CELLS IN X-Y PLANE
C NCP     NC+1
C NZP     NZ+1
C NZP2    NZ+2
C IFLASH  PHASE CHANGE INDICATOR (0/1/2)(NIGMATULIN/SUPPRESSED/SUBCOOLED
C ITB     TOP BOUNDARY CONDITION INDICATOR (0/1)(PRESSURE/VELOCITY)
C IBB     BOTTOM BOUNDARY CONDITION INDICATOR (0/1)(PRESSURE/VELOCITY)
C ICPU    INITIAL CPU TIME
C IWFT    WALL FRICTION INDICATOR FOR TRANSVERSE DIRECTION
C          (0/1)(NO TRANSVERSE FRICTION/GUNTER-SHAW CORRELATION)
C IVEC    INDICATOR FOR TRANSVERSE VELOCITY TO BE USED IN
C         FRICTION CALCULATIONS
C          (0/1) (VX USED/ MAGNITUDE OF V USED)
C NODES   NUMBER OF TEMPERATURE NODES IN FUEL PIN
C NDM1    NUMBER OF CELLS IN FUEL PIN (NODES-1)
C NCF     NUMBER OF CELLS IN FUEL
C NCC     NUMBER OF CELLS IN CLAD
C NG      CELL IN WHICH GAP IS LOCATED
C IHT     HEAT TRANSFER INDICATOR:(0/1/2/3)(NO HEAT TRANSFER/CONSTANT
C          ROD PROPERTIES/CONSTANT GAP CONDUCTANCE/FULL CALCULATION)
C ISS     INDICATOR FOR HEAT TRANSFER CALCULATIONS (0/1/2)
C         (TRANSIENT/STEADY-STATE/STEADY-STATE WITHOUT CHF TEST)
C IQSS    INDICATOR FOR HEAT FLUX BOUNDARY CONDITION (0/1)
C         (CONSTANT HEAT FLUX/ NORMAL)
C ICHF    INDICATOR FOR CHF CORRELATION
C         (BIASI/W-3/CISE)  (1/2/3)
C ITAM    TRANSVERSE AREA INDICATOR (0/1)(NO TRANSVERSE FLOW/NORMAL)
C IRES    RESTART INDICATOR
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C IDUMP   DUMP INDICATOR
C NTITLE  NUMBER OF TITLE WORDS (1 WORD = 4 CHARACTERS)
C ITWMAX  CHANNEL LOCATION OF MAXIMUM WALL TEMPERATURE
C JTWMAX  AXIAL LOCATION OF MAXIMUM WALL TEMPERARURE
C ITRMAX  CHANNEL LOCATION OF MAXIMUM ROD TEMPERATURE
C JTRMAX  AXIAL LOCATION OF MAXIMUM ROD TEMPERATURE
C IMCHFR  CHANNEL LOCATION OF MINIMUM CHF RATIO
C JMCHFR  AXIAL LOCATION OF MINIMUM CHF RATIO
C ICHF    CHF INDICATOR
C IFINTR  INTERFACIAL FRICTION MODEL INDICATOR (0/1)(MIT/LASL)
C IERR    ERROR CODE
C LERR    LOGICAL ERROR FLAG
C IMIXM   INDICATOR FOR MOMENTUM MIXING (0/1)(NO MIXING/MIXING INCLUDED)
C IMIXE   INDICATOR FOR ENERGY MIXING (0/1)(NO MIXING/MIXING INCLUDED)
C IAFM    AXIAL FRICTION MODEL INDICATOR (0/1)(DEFAULT/USER SUPPLIED)
C ITFM    TRANSVERSE FRICTION MODEL INDICATOR (0/1)(DEFAULT/USER SUPPLIE
C IGFM    GRID FRICTION MODEL (0/1)(DEFAULT/USER SUPPLIED)
C
C
C COMMON /RC/     REAL CONSTANTS
C
C DELT    TIME STEP SIZE
C RDELT   1/DELT
C ERRN    NEWTON ITERATION ERROR
C EPSN    NEWTON ITERATION CONVERGENCE CRITERION
C ERRI    INNER ITERATION ERROR
C EPSI    INNER ITERATION CONVERGENCE CRITERION
C DTMIN   MINIMUM TIME STEP SIZE(CURRENTLY DELT=DTMIN)
C DTMAX   MAXIMUM TIME STEP SIZE
C TEND    END OF TIME ZONE
C DTSP    SHORT PRINT TIME INTERVAL
C DTLP    LONG PRINT TIME INTERVAL
C RTNSP   REAL TIME AT NEXT SHORT PRINT
C RTNLP   REAL TIME AT NEXT LONG PRINT
C GRAV    GRAVITATIONAL CONSTANT (NORMALLY -9.8)
C RTIME   REAL TIME
C HDT     HYDRAULIC DIAMETER IN TRANSVERSE DIRECTION
C VELX    VELOCITY MULTIPLIER FOR TRANSVERSE FRICTION CORRELATION
C Q       TOTAL POWER LEVEL (W)
C QO      INITIAL TOTAL POWER (W)
C TO      DELAY TIME (S)
C OMG     INVERSE REACTOR PERIOD (1/S)
C RADR    FUEL ROD RADIUS (M)
C THC     CLAD THICKNESS (M)
C THG     GAP WIDTH (M)
C TWMAX   MAXIMUM WALL TEMPERATURE
C TRMAX   MAXIMUM ROD TEMPERATURE
C AMCHFR  MINIMUM CRITICAL HEAT FLUX RATIO
C
C
C COMMON /PROP/     CONSTANTS FOR FUEL PROPERTIES
C
C FTD     FRACTION OF THEORETICAL DENSITY OF FUEL
C FPUO2   FRACTION OF PUO2
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C FPRESS  FUEL PRESSURE ON CLAD FOR GAP CONDUCTANCE MODEL (PA)
C CPR     COEFFICIENT OF ABOVE PRESSURE
C EXPR    EXPONENT FOR ABOVE PRESSURE
C GRGH    GAP ROUGHNESS (M)
C PGAS    GAP GAS PRESSURE (PA)
C GMIX(1) HELIUM FRACTION IN GAP GAS
C GMIX(2) ARGON FRACTION IN GAP GAS
C GMIX(3) KRYPTON FRACTION IN GAP GAS
C GMIX(4) XENON FRACTION IN GAP GAS
C HGAP    GAP HEAT TRANSFER COEFFICIENT
C BURN    BURNUP
C EFFB    FRACTIONAL EFFECT OF BURNUP
C FRAC    FRACTION OF FUEL PERIMETER CONTACTING CLAD
C
C
C COMMON /FORCE/    TRANSIENT FORCING FUNCTION DATA
C
C BOTFAC(30)   BOTTOM BOUNDARY CONDITION FACTORS
C YB(30)       TIME VECTOR FOR BOTFAC
C TOPFAC(30)   TOP BOUNDARY CONDITION FACTORS
C YT(30)       TIME VECTOR FOR TOPFAC
C TINFAC(30)   INLET TEMPERATURE FACTORS
C YTEMP(30)    TIME VECTOR FOR TINFAC
C QFAC(30)     REACTOR POWER FACTORS
C YQ(30)       TIME VECTOR FOR QFAC
C NB           NUMBER OF ENTRIES IN BOTFAC TABLE   <=30
C NT           NUMBER OF ENTRIES IN TOPFAC TABLE   <=30
C NTEMP        NUMBER OF ENTRIES IN TINFAC TABLE   <=30
C NQ           NUMBER OF ENTRIES IN QFAC TABLE   <=30
C
C
C COMMON /FRICMD/     CONSTANTS IN FRICTION MODEL
C
C FCON(1,1-4)   AXIAL MODEL
C FCON(2,1-4)   GRID MODEL
C FCON(3,1-4)   GRID MODEL WITH FUNNEL EFFECT
C FCON(4,1-4)   TRANSVERSE MODEL
C   .
C COMMON /POINT/     POINTERS FOR ALL ARRAYS
C
C LNCR   NCR(NR)              NUMBER OF CHANNELS PER ROW
C LINDNT INDENT(NR)           INDENTATION OF EACH ROW
C LICC   ICC(4,NC)            INDICES FOR FOUR ADJACENT SUBCHANNELS
C LIWFZ  IWFZ(NZP)            INDICATOR FOR AXIAL WALL FRICTION
C LIHTR  IHTR(NZ,NRODS)       HEAT TRANSFER REGIME INDICATOR
C LICR   ICR(NRODS)           INDICES OF CHANNELS ADJACENT TO RODS
C LIRC   IRC(4,NC)            INDICES OF RODS ADJACENT TO CHANNELS
C
C LP     P(NZP2,NCP)          OLD PRESSURE
C LALP   ALP(NZP2,NCP)        OLD VAPOR VOLUME FRACTION
C LROV   ROV(NZP2,NCP)        OLD VAPOR DENSITY
C LROL   ROL(NZP2,NCP)        OLD LIQUID DENSITY
C LEV    EV(NZP2,NCP)         OLD VAPOR SPECIFIC INTERNAL ENERGY
C LEL    EL(NZP2,NCP)         OLD LIQUID SPECIFIC INTERNAL ENERGY
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C LTV    TV(NZP2,NCP)         OLD VAPOR TEMPERATURE
C LTL    TL(NZP2,NCP)         OLD LIQUID TEMPERATURE
C LTR    TR(NODES,NZ,NRODS)   OLD FUEL PIN TEMPERATURES
C
C LPN    PN(NZP2,NCP)         NEW PRESSURE
C LALPN  ALPN(NZP2,NCP)       NEW VAPOR VOLUME FRACTION
C LROVN  ROVN(NZP2,NCP)       NEW VAPOR DENSITY
C LROLN  ROLN(NZP2,NCP)       NEW LIQUID DENSITY
C LEVN   EVN(NZP2,NCP)        NEW VAPOR SPECIFIC INTERNAL ENERGY
C LELN   ELN(NZP2,NCP)        NEW LIQUID SPECIFIC INTERNAL ENERGY
C LTVN   TVN(NZP2,NCP)        NEW VAPOR TEMPERATURE
C LTLN   TLN(NZP2,NCP)        NEW LIQUID TEMPERATURE
C LTRN   TRN(NODES,NZ,NRODS)  NEW FUEL PIN TEMPERATURES
C
C LVVX   VVX(NZP2,NCP)        OLD VAPOR VELOCITY IN X DIRECTION
C LVLX   VLX(NZP2,NCP)        OLD LIQUID VELOCITY IN X DIRECTION
C LVVY   VVY(NZP2,NCP)        OLD VAPOR VELOCITY IN Y DIRECTION
C LVLY   VLY(NZP2,NCP)        OLD LIQUID VELOCITY IN Y DIRECTION
C LVVZ   VVZ(NZP,NCP)         OLD VAPOR VELOCITY IN Z DIRECTION
C LVLZ   VLZ(NZP,NCP)         OLD LIQUID VELOCITY IN Z DIRECTION
C LHV    HV(NZP2,NCP)         OLD VAPOR SPECIFIC ENTHALPY
C LHL    HL(NZP2,NCP)         OLD LIQUID SPECIFIC ENTHALPY
C LHVS   HVS(NZP2,NCP)        OLD VAPOR SATURATION ENTHALPY
C LHLS   HLS(NZP2,NCP)        OLD LIQUID SATURATION ENTHALPY
C LTSAT  TSAT(NZP2,NCP)       SATURATION TEMPERATURE
C LVISV  VISV(NZP2,NCP)       VISCOSITY OF VAPOR
C LVISL  VISL(NZP2,NCP)       VISCOSITY OF LIQUID
C
C LDX    DX(NCP)              MESH SPACING IN X DIRECTION
C LDY    DY(NCP)              MESH SPACING IN Y DIRECTION
C LDZ    DZ(NZP2)             MESH SPACING IN Z DIRECTION
C LARX   ARX(NZ,NCP)          MESH CELL AREAS IN X DIRECTION
C LARY   ARY(NZ,NCP)          MESH CELL AREAS IN Y DIRECTION
C LARZ   ARZ(NZP,NC)          MESH CELL AREAS IN Z DIRECTION
C LVOL   VOL(NZ,NC)           MESH CELL VOLUMES
C LCPVX  CPVX(NZ,NC)          PRESSURE COEFFICIENT IN X DIR VAP MOM EQ
C LCPVY  CPVY(NZ,NC)          PRESSURE COEFFICIENT IN Y DIR VAP MOM EQ
C LCPVZ  CPVZ(NZP,NC)         PRESSURE COEFFICIENT IN Z DIR VAP MOM EQ
C LCPLX  CPLX(NZ,NC)          PRESSURE COEFFICIENT IN X DIR LIQ MOM EQ
C LCPLY  CPLY(NZ,NC)          PRESSURE COEFFICIENT IN Y DIR LIQ MOM EQ
C LCPLZ  CPLZ(NZP,NC)         PRESSURE COEFFICIENT IN Z DIR LIQ MOM EQ
C LFVX   FVX(NZ,NC)           EXPLICIT TERMS IN X DIRECTION VAP MOM EQ
C LFVY   FVY(NZ,NC)           EXPLICIT TERMS IN Y DIRECTION VAP MOM EQ
C LFVZ   FVZ(NZP,NC)          EXPLICIT TERMS IN Z DIRECTION VAP MOM EQ
C LFLX   FLX(NZ,NC)           EXPLICIT TERMS IN X DIRECTION LIQ MOM EQ
C LFLY   FLY(NZ,NC)           EXPLICIT TERMS IN Y DIRECTION LIQ MOM EQ
C LFLZ   FLZ(NZP,NC)          EXPLICIT TERMS IN Z DIRECTION LIQ MOM EQ
C LAJM1  AJM1(3,NZ,NC)        TRIDIAGONAL PART OF JACOBIAN MATRIX
C LAJM2  AJM2(4,NZ,NC)        REMAINDER OF JACOBIAN MATRIX
C LCPA   CPA(6,NZ,NC)         PRESSURE COEFFICIENTS IN EQ FOR ALPHA
C LCPTV  CPTV(6,NZ,NC)        PRESSURE COEFFICIENTS IN EQ FOR VAPOR TEMP
C LCPTL  CPTL(6,NZ,NC)        PRESSURE COEFFICIENTS IN EQ FOR LIQUID TEMP
C LRHS   RHS(NZ,NC,4)         RIGHT HAND SIDE OF ALL EQUATIONS
C LDP    DP(NZP2,NC)          PRESSURE CHANGE
```

```
C LQPP   QPP(NZ,NRODS)         TOTAL LINEAR HEAT FLUX
C LQV    QV(NZ,NRODS)          HEAT FLUX TO VAPOR FOR TRANSITION BOILING
C LQL    QL(NZ,NRODS)          HEAT FLUX TO LIQUID FOR TRANSITION BOILING
C LHVFC  HVFC(NZ,NRODS)        HEAT TRANSFER COEFFICIENT TO VAPOR
C LHLNB  HLNB(NZ,NRODS)        HEAT TRANSFER COEFFICIENT TO LIQUID
C                               (NUCLEATE BOILING)
C LHLFC  HLFC(NZ,NRODS)        HEAT TRANSFER COEFFICIENT TO LIQUID
C                               (FORCED CONVECTION)
C LDTRN  DTRN(NDM1,NZ,NRODS)   SAVES INTERMEDIATE ROD TEMP SOLUTION
C                               DURING FLUID DYNAMICS ITERATIONS
C LDTW   DTW(NZ,NRODS)         CHANGE IN TW PER FLUID TEMP CHANGE
C LTW    TW(NZ,NRODS)          WALL SURFACE TEMPERATURE
C LCHFR  CHFR(NZ,NRODS)        CRITICAL HEAT FLUX RATIO
C LFRAC  FRACP(NRODS)          FRACTION OF TOTAL HEATED PERIMETER
C                              FACING ITS ADJACENT CHANNEL
C LHDZ   HDZ(NC)               HYDRAULIC DIAMETER OF EACH CHANNEL
C LHDH   HDH(NC)               EQUIVALENT HEAT DIAMETER OF EACH CHANNEL
C LQZ    QZ(NZ)                AXIAL POWER SHAPE FUNCTION
C LQT    QT(NC)                TRANSVERSE POWER SHAPE FUNCTION
C LQR    QR(NDM1)              FUEL PIN RADIAL POWER SHAPE
C LQPPP  QPPP(NDM1)            FUEL PIN POWER DENSITY
C LRN    RN(NC)                NUMBER OF FUEL RODS IN EACH CHANNEL
C LCND   CND(NDM1)             FUEL PIN CONDUCTIVITIES
C LRCP   RCP(NDM1)             FUEL PIN DENSITY TIMES SPECIFIC HEAT
C LRRDR  RRDR(NDM1)            R/(DELTA R) AT FUEL PIN CELL CENTERS
C LVP    VP(NODES)             VOLUME OF HALF CELL OUTSIDE A FUEL PIN NODE
C LVM    VM(NODES)             VOLUME OF HALF CELL INSIDE A FUEL PIN NODE
C LRAD   RAD(NODES)            RADII OF FUEL PIN NODES
C
C LBOTBC BOTBC(NC)             INITIAL BOTTOM BOUNDARY CONDITIONS
C LTOPBC TOPBC(NC)             INITIAL TOP BOUNDARY CONDITIONS
C LTMPBC TMPBC(NC)             INITIAL INLET TEMPERATURES
C LSIJ   SIJ(4,NC)             CHANNEL GAP WIDTHS(M)
C
C LEND                         FIRST FREE CORE LOCATION
C                               (SOME SPACE BEYOND THIS POINTER IS USED
C                                AS SCRATCH PADS.)
C
C ******************************************************************
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR, LICR,LIRC, LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
```

```
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG,  RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      COMMON /PROP/ FTD,FPU02,FPRESS,CPR,EXPR,GRGH,PGAS,GMIX(4),
     1   HGAP,BURN,EFFB,FRAC
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
      COMMON /FORCE/ BOTFAC(30),YB(30),TOPFAC(30),YT(30),
     1         TINFAC(30),YTEMP(30),QFAC(30),YQ(30),NB,NT,NTEMP,NQ
      COMMON /FRICMD/ FCON(4,4)
C
C  THE FOLLOWING STATEMENTS INITIALIZE COMMONS FOR MULTICS PROBE
C
      A(1)=A(1)
      LP=LP
      DELT=DELT
      FTD=FTD
      BOTFAC(1)=BOTFAC(1)
      FCON(1,1)=FCON(1,1)
C
C
C  SET I/O UNITS
C
      NTTY=15
      NINP=5
      NOUT=6
      NRES=8
      NDUMP=9
      NTZC=NINP
      IRES=0
      IERR=0
      LERR=.FALSE.
      LOUTPU=.FALSE.
C
C  READ INPUT DATA
C
  100 CALL INPUT
      IF (LERR) GO TO 200
C
C  INITIALIZE ARRAYS
C
      IF(IRES.EQ.0) CALL INIT
C
C  PERFORM TRANSIENT CALCULATION
C
      CALL TRANS
      IF (LERR) GO TO 200
C
C  TAKE RESTRT DUMP
C
      IF(IDUMP.EQ.1)CALL DUMP
C
C  RETURN FOR ANOTHER CASE
C
```

```
      GO TO 100
C
C  ERROR DETECTED
C
  200 CALL ERROR
      STOP
      END
      BLOCK DATA
      COMMON /FRICMD/ FCON(4,4)
      DATA  FCON  / 64.,    1502.11,    .184, -.2,
     1              0.,     1.,         3., -.1,
     2              0.,     1.,         3., -.1,
     3              180.,  202.5,     1.92, -.145  /
      END
```

```
      SUBROUTINE ERROR
C
C  PRINTS UNCODED ERROR MESSAGE
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
C
      GO TO (10,20,30,40,50,60,70,80,90,100,110), IERR
C
   10 WRITE(NTTY,1001)
      WRITE(NOUT,1001)
      RETURN
   20 WRITE(NTTY,1002)
      WRITE(NOUT,1002)
      RETURN
   30 WRITE(NTTY,1003)
      WRITE(NOUT,1003)
      RETURN
   40 WRITE(NTTY,1004)
      WRITE(NOUT,1004)
      RETURN
   50 WRITE(NTTY,1005)
      WRITE(NOUT,1005)
      RETURN
   60 WRITE(NTTY,1006)
      WRITE(NOUT,1006)
      RETURN
   70 WRITE(NTTY,1007)
      WRITE(NOUT,1007)
      RETURN
   80 WRITE(NTTY,1008)
      WRITE(NOUT,1008)
      RETURN
   90 WRITE(NTTY,1009)
      WRITE(NOUT,1009)
  100 WRITE(NTTY,1010)
      WRITE(NOUT,1010)
      RETURN
  110 WRITE(NTTY,1020)
      WRITE(NOUT,1020)
      RETURN
 1001  FORMAT(41H INPUT ERROR IN INTEGER OR REAL PARAMETER)
 1002  FORMAT(21H INPUT ERROR IN ARRAY)
 1003  FORMAT(41H PRESSURE PROBLEM NOT DIAGONALLY DOMINANT)
 1004  FORMAT(41H PRESSURE OUT OF RANGE OF STATE FUNCTIONS)
 1005  FORMAT(51H LIQUID TEMPERATURE OUT OF RANGE OF STATE FUNCTIONS)
 1006  FORMAT(50H VAPOR TEMPERATURE OUT OF RANGE OF STATE FUNCTIONS)
 1007  FORMAT(23H NEGATIVE VOID FRACTION)
 1008  FORMAT(23H VOID FRACTION OVER ONE)
```

```
1009  FORMAT(37H NEWTON ITERATIONS FAILED TO CONVERGE)
1010  FORMAT(43H CONVECTIVE TIME STEP LIMIT LESS THAN DTMIN)
1020 FORMAT(23H NEGATIVE HEAT TRANSFER)
     END
```

```
      SUBROUTINE START
C
C  PREPARES TO RESTRT A PREVIOUS CALCULATION BY READING IN
C   COMMONS FROM AN UNFORMATTED DATA FILE
C
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR,  LICR,LIRC,LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      COMMON /PROP/ FTD,FPUO2,FPRESS,CPR,EXPR,GRGH,PGAS,GMIX(4),
     1   HGAP,BURN,EFFB,FRAC
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
      COMMON/FORCE/ BOTFAC(30),YB(30),TOPFAC(30),YT(30),
     1      TINFAC(30),YTEMP(30),QFAC(30),YQ(30),NB,NT,NTEMP,NQ
      COMMON /FRICMD/ FCON(4,4)
      DIMENSION D1(1),D2(1),D3(1),D4(1),D5(1),D6(1)
      EQUIVALENCE (D1(1),LNCR),(D2(1),NSTEP),(D3(1),DELT),(D4(1),FTD),
     1            (D5(1),BOTFAC(1)),(D6(1),FCON(1,1))
C
C  RESTORE COMMONS
C
      REWIND NRES
      READ(NRES)(D1(I),I=1,93)
      READ(NRES)(D2(I),I=1,50)
      READ(NRES)(D3(I),I=1,27)
      READ(NRES)(D4(I),I=1,15)
      READ(NRES)(D5(I),I=1,244)
      READ(NRES)(D6(I),I=1,16)
      READ(NRES)(A(I),I=1,LEND)
      WRITE(NTTY,1001) NRES
 1001 FORMAT(23H COMMONS READ FROM FILE,I3)
      RETURN
      END
```

```
      SUBROUTINE DUMP
C
C  AT THE END OF A CALCULATION, THIS SUBROUTINE DUMPS ALL COMMONS
C   ONTO AN UNFORMATTED DATA FILE FOR LATER USE WITH RESTRT
C
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR,  LICR,LIRC,LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      COMMON /PROP/ FTD,FPUO2,FPRESS,CPR,EXPR,GRGH,PGAS,GMIX(4),
     1   HGAP,BURN,EFFB,FRAC
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
      COMMON/FORCE/ BOTFAC(30),YB(30),TOPFAC(30),YT(30),
     1  TINFAC(30),YTEMP(30),QFAC(30),YQ(30),NB,NT,NTEMP,NQ
      COMMON /FRICMD/ FCON(4,4)
      DIMENSION D1(1),D2(1),D3(1),D4(1),D5(1),D6(1)
      EQUIVALENCE (D1(1),LNCR),(D2(1),NSTEP),(D3(1),DELT),(D4(1),FTD)
     1            ,(D5(1),BOTFAC(1)),(D6(1),FCON(1,1))
C
C  DUMP COMMONS
C
      REWIND NDUMP
      WRITE(NDUMP)(D1(I),I=1,93)
      WRITE(NDUMP)(D2(I),I=1,50)
      WRITE(NDUMP)(D3(I),I=1,27)
      WRITE(NDUMP)(D4(I),I=1,15)
      WRITE(NDUMP)(D5(I),I=1,244)
      WRITE(NDUMP) (D6(I),I=1,16)
      WRITE(NDUMP)(A(I),I=1,LEND)
      WRITE(NTTY,1001) NDUMP
 1001 FORMAT(23H COMMONS DUMPED ON FILE,I3)
      RETURN
      END
```

```
      SUBROUTINE NIPS(IH1,IH2,INX,X,NK,IERR,IFLAG)
C
C  A BUILT-IN FREE FORMAT INPUT INTERPRETER FOR ARRAY DATA
C
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
      DIMENSION X(NK),INX(NK),NMULT(10),IND(10)
      INTEGER INED(18),A(80),XX
      DATA INED/4H    ,4H0   ,4H1   ,4H2   ,4H3   ,4H4   ,
     1  4H5   ,4H6   ,4H7   ,4H8   ,4H9   ,4H.   ,4H-   ,4H+   ,
     2    4HE   ,4H(   ,4H)   ,4H$   /
C
C  PRINT ECHO CHECK
C
      WRITE(NOUT,1238) IH1,IH2
 1238 FORMAT(1H ,2A4)
      READ(NINP,1234) A
 1234 FORMAT(80A1)
      WRITE(NOUT,1235) A
 1235 FORMAT(1H ,'CARD IMAGE>',80A1,'<')
      NPAR  = 1
      IXA=1
      NN = 0
      KOUNTA=1
      IF (IFLAG.EQ.1) GO TO 500
      N=5
      GO TO 58
    7 IF (KOUNTA-80) 9,9,8
    8 KOUNTA = 1
      READ(NINP,1234) A
      WRITE(NOUT,1235) A
    9 XX=A(KOUNTA)
      KOUNTA=KOUNTA+1
      DO 100 IPT = 1, 19
      IF(XX-INED(IPT)) 100,200,100
  100 CONTINUE
      GO TO 301
  200 K=IPT
C
CC    K IS THE CHARACTER NUMBER ( RANGE - 1 TO 18 )
CC    N IS THE OPERATION NUMBER
CC          OPERATION BRANCH FOR COMMENTS
C
 10   CONTINUE
      IF (N)11,11,13
11    CONTINUE
      IF (K-17)7,12,7
   12 N=5
      GO TO 7
   13 CONTINUE
      GO TO (14,15,16,17,18,19,20,21,22,23,24,25,27,30,33,60,80,250)
     1,K
CC
CC
CC
```

```
CC          CHARACTER BRANCH
CC
   14 CONTINUE
      GO TO (50,48,45,301,7),N
   15 XT=0.0
      GO TO 40
   16 XT=1.0
      GO TO 40
   17 XT=2.0
      GO TO 40
   18 XT=3.0
      GO TO 40
   19 XT=4.0
      GO TO 40
   20 XT=5.0
      GO TO 40
   21 XT=6.0
      GO TO 40
   22 XT=7.0
      GO TO 40
   23 XT=8.0
      GO TO 40
   24 XT=9.0
      GO TO 40
CC          OPERATION BRANCH FOR .
   25 GO TO (26,301,301,301,26),N
   26 N=2
      GO TO 7
CC          OPERATION BRANCH FOR -
   27 GO TO (301,28,28,301,29),N
   28 ISGNB=-1
   31 N=3
      GO TO 7
   29 ISGNA=-1
      N=1
      GO TO 7
CC          OPERATION BRANCH FOR +
   30 GO TO (301,31,7,7,32),N
   32 N=1
      GO TO 7
CC          OPERATION BRANCH FOR E
   33 IF (N-2)301,31,301
CC
CC          OPERATION BRANCH FOR (
CC
   60 IF (NPAR.GT.10) GO TO 70
      IF (N.EQ.5) GO TO 65
      IF (N.NE.1) GO TO 62
      IF (ISGNA.LT.0) GO TO 62
      NMULT(NPAR) = XL-1
      XL = 0.
      XR = 10.
   61 IND(NPAR) = IXA
      NPAR = NPAR+1
```

```
      N = 5
      GO TO 7
   62 WRITE(NOUT,64)
   64 FORMAT(1H ,'MULTIPLIER INCORRECT')
      GO TO 301
   65 NMULT(NPAR) = 0
      GO TO 61
   70 WRITE(NOUT,75)
   75 FORMAT(1H ,'GREATER THAN TEN LEVELS OF PARENTHESES')
      GO TO 301
CC
CC          OPERATION BRANCH FOR )
CC
   80 IF (NPAR.LE.1) GO TO 86
      NPAR = NPAR-1
      IF (N.EQ.5) GO TO 82
      NN = -1
      GO  TO 14
   82 NEL = IXA-IND(NPAR)
      IF (NEL.EQ.0) GO TO 85
      IF (NMULT(NPAR).EQ.0) GO TO 85
      JTEMP=NMULT(NPAR)
      DO 89 JJ = 1,JTEMP
      DO 84 I = 1,NEL
      IF (IXA.GT.NK) GO TO 400
      X(IXA) = X(IND(NPAR)+I-1)
   84 IXA = IXA+1
   89 CONTINUE
   85 NN = 0
      GO TO 58
   86 WRITE(NOUT,88)
   88 FORMAT(1H ,'UNEXPECTED RIGHT PARENTHESIS FOUND')
      GO TO 301
CC
CC          OPERATION BRANCH FOR INTEGERS
   40 GO TO (41,42,43,43,44,41),N
   41 XL=XL*10.0+XT
      GO TO 7
C  THE REAL DIVIDE - XT/XR ON CDC 6600  IS INACCURATE IN PLACE 15.
C  THE SCALE FACTOR BELOW IS TO ELIMINATE THE PROBLEM CAUSED WHEN XL
C  IS LATER STORED INTO AN INTEGER IN RDV1 ETC.  TRUNCATION PROBLEM.
C  NOT SURE THAT THIS SCALE FACTOR IS BIG ENOUGH FOR IBM
   42 XL=XL+(XT/XR)*1.
      XR=XR*10.0
      GO TO 7
   43 IXE=IXE*10+K-2
      GO TO 7
   44 N=1
      XL=XT
      GO TO 7
CC          TERMINATION FOR FLOATING VALUE WITH EXPONENT
   45 IF (ISGNB)46,47,47
   46 IXE=-IXE
   47 XL=XL*10.0**IXE
```

```
CC          TERMINATION FOR FLOATING VALUE
   50 CONTINUE
   48 IF (ISGNA)49,55,55
   49 XL=-XL
      GO TO 55
CC          LOAD THE VALUE
   55 IF (IXA.GT.NK) GO TO 400
      X(IXA) = XL
      IXA=IXA+1
CC          INITIALIZE FOR NEXT VALUE
      IF (NN) 82,58,255
   58 XL = 0.0
      XR=10.0
      IXE=0
      ISGNA=1
      ISGNB=1
      N=5
      GO TO 7
CC
CC          OPERATION BRANCH FOR TERMINATION
CC
  250 IF (N.EQ.5) GO TO 255
      NN = 1
      GO TO 14
  255 IXA1 = IXA-1
      IF (IXA1.NE.NK) GO TO 400
C 260 WRITE(NOUT,1239) X
 1239 FORMAT(1H ,10E12.4)
      RETURN
  500 N = 0
      GO TO 592
  507 IF (KOUNTA-80) 509,509,508
  508 KOUNTA = 1
      READ(NINP,1234) A
      WRITE(NOUT,1235) A
  509 XX = A(KOUNTA)
      KOUNTA = KOUNTA + 1
      DO 520 IPT = 1,18
      IF (XX-INED(IPT)) 520,540,520
  520 CONTINUE
      GO TO 301
  540 GO TO (545,550,550,550,550,550,550,550,550,
     1     550,550,301,555,560,301,570,580,600), IPT
CC
  545 IF (N) 590,507,590
CC
  550 II = IPT-2
      IT = IT*10+II
      IF (N.NE.0) GO TO 507
      N = 1
      GO TO 507
CC
CC     OPERATION BRANCH FOR -
CC
```

```
  555 IF (N) 301,556,301
  556 N = -1
      GO TO 507
CC
CC            OPERATION BRANCH FOR +
CC.
  560 IF (N) 301,562,301
  562 N = 1
      GO TO 507
CC
CC            OPERATION BRANCH FOR (
CC
  570 IF (NPAR.GT.10) GO TO 70
      IF (N) 301,574,571
  571 NMULT(NPAR) = IT-1
      II = 0
      IT = 0
  572 IND(NPAR) = IXA
      NPAR = NPAR+1
      N = 0
      GO TO 507
  574 NMULT(NPAR) = 0
      GO TO 572
CC
CC            OPERATION BRANCH FOR )
CC
  580 IF (NPAR.LE.1) GO TO 86
      NPAR = NPAR-1
      IF (N.EQ.0) GO TO 583
      IF (IXA.GT.NK) GO TO 400
      INX(IXA) = IT*N
      IXA = IXA+1
  583 NEL = IXA-IND(NPAR)
      IF (NEL.EQ.0) GO TO 589
      IF (NMULT(NPAR).EQ.0) GO TO 589
      JTEMP=NMULT(NPAR)
      DO 588 IXX = 1,JTEMP
      DO 584 IXY = 1,NEL
      IF (IXA.GT.NK) GO TO 400
      INX(IXA) = INX(IND(NPAR)+IXY-1)
  584 IXA = IXA+1
  588 CONTINUE
  589 GO TO 592
CC
  5   IF (IXA.GT.NK) GO TO 400
      INX(IXA) = IT*N
      IXA = IXA+1
  592 N = 0
      IT = 0
      II = 0
      GO TO 507
CC
CC            OPERATION BRANCH FOR TERMINATION
CC
```

```
  600 IF (N.EQ.0) GO TO 604
  602 INX(IXA) = IT*N
      IXA = IXA+1
  604 IXA1 = IXA-1
      IF (IXA1.NE.NK) GO TO 400
C     WRITE(NOUT,1267) INX
 1267 FORMAT(1H ,20(1X,I5))
      RETURN
CC
CC          ERROR RETURN
CC
  301 CONTINUE
      KOUNTA = KOUNTA - 1
      WRITE(NOUT,1266) KOUNTA, IH1,IH2
 1266 FORMAT(1H ,'  ERROR AT COLUMN',I4,' TRYING TO READ ',2A4)
      IERR = -1
      RETURN
  400 IERR = -1
      WRITE(NOUT,444) IH1,IH2
  444 FORMAT(1H ,'NIPS ERROR - WRONG NUMBER OF VALUES',
     1           ' WHILE TRYING TO READ ',2A4)
      RETURN
      END
```

```
      SUBROUTINE INPUT
C
C  READS ONE FULL BLOCK OF INPUT DATA
C   ALSO SETS POINTERS FOR VARIABLY DIMENSIONED ARRAYS
C
      REAL*8 BCTYPE(2),FPTYPE(4,4),QPPTYP(2),CHFTYP(5),TRNFLO(2,2),
     1       MIXMOD(3,2)
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR,  LICR,LIRC,LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      COMMON /FRICMD/ FCON(4,4)
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      COMMON /PROP/ FTD,FPUO2,FPRESS,CPR,EXPR,GRGH,PGAS,GMIX(4),
     1   HGAP,BURN,EFFB,FRAC
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
       COMMON/FORCE/BOTFAC(30),YB(30),TOPFAC(30),YT(30),TINFAC(30),
     1              YTEMP(30),QFAC(30),YQ(30),NB,NT,NTEMP,NQ
      DIMENSION IA(1)
      DIMENSION GTYPE(3,3),FITYPE(2),HTTYPE(3,3),CHFCHK(5,3),
     1          TFTYPE(3,2),TVTYPE(3,2)
      EQUIVALENCE (A(1),IA(1))
      NAMELIST/RESTRT/NITMAX,IITMAX,IFLASH,ITB,IBB,IWFT,IHT,ISS,EPSN,
     1 EPSI,GRAV,HDT,Q0,T0,OMG,ITAM,ICHF,IDUMP,IQSS,IVEC,IMIXM,IMIXE
     2  ,THETAM
      NAMELIST/TFDATA/BOTFAC,TOPFAC,TINFAC,QFAC,YB,YT,YTEMP,YQ,NB,NT,
     1     NTEMP,NQ
C
C  DATA FOR THERMAL-HYDRAULIC OPTIONS
C
      DATA BCTYPE/8HPRESSURE,8HVELOCITY/
      DATA GTYPE/4HNIGM,4HATUL,4HIN  ,4HSUPP,4HRESS,4HED  ,4HSUBC,
     1          4HOOLE,4HD   /
      DATA FITYPE/4HMIT ,4HLASL/
      DATA FPTYPE/8HNO FUEL ,8HPIN MODE,8HL       ,8H        ,
     1          8HCONSTANT,8H PROPERT,8HY FUEL P,8HIN MODEL,
     2          8HCONSTANT,8H HGAP FU,8HEL PIN M,8HODEL    ,
     3          8HFULL CAL,8HCULATION,8H FUEL PI,8HN MODEL /
      DATA HTTYPE/4HTRAN,4HSIEN,4HT   ,
     1          4HSTEA,4HDY-S,4HTATE,
```

```
     2              4HSTEA,4HDY-S,4HTATE/
      DATA CHFCHK/4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,4H    ,
     1           4H    ,4H    ,4H    ,4HWITH,4HOUT ,4HCHF ,4HCHEC,4HK   /
      DATA QPPTYP/8HCONSTANT,8HCOUPLED /
      DATA CHFTYP/8HBIASI   ,8HW-3     ,8HCISE-4  ,
     +              8HBARNETT ,8HBOWRING /
      DATA TFTYPE/4HNONE,4H    ,4H    ,4HGUNT,4HER-S,4HHAW /
      DATA TVTYPE/4HTRAN,4HSVER,4HSE  ,4HMAGN,4HITUD,4HE OF/
      DATA TRNFLO/8HNOT CALC,8HULATED  ,8HCALCULAT,8HED      /
      DATA MIXMOD/8HNO MIXIN,8HG MODEL ,8H        ,
     1              8HMIXING M,8HODEL INC,8HLUDED   /
C
C  TEST FOR RESTRT
C
      IF(IRES.NE.0)GO TO 100
C
C  READ TITLE
C
      READ(NINP,*)NTC
C
C  IF NTC=0 STOP
C
      IF(NTC.EQ.0)STOP
C
C  IF NTC<0 RESTRT
C
      IRES=IABS(NTC)
      IF(NTC.LT.0)GO TO 100
      IRES=0
      NTITLE=20*NTC
      READ(NINP,1002)(A(I),I=1,NTITLE)
      WRITE(NOUT,1011)
      WRITE(NOUT,1003)(A(I),I=1,NTITLE)
C
C  READ ARRAY DIMENSIONS
C
      READ(NINP,*) NC,NR,NRODS,NZ,NCF,NCC
C
C   READ THERMAL-HYDRAULIC DATA
C
      READ(NINP,*) ITB,IBB,IFLASH,IFINTR,IHT,ISS,IQSS,ICHF,
     1               IWFT,IVEC,ITAM,IMIXM,IMIXE,IAFM,ITFM,IGFM,
     2               GRAV,HDT,VELX
      IF(IAFM.EQ.1) READ(NINP,*) (FCON(J,1),J=1,4)
      IF(ITFM.EQ.1) READ(NINP,*) (FCON(J,4),J=1,4)
      IF(IGFM.NE.1) GO TO 7
      READ(NINP,*) (FCON(J,2),J=3,4)
      FCON(3,3)=FCON(3,2)
      FCON(4,3)=FCON(4,2)
 7    CONTINUE
C
C   READ ITERATION CONTROL DATA
C
      READ(NINP,*) IDUMP,NITMAX,IITMAX,EPSN,EPSI
```

```
      IF (MAXO(ITB,IBB,IWFT,IVEC,ITAM,IMIXM,IMIXE,IQSS,IDUMP,IFINTR,
     1     IAFM,ITFM,IGFM) .GT.1) GO TO 901
      IF (MAXO(IFLASH,ISS).GT.2) GO TO 901
      IF (ICHF.GT.5) GO TO 901
      IF (MINO(NC,NRODS,NZ,NR,IFLASH,ITB,IBB,IWFT,IVEC,NCF,NCC,IHT,
     1    IAFM,ITFM,IGFM,
     T       ISS,IQSS,ICHF,ITAM,IMIXE,IMIXM,IFINTR).LT.0) GO TO 901
      IF(IHT.EQ.0) GO TO 10
C
C   READ HEAT TRANSFER DATA
C
      READ(NINP,*)Q0,TO,OMG,RADR,THC,THG,HGAP,FTD,FPUO2,
     1 FPRESS,CPR,EXPR,GRGH,PGAS,(GMIX(K),K=1,4),BURN
      IF(AMIN1(RADR,THC,THG,FTD,FPUO2,HGAP,BURN).LT.0.)GOTO901
      IF (AMAX1(FTD,FPUO2,GMIX(1),GMIX(2),GMIX(3),GMIX(4)).GT.1.)
     T  GO TO 901
   10 CONTINUE
C
C   WRITE PROBLEM DATA
C
      WRITE(NOUT,1005) NC,NR,NRODS,NZ,NCF,NCC
      WRITE(NOUT,1006) BCTYPE(ITB+1),BCTYPE(IBB+1),(GTYPE(I,IFLASH+1)
     1      ,I=1,3),FITYPE(IFINTR+1),(FPTYPE(I,IHT+1),I=1,4),(HTTYPE(I,
     2      ISS+1),I=1,3),(CHFCHK(I,ISS+1),I=1,5),QPPTYP(IQSS+1),
     3      CHFTYP(ICHF),(TFTYPE(I,IWFT+1),I=1,3),(TVTYPE(I,IVEC+1),
     4      I=1,3),(TRNFLO(I,ITAM+1),I=1,2),(MIXMOD(I,IMIXM+1),I=1,3),
     5      GRAV,HDT,VELX
      WRITE(NOUT,1066) FCON(3,1),FCON(4,1),FCON(3,4),FCON(4,4),
     1                 FCON(3,2),FCON(4,2)
      WRITE(NOUT,1007) IDUMP,NITMAX,IITMAX,EPSN,EPSI
      IF(IHT.EQ.0) GO TO 11
      WRITE(NOUT,1008) Q0,TO,OMG,RADR,THC,THG,HGAP
      IF(IHT.GT.2) WRITE(NOUT,1014) FTD,FPUO2,FPRESS,CPR,EXPR,
     1               GRGH,PGAS,(GMIX(K),K=1,4),BURN
 11   CONTINUE
C
C  SET UP STORAGE REQUIREMENTS
C
C  INTEGER ARRAYS
C
      LNCR=NTITLE+1
      LINDNT=LNCR+NR
      LICC=LINDNT+NR
      LIWFZ=LICC+4*NC
      LIHTR=LIWFZ+NZ+1
      LICR = LIHTR+ NZ*NRODS
      LIRC = LICR + NRODS
      IEND = LIRC + 4*NC
C  REAL ARRAYS
C
      NZP=NZ+1
      NZP2=NZP+1
      NCP=NC+1
      L1=NZP2*NCP
```

```
      L2=NZP2*NC
      L3=NZP*NC
      L4=NZ*NC
      L5=NZ*NCP
      L6 = NRODS*NZ
      NODES=NCF+NCC+2
      IF (IHT.EQ.0) NODES=0
      NDM1=NODES-1
      IF (IHT.EQ.0) NDM1=0
      NM=8*L1+NODES*NZ*NRODS
C
      LP=IEND
      LALP=LP+L1
      LROV=LALP+L1
      LROL=LROV+L1
      LEV=LROL+L1
      LEL=LEV+L1
      LTV=LEL+L1
      LTL=LTV+L1
      LTR=LTL+L1
      LPN=LTR+NODES*NZ*NRODS
      LALPN=LPN+L1
      LROVN=LALPN+L1
      LROLN=LROVN+L1
      LEVN=LROLN+L1
      LELN=LEVN+L1
      LTVN=LELN+L1
      LTLN=LTVN+L1
      LTRN=LTLN+L1
      LVVX=LTRN+NODES*NZ*NRODS
      LVLX=LVVX+L1
      LVVY=LVLX+L1
      LVLY=LVVY+L1
      LVVZ=LVLY+L1
      LVLZ=LVVZ+NZP*NCP
      LHV=LVLZ+NZP*NCP
      LHL=LHV+L1
      LHVS = LHL +L1
      LHLS=LHVS+L1
      LTSAT=LHLS+L1
      LVISV=LTSAT+L1
      LVISL=LVISV+L1
      LDX=LVISL+L1
      LDY=LDX+NCP
      LDZ=LDY+NCP
      LARX=LDZ+NZP2
      LARY=LARX+L5
      LARZ=LARY+L5
      LVOL=LARZ+L3
      LCPVX=LVOL+L4
      LCPVY=LCPVX+L4
      LCPVZ=LCPVY+L4
      LCPLX=LCPVZ+L3
      LCPLY=LCPLX+L4
```

```
      LCPLZ=LCPLY+L4
      LFVX=LCPLZ+L3
      LFVY=LFVX+L4
      LFVZ=LFVY+L4
      LFLX=LFVZ+L3
      LFLY=LFLX+L4
      LFLZ=LFLY+L4
      LAJM1=LFLZ+L3
      LAJM2=LAJM1+3*L4
      LCPA=LAJM2+4*L4
      LCPTV=LCPA+6*L4
      LCPTL=LCPTV+6*L4
      LRHS=LCPTL+6*L4
      LDP=LRHS+4*L4
      LQPP=LDP+L2
      LQV=LQPP+L6
      LQL=LQV+L6
      LHVFC=LQL+L6
      LHLNB=LHVFC+L6
      LHLFC=LHLNB+L6
      LDTRN=LHLFC+L6
      LDTW=LDTRN+L6*NDM1
      LTW=LDTW+L6
      LCHFR=LTW+L6
      LFRAC =LCHFR+L6
      LHDZ=LFRAC+NRODS
      LHDH=LHDZ+NC
      LQZ=LHDH+NC
      LQT=LQZ+NZ
      LQR=LQT+NRODS
      LQPPP=LQR+NDM1
      LRN=LQPPP+NDM1
      LCND=LRN+NRODS
      LRCP=LCND+NDM1
      LRRDR=LRCP+NDM1
      LVP=LRRDR+NDM1
      LVM=LVP+NODES
      LRAD=LVM+NODES
      LBOTBC=LRAD+NODES
      LTOPBC=LBOTBC+NC
      LTMPBC=LTOPBC+NC
      LSIJ= LTMPBC+NC
      LEND= LSIJ+4*NC
C--SPACE IN ARRAY  A  IS USED BEYOND LEND, AS SCRATCH SPACE.
C  SEE CALLS TO [illegible]NER AND RTEMP.
C
C  CLEAR ALL ARRAYS
C
      I1=LNCR
      I2=IEND-1
      DO 15 I=I1,I2
   15 IA(I)=0
      CALL CLEAR (0.0,A(LP),LEND-LP)
        DO 17 I=1,30
```

```
        BOTFAC(I) =1.0
        TOPFAC(I) =1.0
        TINFAC(I) =1.0
        QFAC(I)   =1.0
        YB(I) =0.
        YT(I) =0.
        YTEMP(I) =0.
        YQ(I) =0.
 17     CONTINUE
C
C  READ ARRAYS
C
C   READ GEOMETRICAL DATA
C
      WRITE(NOUT,1010)
C
      CALL NIPS(4H NCR,4H    ,IA(LNCR),RDUM,NR,IERR,1)
      CALL NIPS(4H IND,4HENT ,IA(LINDNT),RDUM,NR,IERR,1)
      CALL NIPS(4HARX ,4H    ,IDUM,A(LARX),L4,IERR,0)
      CALL NIPS(4HARY ,4H    ,IDUM,A(LARY),L4,IERR,0)
      CALL NIPS(4HARZ ,4H    ,IDUM,A(LARZ),L3,IERR,0)
      CALL NIPS(4HVOL ,4H    ,IDUM,A(LVOL),L4,IERR,0)
      CALL NIPS(4HDX  ,4H    ,IDUM,A(LDX),NC,IERR,0)
      CALL NIPS(4HDY  ,4H    ,IDUM,A(LDY),NC,IERR,0)
      CALL NIPS(4HDZ  ,4H    ,IDUM,A(LDZ),NZP2,IERR,0)
      CALL NIPS(4HHDZ ,4H    ,IDUM,A(LHDZ),NC,IERR,0)
      CALL NIPS(4HSIJ ,4H    ,IDUM,A(LSIJ),4*NC,IERR,0)
C
C   READ AXIAL FRICTION MODEL
C
      CALL NIPS(4HIND ,4HFRIC,IA(LIWFZ),RDUM,NZP,IERR,1)
C
C   READ  INITIAL CONDITIONS
C
      CALL NIPS(4HP   ,4H    ,IDUM,A(LP),L2,IERR,0)
      CALL NIPS(4HALP ,4H    ,IDUM,A(LALP),L2,IERR,0)
      CALL NIPS(4HTEMP,4H    ,IDUM,A(LTV),L2,IERR,0)
      CALL NIPS(4HVZ  ,4H    ,IDUM,A(LVVZ),L3,IERR,0)
      IF(IHT.EQ.0) GO TO 20
      CALL NIPS(4HIND ,4HRODS,IA(LICR),RDUM,NRODS,IERR,1)
      CALL NIPS(4HHDH ,4H    ,IDUM,A(LHDH),NC,IERR,0)
      CALL NIPS(4HTW  ,4H    ,IDUM,A(LTW),L6,IERR,0)
      CALL NIPS(4H    ,4H  QZ,IDUM,A(LQZ),NZ,IERR,0)
      CALL NIPS(4H    ,4H  QT,IDUM,A(LQT),NRODS,IERR,0)
      CALL NIPS(4H    ,4H  QR,IDUM,A(LQR),NDM1,IERR,0)
      CALL NIPS(4H    ,4H  RN,IDUM,A(LRN),NRODS,IERR,0)
      CALL NIPS(4HFRAC,4H PH ,IDUM,A(LFRAC),NRODS,IERR,0)
   20 CONTINUE
C
C  READ IN TRANSIENT FORCING FUNCTIONS
C
      READ(NINP,*) NB,NT,NTEMP,NQ
      IF(MIN0(NB,NT,NTEMP,NQ).LT.0) GO TO 902
       IF(NB.GT.0) READ(NINP,*)(BOTFAC(I),YB(I),I=1,NB)
```

```
       IF(NT.GT.0) READ(NINP,*) (TOPFAC(I),YT(I),I=1,NT)
       IF(NTEMP.GT.0) READ(NINP,*) (TINFAC(I),YTEMP(I),I=1,NTEMP)
       IF(NQ.GT.0) READ(NINP,*) (QFAC(I),YQ(I),I=1,NQ)
      IF(NB.GT.0) WRITE(NOUT,1020) (YB(I),BOTFAC(I),I=1,NB)
      IF(NT.GT.0) WRITE(NOUT,1021) (YT(I),TOPFAC(I),I=1,NT)
      IF(NTEMP.GT.0) WRITE(NOUT,1022) (YTEMP(I),TINFAC(I),I=1,NTEMP)
      IF(NQ.GT.0) WRITE(NOUT,1023) (YQ(I),QFAC(I),I=1,NQ)
C
C
C  TEST FOR NIPS-DETECTED ERROR
C
      IF(IERR.NE.0) GO TO 902
      RETURN
C
C  RESTRT OPTION
C  (WORKS FOR MULTICS ONLY)
C
  100 CONTINUE
      ITEMP=IRES
      IF(IRES.GE.2)CALL START
      IF(NTZC.EQ.NTTY)WRITE(NTTY,1009)
      READ(NTZC,RESTRT)
      IRES=ITEMP
      ICPU=0
      IF(NTZC.EQ.NTTY) WRITE(NTTY,1024)
      READ(NTZC,TFDATA)
      IF(IRES.NE.3) GO TO 108
      DELT= 0.
      RTIME= 0.
      NSTEP= 0
C
C  SET BOUNDARY CONDITIONS
C
      CALL INITFD(A(LP),A(LALP),A(LROV),A(LROL),A(LEV),A(LEL),
     1     A(LTV),A(LTL),A(LVVX),A(LVLX),A(LVVY),A(LVLY),A(LVVZ),
     2     A(LVLZ),A(LHV),A(LHL),A(LPN),A(LTSAT),A(LVISV),
     3     A(LVISL),A(LBOTBC),A(LTOPBC),A(LTMPBC),A(LHLS),A(LHVS),NZP,
     4     NZP2,2)
 108  CONTINUE
C
C  IF Q0<0, THEN Q0 IS SET TO CURRENT Q
C
      IF(Q0.LT.0.0) Q0=Q
C
C  PRINT NEW PROBLEM DATA
C
      WRITE(NOUT,1010)
      WRITE(NOUT,1003)(A(I),I=1,NTITLE)
      WRITE(NOUT,1005)NC,NR,NRODS,NZ,NCF,NCC
      WRITE(NOUT,1006) BCTYPE(ITB+1),BCTYPE(IBB+1),(GTYPE(I,IFLASH+1)
     1      ,I=1,3),FITYPE(IFINTR+1),(FPTYPE(I,IHT+1),I=1,4),(HTTYPE(I,
     2      ISS+1),I=1,3),(CHFCHK(I,ISS+1),I=1,5),QPPTYP(IQSS+1),
     3      CHFTYP(ICHF),(TFTYPE(I,IWFT+1),I=1,3),(TVTYPE(I,IVEC+1),
     4      I=1,3),(TRNFLO(I,ITAM+1),I=1,2),(MIXMOD(I,IMIXM+1),I=1,3),
```

```
     5     GRAV,HDT,VELX
      WRITE(NOUT,1066) FCON(3,1),FCON(4,1),FCON(3,4),FCON(4,4),
     1                 FCON(3,2),FCON(4,2)
      WRITE(NOUT,1007) IDUMP,NITMAX,IITMAX,EPSN,EPSI
      IF(IHT.EQ.0) GO TO 110
      WRITE(NOUT,1008) Q0,T0,OMG,RADR,THC,THG,HGAP
      IF(IHT.GT.2) WRITE(NOUT,1014) FTD,FPUO2,FPRESS,CPR,EXPR,
     1               GRGH,PGAS,(GMIX(K),K=1,4),BURN
  110 CONTINUE
      IF(NB.GT.0)WRITE(NOUT,1020) (YB(I),BOTFAC(I),I=1,NB)
      IF(NT.GT.0)WRITE(NOUT,1021) (YT(I),TOPFAC(I),I=1,NT)
      IF(NTEMP.GT.0)
     1    WRITE(NOUT,1022) (YTEMP(I),TINFAC(I),I=1,NTEMP)
      IF(NQ.GT.0) WRITE(NOUT,1023) (YQ(I),QFAC(I),I=1,NQ)
      IF(IRES.GE.2)
     A CALL EDIT(A(LPN),A(LALPN),A(LROVN),A(LROLN),A(LEVN),A(LELN),
     1 A(LTVN),A(LTLN),A(LVVX),A(LVLX),A(LVVY),A(LVLY),A(LVVZ),A(LVLZ),
     2 A(LTSAT),A(LHV),A(LHL),A(LTRN),A(LIHTR),A(LQPP),A(LDZ),A(LARZ),
     3 A(LRN),A(LFRAC),A(LCHFR),NZP2,NZP,NODES,NZ)
      RETURN
C
C  INPUT DATA ERROR
C
  901 IERR = 1
      GO TO 999
  902 IERR = 2
  999 LERR = .TRUE.
      RETURN
C
C1001 FORMAT(V)
 1002 FORMAT(20A4)
 1003 FORMAT((25X,20A4/)/)
C1004 FORMAT(V)
 1005 FORMAT(1H0,/,13X,16HARRAY DIMENSIONS,//,
     1        35H NUMBER OF CHANNELS                 =,I4,/,
     2        35H NUMBER OF ROWS                     =,I4,/,
     3        35H NUMBER OF FUEL RODS MODELED        =,I4,/,
     4        35H NUMBER OF AXIAL NODES              =,I4,/,
     5        35H NUMBER OF CELLS IN FUEL            =,I4,/,
     6        35H NUMBER OF CELLS IN CLAD            =,I4)
 1006 FORMAT(1H0,//,10X,33HTHERMAL-HYDRAULIC OPTIONS IN USE ,//,
     1   1X,A8,32H BOUNDARY CONDITION AT CORE EXIT,/,
     2   1X,A8,33H BOUNDARY CONDITION AT CORE INLET,/,
     3   1X,3A4,13HBOILING MODEL,/,
     4   1X,A4,36H INTERFACIAL MOMENTUM EXCHANGE MODEL,/,
     5   1X,4A8,/,
     6   1X,3A4,27H HEAT TRANSFER CALCULATION ,5A4,/,
     7   1X,A8,29H HEAT FLUX BOUNDARY CONDITION,/,
     8   1X,A8,31H CRITICAL HEAT FLUX CORRELATION,/,
     9   29H TRANSVERSE FRICTION MODEL - ,3A4,/,
     A   1X,3A4,50H VELOCITY USED IN TRANSVERSE MOMENTUM CALCULATIONS,/,
     B   20H TRANSVERSE FLOW IS ,2A8,/,
     B   1X,3A8,/,
     C   34H GRAVITATIONAL CONSTANT          = ,F10.5,/,
```

```
     D   34H TRANSVERSE HYDRAULIC DIAMETER  = ,E12.5,/,
     E   34H TRANSVERSE FRICTION MULTIPLIER = ,E12.5)

 1066 FORMAT(1H0,//,10X,14HFRICTION MODEL,//,
     1       18H AXIAL        F = ,F6.3,5H*RE**,F6.3,/,
     2       18H TRANSVERSE   F = ,F6.3,5H*RE**,F6.3,/,
     3       18H GRID SPACER  K = ,F6.3,5H*RE**,F6.3)
 1007 FORMAT(1H0,//,10X,28HITERATION CONTROL PARAMETERS,//,
     1       35H DUMP INDICATOR (0/1)(NO/YES)      =,I4,/,
     1       35H MAX NUMBER OF NEWTON ITERATIONS  =,I4,/,
     2       35H MAX NUMBER OF INNER ITERATIONS   =,I4,/
     A       35H CONVERGENCE CRIT. FOR NEWTON ITER=,E12.5,/
     1       35H CONVERGENCE CRIT. FOR INNER ITER =,E12.5)
 1008 FORMAT(1H0,//,24H     FUEL ROD MODEL DATA,//,
     1       35H INITIAL TOTAL POWER               =,E12.5,/,
     Z       35H DELAY TIME                        =,E12.5,/
     Z       35H INVERSE REACTOR PERIOD            =,E12.5,/
     1       35H ROD RADIUS                        =,E12.5,/
     2       35H CLAD THICKNESS                    =,E12.5,/
     3       35H GAP THICKNESS                     =,E12.5,/
     4       35H GAP CONDUCTIVITY                  =,E12.5)
 1014 FORMAT(1H0,//,30H    CONSTANTS FOR MATPRO MODEL,//,
     5       35H FRACTION OF THEOR. DENSITY (FUEL)=,F8.5,/
     6       35H FRACTION PUO2                    =,F8.5,/
     8       35H FUEL CONTACT PRESSURE            =,E12.5,/
     9       35H COEFFICIENT OF FUEL PRESSURE     =,E12.5,/
     A       35H EXPONENT OF FUEL PRESSURE        =,F8.5,/
     B       35H GAP ROUGHNESS                    =,E12.5,/
     C       35H GAP GAS PRESSURE                 =,E12.5,/
     D       35H HELIUM FRACTION                  =,F8.5,/
     E       35H ARGON FRACTION                   =,F8.5,/
     F       35H KRYPTON FRACTION                 =,F8.5,/
     G       35H XENON FRACTION                   =,F8.5,/
     H       35H BURNUP                           =,E12.5)
 1009 FORMAT(25H PLEASE ENTER RESTRT DATA)
 1010 FORMAT(1H1)
 1011 FORMAT(1H1,52X,31H THERMIT  AS OF  10 JULY   1981,//)
C
 1020 FORMAT('0',10X,'FORCING FUNCTION FOR BOTTOM BOUNDARY CONDITION'
     1 //15X,'TIME',8X,' FACTOR'/(14X,F6.4,8X,F6.4))
 1021 FORMAT('0',10X,'FORCING FUNCTION FOR TOP BOUNDARY CONDITION'/
     1  /15X,'TIME',8X,' FACTOR'/(14X,F6.4,8X,F6.4))
 1022 FORMAT('0',10X,'FORCING FUNCTION FOR INLET TEMPERATURE'//
     1  15X,'TIME',8X,' FACTOR'/(14X,F6.4,8X,F6.4))
 1023 FORMAT('0',10X,'FORCING FUNCTION FOR REACTOR PO   '//
     1   15X,'TIME',8X,'     FACTOR'/(14X,F6.4,8X,E12.  )
 1024  FORMAT(' PLEASE ENTER TRANSIENT FORCING FUNCTIO  DATA ')
       END
```

```
      SUBROUTINE INIT
C
C  CALLS INDIVIDUAL INITIALIZATION SUBROUTINES AND INITIAL STATE
C   PRINTOUT
C
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR,  LICR,LIRC,LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,TO,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      DIMENSION IA(1)
       EQUIVALENCE (A(1),IA(1))
C
C  PRINT MAP OF CHANNELS
C
      IF(NC.GT.1) CALL MAPPER(A(LNCR),A(LINDNT),NR,NC)
C
C  DETERMINE CHANNEL COUPLING ARRAY
C
      CALL SETICC(A(LICC),A(LNCR),A(LINDNT),NR,NC)
C
C  DETERMINE ROD AND CHANNEL COUPLING
C
      DO 6 I=1,NRODS
      IR=IA(LICR+(I-1))
      DO 5 J=1,4
      IF(IA(LIRC+4*(IR-1)+(J-1)).NE.0) GO TO 5
      IA(LIRC+4*(IR-1)+(J-1)) = I
      GO TO 6
 5     CONTINUE
 6     CONTINUE
C
C  INITIALIZE FLUID DYNAMICS ARRAYS
C
      CALL INITFD(A(LP),A(LALP),A(LROV),A(LROL),A(LEV),A(LEL),
     1 A(LTV),A(LTL),A(LVVX),A(LVLX),A(LVVY),A(LVLY),A(LVVZ),
     2 A(LVLZ),A(LHV),A(LHL),A(LPN),A(LTSAT),A(LVISV),A(LVISL),
     3 A(LBOTBC),A(LTOPBC),A(LTMPBC),A(LHLS),A(LHVS),NZP,NZP2,1)
C
C  INITIALIZE ROD CONDUCTION ARRAYS
```

```
C
      IF(IHT.EQ.0) GO TO 10
      CALL INITRC(A(LRAD),A(LRRDR),A(LVM),A(LVP),A(LCND),A(LRCP),
     1 A(LQZ),A(LQT),A(LQR),A(LRN),A(LFRAC),A(LDZ),A(LTW),A(LTR),
     2  A(LTRN),A(LQL),NODES,NZ)
   10 CONTINUE
      RTIME=0.0
      RTNSP=0.
      RTNLP=0.
      NSTEP=0
      NITNO=0
      IITOT=0
      DELT=0.0
      KRED=0
      ICPU=0
      Q=Q0
      TWMAX =0.0
      TRMAX =0.0
      AMCHFR=0.0
      ITWMAX=0
      ITRMAX=0
      JTWMAX=0
      JTRMAX=0
      IMCHFR=0
      JMCHFR=0
C
C  PRINT INITIAL CONDITIONS
C
       CALL EDIT(A(LPN),A(LALPN),A(LROVN),A(LROLN),A(LEVN),A(LELN),
     1 A(LTVN),A(LTLN),A(LVVX),A(LVLX),A(LVVY),A(LVLY),A(LVVZ),A(LVLZ),
     2 A(LTSAT),A(LHV),A(LHL),A(LTRN),A(LIHTR),A(LQPP),A(LDZ),A(LARZ),
     3 A(LRN),A(LFRAC),A(LCHFR),NZP2,NZP,NODES,NZ)
      RETURN
      END
```

```
      SUBROUTINE CLEAR(X,A,N)
      DIMENSION A(1)
      DO 10 I=1,N
        A(I)=X
   10   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MAPPER(NCR,INDENT,NR,NC)
C
C      FUNCTION: PRINTS A MAP OF THE CHANNEL OVERLAY
C
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
      DIMENSION NCR(1),INDENT(1),IDIGIT(10),IFORM(6)
      DATA IDIGIT/4H1   ,4H2   ,4H3   ,4H4   ,4H5   ,
     1            4H6   ,4H7   ,4H8   ,4H9   ,4H0   /
      DATA  IFORM/4H(1H ,4H,   ,2*4H    ,4HX,20,4HI4/)/
C
C
   10 FORMAT(1H1/56X,20H< CHANNEL  OVERLAY >//)
   20 FORMAT(1H )
      WRITE(NOUT,10)
C
      INDSML = INDENT(1)
      ISIZE = INDENT(1)+NCR(1)
      DO 2 I=1,NR
        IF(INDENT(I).LT.INDSML) INDSML = INDENT(I)
        IF(INDENT(I)+NCR(I).GT.ISIZE) ISIZE = INDENT(I)+NCR(I)
    2   CONTINUE
      ISIZE = ISIZE-INDSML
      ISPACE = (130-4*ISIZE)/2
C
      ICF = NC-NCR(NR)+1
      ICL = NC
C
      DO 4 I=1,NR
        IR = NR+1-I
        IF(I.EQ.1) GO TO 3
        ICF = ICF-NCR(IR)
        ICL = ICL-NCR(IR+1)
    3   CONTINUE
C
C  CONSTRUCT FORMAT(1H ,NNX,20I4/), WHERE NN=10*N1+N2
C
        INDMOD = INDENT(IR)-INDSML
        NN = 4*INDMOD+ISPACE
        N1 = NN/10
        IFORM(3) = IDIGIT(10)
        IF(N1.NE.0) IFORM(3) = IDIGIT(N1)
        N2 = NN-10*N1
        IFORM(4) = IDIGIT(10)
        IF(N2.NE.0) IFORM(4) = IDIGIT(N2)
C
        WRITE(NOUT,IFORM) (J,J=ICF,ICL)
        WRITE(NOUT,20)
    4   CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE SETICC(ICC,NCR,INDENT,NR,NC)
      DIMENSION ICC(4,1),NCR(1),INDENT(1)
C
C  SETS AN ARRAY WHICH, FOR EACH CHANNEL, DETERMINES ITS (UP TO FOUR)
C    NEIGHBORS
C
C     ARGUMENTS:
C           ICC = INDICATOR FOR CHANNEL COUPLING
C           NCR = NUMBER OF CHANNELS PER ROW
C        INDENT = INDENTATION OF EACH ROW
C            NR = NUMBER OF ROWS
C            NC = NUMBER OF CHANNELS
C
C  THE CONVENTION FOR NEIGHBOR NUMBERING VIA  ICC  IS:
C
C              4
C            2 X 3
C              1
C
      DO 10 IC=1,NC
        DO 10 KC=1,4
   10     ICC(KC,IC) = NC+1
C
      IROW = 1
      IRP = 1
      DO 100 IC=1,NC
        IF(IRP.NE.1)          ICC(2,IC) = IC-1
        IF(IRP.NE.NCR(IROW)) ICC(3,IC) = IC+1
        IF(IROW.EQ.1) GO TO 20
        IX = INDENT(IROW)+IRP-INDENT(IROW-1)
        IF(IX.GE.1.AND.IX.LE.NCR(IROW-1)) ICC(1,IC) =
     1    IC-NCR(IROW-1)-INDENT(IROW-1)+INDENT(IROW)
   20   CONTINUE
        IF(IROW.EQ.NR) GO TO 30
        IX = INDENT(IROW)+IRP-INDENT(IROW+1)
        IF(IX.GE.1.AND.IX.LE.NCR(IROW+1)) ICC(4,IC) =
     1    IC+NCR( IROW )+INDENT(IROW)-INDENT(IROW+1)
   30   CONTINUE
        IRP = IRP+1
        IF(IRP.LE.NCR(IROW)) GO TO 100
        IROW = IROW+1
        IRP = 1
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INITFD(P,ALP,ROV,ROL,EV,EL,TV,TL,VVX,VLX,VVY,
     1  VLY,VVZ,VLZ,HV,HL,PN,TSAT,VISV,VISL,BOTBC,TOPBC,TMPBC,
     2  HLS,HVS,M2,M1,IPART)
C
C  INITIALIZE FLUID DYNAMICS ARRAYS
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      DIMENSION P(M1,1),ALP(M1,1),ROV(M1,1),ROL(M1,1),
     1  EV(M1,1),EL(M1,1),TV(M1,1),TL(M1,1),VVX(M1,1),
     2  VLX(M1,1),VVY(M1,1),VLY(M1,1),VVZ(M2,1),VLZ(M2,1),
     3  HV(M1,1),HL(M1,1),PN(M1,1),TSAT(M1,1),VISV(M1,1),VISL(M1,1)
     4  ,BOTBC(1),TOPBC(1),TMPBC(1),HLS(M1,1),HVS(M1,1)
      IF(IPART.EQ.2) GO TO 215
C
C  SET OLD VARIABLES
C
      DO 100 J=1,NZP2
        DO 50 I=1,NC
          TL(J,I)=TV(J,I)
          CALL STATE(P(J,I),TV(J,I),TL(J,I),ROV(J,I),ROL(J,I),EV(J,I),
     1   EL(J,I),TSAT(J,I),HVS(J,I),HLS(J,I),D1,D2,D3,D4,D5,D6,D7,D8,
     2   D9,0,IERR)
          HV(J,I)=EV(J,I)+P(J,I)/ROV(J,I)
          HL(J,I)=EL(J,I)+P(J,I)/ROL(J,I)
          VISV(J,I)=VISVP(TV(J,I))
          VISL(J,I)=VISLQ(TL(J,I))
   50     CONTINUE
        P(J,NCP)=0.0
        ALP(J,NCP)=0.0
        TV(J,NCP)=0.0
        TL(J,NCP)=0.0
        ROV(J,NCP)=0.0
        ROL(J,NCP)=0.0
        EV(J,NCP)=0.0
        EL(J,NCP)=0.0
        TSAT(J,NCP)=0.0
        HV(J,NCP)=0.0
        HL(J,NCP)=0.0
        VISV(J,NCP)=0.0
        VISL(J,NCP)=0.0
  100   CONTINUE
C
C  SET NEW VARIABLES
C
      CALL MOVE(P,PN,8*NZP2*NCP)
C
C  SET VELOCITIES
C
      DO 200 I=1,NCP
```

```
        DO 200 J=1,NZP
  200     VLZ(J,I)=VVZ(J,I)
      DO 210 I=1,NCP
        DO 210 J=1,NZP2
          VVX(J,I)=0.0
          VLX(J,I)=0.0
          VVY(J,I)=0.0
          VLY(J,I)=0.0
  210     CONTINUE
  215    CONTINUE
C
C   SAVE INITIAL BOUNDARY CONDITIONS
C
       DO 260 I=1,NC
       IF(IBB.EQ.0) GO TO 230
       BOTBC(I) = VLZ(1,I)
       GO TO 240
 230    BOTBC(I) = PN(1,I)
 240    TMPBC(I) = TL(1,I)
       IF(ITB.EQ.0) GO TO 250
       TOPBC(I) = VLZ(NZP,I)
       GO TO 260
 250   TOPBC(I) = PN(NZP2,I)
 260   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INITRC(RAD,RRDR,VM,VP,CND,RCP,QZ,QT,QR,RN,FRACP,
     1 DZ,TW,TR,TRN,QL,M1,M2)
C
C  INITIALIZE ROD CONDUCTION ARRAYS
C   AND MAKE INITIALIZING CALL TO GAP CONDUCTANCE SUBROUTINE
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      COMMON /PROP/ FTD,FPUO2,FPRESS,CPR,EXPR,GRGH,PGAS,GMIX(4),
     1   HGAP,BURN,EFFB,FRAC
      DIMENSION RAD(1),RRDR(1),VM(1),VP(1),CND(1),RCP(1),QZ(1),QT(1),
     1 QR(1),RN(1),FRACP(1),DZ(1),TW(M2,1),TR(M1,M2,1),TRN(M1,M2,1)
     2 , QL(M2,1)
      DATA PI/3.1415926/
C
C  GEOMETRY ARRAYS
C
      NG=NCF+1
      DRF=(RADR-THC-THG)/NCF
      DRC=THC/NCC
      RAD(1)=0.0
      DO 10 K=1,NCF
   10   RAD(K+1)=K*DRF
      RAD(NG+1)=RAD(NCF+1)+THG
      DO 20 K=1,NCC
   20   RAD(NG+1+K)=RAD(NG+1)+K*DRC
      DO 30 K=1,NDM1
        IF(K.EQ.NG)RRDR(K)=.5*(RAD(K+1)+RAD(K))
        IF(K.NE.NG)RRDR(K)=.5*(RAD(K+1)+RAD(K))/(RAD(K+1)-RAD(K))
   30   CONTINUE
      VM(1)=0.0
      VP(1)=0.0
      VP(1)=DRF*DRF/8.0
      DO 40 K=2,NDM1
        RP=0.5*(RAD(K+1)+RAD(K))
        RM=0.5*(RAD(K)+RAD(K-1))
        VP(K)=0.5*(RP*RP-RAD(K)*RAD(K))
   40   VM(K)=0.5*(RAD(K)*RAD(K)-RM*RM)
      RM=0.5*(RADR+RAD(NDM1))
      VM(NODES)=0.5*(RADR*RADR-RM*RM)
      VP(NODES)=0.0
C
C  MATERIAL PROPERTY ARRAYS
C
      IF(IHT.GE.2)  GO TO 200
      DO 110 K=1,NCF
        CND(K)=2.4
```

```
  110   RCP(K)=3.4125E6
      CND(NG)=HGAP
      RCP(NG)=0.0
      DO 120 K=1,NCC
        CND(NG+K)=10.7
  120   RCP(NG+K)=2.093E6
  200 CONTINUE
C
C  INITIALIZE GAP CONDUCTANCE DATA
C
      IF(IHT.LT.3)GO TO 205
      CALL MPG(.TRUE.,BURN,D1,D2,D3,D4,D5,GRGH,RAD(NG),RAD(NG+1),
     1 D6,D7,D8,D9,D10,D11)
  205 CONTINUE
C
C  HEAT SOURCE DISTRIBUTION ARRAYS
C
      SUM=0.0
      DO 210 J=1,NZ
        JJ=J+1
  210   SUM=SUM+QZ(J)*DZ(JJ)
      DO 220 J=1,NZ
  220   QZ(J)=QZ(J)/SUM
      SUM=0.0
      DO 230 I=1,NRODS
  230   SUM=SUM+QT(I)*RN(I)*FRACP(I)
      DO 240 I=1,NRODS
  240   QT(I)=QT(I)/SUM
      SUM=0.0
      DO 250 K=1,NDM1
  250   SUM=SUM+QR(K)*PI*(RAD(K+1)*RAD(K+1)-RAD(K)*RAD(K))
      DO 260 K=1,NDM1
  260   QR(K)=QR(K)/SUM
C
C  SET INITIAL ROD TEMPERATURES
C
      DO 310 I=1,NRODS
        DO 310 J=1,NZ
          DO 310 K=1,NODES
            TRN(K,J,I)=TW(J,I)
  310       TR(K,J,I)=TW(J,I)
       IF(IQSS.NE.0) GO TO 410
       DO 400 I=1,NRODS
       DO 400 J=1,NZ
       QL(J,I) = QZ(J)*QT(I)*Q0/(2. * PI * RADR)
 400   CONTINUE
 410   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TRANS
C
C  GOVERNS TRANSIENT CALCULATION
C
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR,  LICR,LIRC,LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,QO,TO,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
C
C  BEGIN ONE TIME ZONE, OBTAIN INITIAL CPU TIME
C
      CALL TIMING(ICPU)
C
C   OBTAIN TIME STEP CONTROL PARAMETERS
C
   10 CONTINUE
      IF(NTZC.EQ.NTTY)WRITE(NTTY,1001)
      READ(NTZC,*)TEND,DTMIN,DTMAX,DTSP,DTLP,CLM,IREDMX
      RTNSP=RTIME+DTSP
      RTNLP=RTIME+DTLP
      IF(TEND.GT.0.0)GO TO 20
      IRES=0
      IF(TEND.EQ.0.0) RETURN
      IF(NTZC.EQ.NINP)GO TO 15
      IRES=1
      RETURN
   15 NTZC=NTTY
      GO TO 10
C
C  BEGIN ONE TIME STEP, DETERMINE TIME STEP SIZE
C
   20 CONTINUE
      CALL TIMSTP(A(LVVZ),A(LDZ),CLM,DELT,DTMIN,DTMAX,RTIME,TEND,
     1 INI,IRD,NZP)
      IRED = 0
   21 RDELT=1./DELT
      IF(INI.EQ.1)GO TO 10
C
```

```
C  DETERMINE POWER LEVEL
C
      IF (IHT.EQ.0.OR.IQSS.EQ.0) GO TO 25
      CALL POWER(Q,Q0,T0,OMG,RTIME,DELT)
C
C   DETERMINE BOUNDARY CONDITIONS
C
      CALL BOTBCV(A(LPN),A(LROVN),A(LROLN),A(LEVN),A(LELN),
     1            A(LTVN),A(LTLN),A(LTSAT),A(LVVZ),A(LVLZ),
     2            A(LBOTBC),A(LTMPBC),RTIME,DELT,
     3            NZP,NZP2)
C
      CALL TOPBCV(A(LPN),A(LROVN),A(LROLN),A(LEVN),A(LELN),
     1            A(LTVN),A(LTLN),A(LTSAT),A(LVVZ),A(LVLZ),
     2            A(LTOPBC),RTIME,DELT,NZP,NZP2)
C
C
C  OBTAIN HEAT TRANSFER COEFFICIENTS
C
      CALL HCONV(A(LIHTR),A(LQV),A(LQL),A(LHVFC),A(LHLNB),A(LHLFC),
     1 A(LTW),A(LTL),A(LTV),A(LP),A(LALP),A(LROV),A(LROL),
     2 A(LHV),A(LHL),A(LHVS),A(LHLS),A(LQPP),A(LDZ),A(LFRAC),A(LQZ),
     3 A(LQT),A(LVVZ),A(LVLZ),A(LICR),A(LHDZ),A(LHDH),A(LCHFR),
     4 NZ,NZP2,NZP)
C
C  SET UP FUEL ROD TEMPERATURE PROBLEM, GET INITIAL GUESS FOR HEAT
C   FLUX AND ITS VARIATION
C
      CALL HCONDO (A(LTRN),A(LQPP),A(LQV),A(LQL),A(LHVFC),A(LHLNB),
     1 A(LHLFC),A(LTSAT),A(LTLN),A(LTVN),A(LQPPP),A(LTR),
     2 A(LQZ),A(LQT),A(LQR),A(LDTRN),A(LDTW),A(LIHTR),A(LICR),A(LTW),
     3 NODES,NZ,NZP2,NDM1)
   25 CONTINUE
C
C  PERFORM FLUID DYNAMICS CALCULATION
C
      CALL NEWTON
      IF (LERR) GO TO 100
      RTIME=RTIME+DELT
      NSTEP=NSTEP+1
C
C  OBTAIN FINAL FUEL ROD TEMPERATURES
C
      IF(IHT.EQ.0) GO TO 30
      CALL HCOND1 (A(LTRN),A(LQPP),A(LQV),A(LQL),A(LHVFC),A(LHLNB),
     1 A(LHLFC),A(LTSAT),A(LTLN),A(LTVN),
     2 A(LDTRN),A(LDTW),A(LTW),A(LICR),NODES,NZ,NZP2,NDM1)
C
C  PRINT RESULTS
C
   30 CALL EDIT(A(LPN),A(LALPN),A(LROVN),A(LROLN),A(LEVN),A(LELN),
     1 A(LTVN),A(LTLN),A(LVVX),A(LVLX),A(LVVY),A(LVLY),
     2 A(LVVZ),A(LVLZ),A(LTSAT),A(LHV),A(LHL),A(LTRN),A(LIHTR),A(LQPP),
     3 A(LDZ),A(LARZ),A(LRN),A(LFRAC),A(LCHFR),NZP2,NZP,NODES,NZ)
```

```
      IF(LERR.OR.TEND.EQ.0.0) RETURN
C
C  STOP IF TIME STEP IS LESS THAN DTMIN
C
      IF(DELT.GE.DTMIN) GO TO 45
      LERR=.TRUE.
      IERR=10
      RETURN
C
C  ADVANCE TIME STEP
C
 45     CALL MOVE(A(LPN),A(LP),NM)
C
C  END OF ONE TIME STEP, RETURN FOR ANOTHER TIME STEP
C
      IERR = 0
      GO TO 20
C
C  ERROR DETECTED DURING NEWTON ITERATIONS,
C    BACK UP AND REDUCE TIME STEP
C
  100 IF ((IRED.EQ.IREDMX).OR.(DTMIN.GE.DTMAX)) GO TO 200
      TS = 0.1
      IF ((IRD.EQ.1).AND.(IRED.EQ.0)) TS = 0.5
      DELT = TS*DELT
      IF ((IRD.EQ.0).AND.(IRED.EQ.0)) KRED = KRED+1
      IRED = IRED + 1
      IF (DELT.LT.DTMIN) GO TO 200
      CALL MOVE(A(LP),A(LPN),NM)
      LERR = .FALSE.
      GO TO 21
C
C  TOO MUCH REDUCTION, ERROR STOPS CALCULATION
C
  200 RTNLP = RTIME
      GO TO 30
C
C1000 FORMAT(V)
 1001 FORMAT (32H PLEASE ENTER NEW TIME ZONE CARD )
      END
```

```
      SUBROUTINE TIMSTP (VVZ,DZ,CLM,DELT,DTMIN,DTMAX,RTIME,TEND,INI,
     1 IRD,M1)
C
C  DETERMINES TIME STEP SIZE
C    IF DTMIN>=DTMAX,  DELT=DTMIN
C    OTHERWISE,         DELT=MINIMUM( DTMAX, DTCONV*CLM, 2*DTPREV )
C  THE CONVECTIVE LIMIT VALUE  DTCONV  IS DETERMINED ONLY
C    FROM THE AXIAL VAPOR VELOCITIES.
C
      DIMENSION VVZ(M1,1),DZ(1)
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1    NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2    NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3    ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4    ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      DATA EPS/1.E-7/
C
      IRD=0
      INI=1
      IF (RTIME .GT. TEND-EPS) RETURN
      INI=0
      DTPREV = DELT
      IF (DTPREV.EQ.0.) DTPREV = DTMAX
      DELT = DTMIN
      IF (DTMIN.GE.DTMAX) RETURN
C
      TS = DTMAX
      DO 20 J=1,NZ
        TS1 = 0.
        JJ=J+1
        DO 10 I=1,NC
   10     TS1 = AMAX1 (TS1, ABS(VVZ(J,I)) )
        IF(TS1.GT.0.) TS = AMIN1 (TS, CLM*DZ(JJ)/TS1 )
   20   CONTINUE
      DELT = AMIN1( TS, 2.*DTPREV )
      IF (DELT.LT.0.9*TS) IRD = 1
      KRED = KRED + IRD
      RETURN
      END
```

```
      SUBROUTINE TABLE(FX,X,F,Y,N)
C  PERFORMS TABULAR LOOK-UP
C  FX  =  QUANTITY TO BE FOUND
C   X  =  INDEPENDENT VARIABLE
C   F  =  ARRAY CONTAINING ORDINATE VALUES
C   Y  =  ARRAY CONTAINING ABCISSA VALUES
C   N  =  NUMBER OF VALUES IN F OR Y ARRAYS
C
      DIMENSION F(1),Y(1)
      DO 120 I=1,N
      IF(X-Y(I)) 130,110,120
 110   IF (I.EQ.N) GO TO 140
 120   CONTINUE
      GO TO 170
 130   IF(I.EQ.1) GO TO 160
 140   SLOPE=(X-Y(I-1))/(Y(I)-Y(I-1))
 150   FX=F(I-1)+ SLOPE*(F(I)-F(I-1))
       RETURN
 160   FX=1.0
       RETURN
 170   FX=F(N)
      RETURN
      END
```

```
      SUBROUTINE TOPBCV(PN,ROVN,ROLN,EVN,ELN,TVN,TLN,TSAT,VVZ,VLZ,
     1                  TOPBC,RTIME,DELT,M1,M2)
C   SETS BOUNDARY CONDITION IN TOP CELLS AS A FUNCTION OF TIME
      COMMON/FORCE/BOTFAC(30),YB(30),TOPFAC(30),YT(30),TINFAC(30),
     1             YTEMP(30),QFAC(30),YQ(30),NB,NT,NTEMP,NQ
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      DIMENSION PN(M2,1),ROVN(M2,1),ROLN(M2,1),
     1          EVN(M2,1),ELN(M2,1),TVN(M2,1),TLN(M2,1),
     2          TSAT(M2,1),VVZ(M1,1),VLZ(M1,1),TOPBC(1)
      IF(NT.LE.0) RETURN
      RTC= RTIME+DELT
      DUMY= 1.0
      CALL TABLE(DUMY,RTC,TOPFAC,YT,NT)
      DO 50 I=1,NC
       IF(ITB.EQ.0) GO TO 30
       VLZ(NZP,I) = DUMY * TOPBC(I)
       VVZ(NZP,I) = DUMY * TOPBC(I)
       GO TO 40
 30    PN(NZP2,I) = DUMY * TOPBC(I)
 40     CALL STATE(PN(NZP2,I),TVN(NZP2,I),TLN(NZP2,I),ROVN(NZP2,I),
     1             ROLN(NZP2,I),EVN(NZP2,I),ELN(NZP2,I),TSAT(NZP2,I),
     2              D0,D00,D1,D2,D3,D4,D5,D6,D7,D8,D9,2,IERR)
 50     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE BOTBCV(PN,ROVN,ROLN,EVN,ELN,TVN,TLN,TSAT,VVZ,VLZ,
     1                 BOTBC,TMPBC,RTIME,DELT,M1,M2)
C    SETS BOUNDARY CONDITIONS IN BOTTOM CELLS AS A FUNCTION OF TIME
      COMMON/FORCE/BOTFAC(30),YB(30),TOPFAC(30),YT(30),TINFAC(30),
     1              YTEMP(30),QFAC(30),YQ(30),NB,NT,NTEMP,NQ
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      DIMENSION PN(M2,1),ROVN(M2,1),ROLN(M2,1),
     1          EVN(M2,1),ELN(M2,1),TVN(M2,1),TLN(M2,1),
     2          TSAT(M2,1),VVZ(M1,1),VLZ(M1,1),BOTBC(1),TMPBC(1)
      IF(NTEMP.EQ.0.AND.NB.EQ.0) RETURN
      RTC= RTIME+ DELT
      IF (NTEMP.EQ.0) GO TO 25
      DUMY = 1.0
      IF(NTEMP.GT.0) CALL TABLE(DUMY,RTC,TINFAC,YTEMP,NTEMP)
       DO 20 I=1,NC
       TLN(1,I)= DUMY * TMPBC(I)
 20    TVN(1,I) = DUMY * TMPBC(I)
 25   IF(NB.EQ.0) GO TO 45
      DUMY = 1.0
      IF(NB.GT.0) CALL TABLE(DUMY,RTC,BOTFAC,YB,NB)
       DO 40 I=1,NC
       IF(IBB.EQ.0) GO TO 30
       VLZ(1,I)= DUMY * BOTBC(I)
       VVZ(1,I)= DUMY * BOTBC(I)
       GO TO 40
 30    PN(1,I)= DUMY * BOTBC(I)
 40    CONTINUE
 45    CONTINUE
       DO 50 I=I,NC
       CALL STATE(PN(1,I),TVN(1,I),TLN(1,I),ROVN(1,I),ROLN(1,I),
     1        EVN(1,I),ELN(1,I),TSAT(1,I),D0,D00,D1,D2,D3,D4,D5,D6,
     2            D7,D8,D9,2,IERR)
 50    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE POWER(Q,Q0,T0,OMG,RTIME,DELT)
      COMMON/FORCE/ BOTFAC(30),YB(30),TOPFAC(30),YT(30),TINFAC(30),
     1                YTEMP(30),QFAC(30),YQ(30),NB,NT,NTEMP,NQ
C
C   COMPUTES TOTAL POWER AS A FUNCTION OF TIME
C
      RTC= RTIME+ DELT
      IF(NQ.GT.0) GO TO 100
      Q=Q0
      IF(RTC.GT.T0) Q=Q0*EXP(OMG*(RTC-T0))
      RETURN
 100    CONTINUE
C
C   FIND Q FROM TABULAR LOOK-UP
C
       DUMY=1.0
       CALL TABLE(DUMY,RTC,QFAC,YQ,NQ)
       Q=Q0*DUMY
       RETURN
      END
```

```
      SUBROUTINE HCONV(IHTR,QV,QL,HVFC,HLNB,HLFC,TW,TL,TV,P,ALP,
     1 ROV,ROL,HV,HL,HVS,HLS,QPP,DZ,FRACP,QZ,QT,VVZ,VLZ,ICR,HDZ,HDH,
     2 CHFR,M1,M2,M3)
C
C  EXPLICIT PORTION OF HEAT TRANSFER (BEGINNING OF TIME STEP)
C
      DIMENSION IHTR(M1,1),QV(M1,1),QL(M1,1),HVFC(M1,1),HLNB(M1,1),
     1 HLFC(M1,1),TW(M1,1),TL(M2,1),TV(M2,1),P(M2,1),ALP(M2,1),
     2 ROV(M2,1),ROL(M2,1),VVZ(M3,1),VLZ(M3,1),ICR(1),
     3 HDZ(1),HDH(1),QPP(M1,1),HL(M2,1),HV(M2,1),HLS(M2,1),HVS(M2,1),
     4 CHFR(M1,1),DZ(1),FRACP(1),QZ(1),QT(1)
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
       DATA GCONV/7.3732572E-4/
      DATA PI/3.1416/
C
      AMCHFR = 99.0
      FTONG=1.
      DO 200 I=1,NRODS
      JBOIL = 0
      TOTZ=0.
        DO 200 J=1,NZ
        BL = 0.
      JJ=J+1
      TOTZ=TOTZ+DZ(JJ)
      II=ICR(I)
C
      QW=QZ(J)*QT(I)/(2.*PI*RADR)
      IF(QW.GT.0.) GO TO 10
      HVFC(J,I) = 0.
      HLNB(J,I) = 0.
      HLFC(J,I) = 0.
      QV(J,I) = 0.
      QL(J,I) = 0.
      IHTR(J,I) = 0
      IF(ALP(JJ,II).GT.0.) IHTR(J,I)=IHTR(J-1,I)
      CHFR(J,I) = 99.
      GO TO 20
C
C  COMPUTE AVERAGE VELOCITIES IN Z DIRECTION
C   NOTE: TRANSVERSE VELOCITIES ARE IGNORED AT PRESENT
C
10          VV=0.5*(VVZ(J,II)+VVZ(JJ,II))
            VL=0.5*(VLZ(J,II)+VLZ(JJ,II))
       IF((VV.LE.0.).OR.(VL.LE.0.)) GO TO 15
             ROLALP= (1. - ALP(JJ,II))*VL*ROL(JJ,II)
            ROVALP = ALP(JJ,II) * VV*ROV(JJ,II)
```

```
C      COMPUTE EQUILIBRIUM QUALITY

          XEQUIL = ((ROLALP*HL(JJ,II) + ROVALP*HV(JJ,II))/(ROLALP
     1    +ROVALP) - HLS(JJ,II))/(HVS(JJ,II) -HLS(JJ,II))
      GO TO 25
15    XEQUIL=ALP(JJ,II)*ROV(JJ,II)/(ALP(JJ,II)*ROV(JJ,II)+
     +        (1.-ALP(JJ,II))*ROL(JJ,II))
C
C      COMPUTE F FACTOR FOR W-3
C
 25   IF(QPP(J,I).LE.0.) GO TO 190
       Z=0.
      XFTONG=1.
      QZO=QZ(J)
      DO 60 JX=1,NZ
      IF(QZ(JX).EQ.QZO) GO TO 60
      XFTONG=0.
 60    CONTINUE
      IF(XFTONG.GT.0.) GO TO 90
       SUM=0.
      ROLALP=ABS(ROLALP)
      ROVALP=ABS(ROVALP)
      GBRIT = (ROLALP+ROVALP)*GCONV
       C=0.44*POW((1.-XEQUIL),7.9)*POW(GBRIT,-1.72)
       DO 50 JX=1,J
       JXP1 = JX +1
       ZP1 = Z + DZ(JXP1) * 39.37079
       SUM = SUM + QPP(JX,I)*(EXP(C*ZP1)-EXP(C*Z))
       Z = ZP1
 50    CONTINUE
       FTONG = SUM/QPP(J,I)/(EXP(C*Z)-1.)
90    CONTINUE
C
C     COMPUTE BOILING LENGTH AND POWER INPUT OVER BOILING LENGTH
C
      IF(JBOIL.GT.1) GO TO 160
      IF(XEQUIL.LE.0.) GO TO 190
      JBOIL=JJ
160   CONTINUE
      DO 170 JX=JBOIL,JJ
      BL = BL + DZ(JX)
170   CONTINUE
190   CONTINUE
C  OBTAIN HEAT TRANSFER COEFFICIENTS AND/OR HEAT FLUX
C
          CALL HTCOR(IHTR(J,I),QV(J,I),QL(J,I),HVFC(J,I),HLNB(J,I),
     1     HLFC(J,I),TW(J,I),TL(JJ,II),TV(JJ,II),P(JJ,II),ALP(JJ,II),
     2     ROV(JJ,II),ROL(JJ,II),VV,VL,HDZ(II),HDH(II),ISS,CHFR(J,I),
     3     HL(1,II),HLS(JJ,II),HVS(JJ,II),FTONG,BL,ICHF,
     4     HV(JJ,II),HL(JJ,II),TOTZ,QW,Q,RADR)
C
C  FIND MININUM CRITICAL HEAT FLUX RATIO
C
          IF(AMCHFR.LE.CHFR(J,I)) GO TO 200
```

```
20          AMCHFR = CHFR(J,I)
            IMCHFR = I
            JMCHFR = J
 200        CONTINUE
C
      IF(AMCHFR.NE.1.0.AND.AMCHFR.NE.99.0) RETURN
      IMCHFR = 0
      JMCHFR = 0
      RETURN
      END
```

```
      SUBROUTINE NEWTON
C
C  PERFORMS NEWTON ITERATIONS FOR FLUID DYNAMICS EQUATIONS
C
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR,  LICR,LIRC,LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
C
C  PERFORM EXPLICIT CALCULATIONS
C
      CALL EXPLCT(A(LICC),A(LIRC),A(LDX),A(LDY),A(LDZ),A(LVVX),A(LVVY),
     1 A(LVVZ),A(LVLX),A(LVLY),A(LVLZ),A(LP),A(LALP),A(LROV),A(LROL),
     2 A(LCPVX),A(LCPLX),A(LCPVY),A(LCPLY),A(LCPVZ),A(LCPLZ),A(LFVX),
     3 A(LFLX),A(LFVY),A(LFLY),A(LFVZ),A(LFLZ),A(LARX),A(LARY),
     4 A(LARZ),A(LIWFZ),A(LVISV),A(LVISL),A(LIHTR),A(LQV),A(LQL),
     5 A(LHDZ),A(LFRAC),A(LSIJ),NC,NZ,NZP,NZP2)
C
C  BEGIN NEWTON ITERATION
C
      IITOT=0
      LIM = IABS(NITMAX)
      DO 100 IT=1,LIM
        NITNO=IT
C
C  SET UP JACOBIAN MATRIX
C
        CALL JACOB(A(LICC),A(LICR),A(LIRC),A(LDZ),A(LVOL),A(LROV),
     1   A(LROL),A(LALP),A(LP),A(LEV),A(LEL),A(LROVN),
     2   A(LROLN),A(LALPN),A(LPN),A(LEVN),A(LELN),A(LTVN),A(LTLN),
     3   A(LTW),A(LARX),A(LARY),A(LARZ),A(LCPVX),A(LCPLX),A(LCPVY),
     4   A(LCPLY),A(LCPVZ),A(LCPLZ),A(LFVX),A(LFLX),A(LFVY),A(LFLY),
     5   A(LFVZ),A(LFLZ),A(LRN),A(LQV),A(LHVFC),A(LHLNB),
     6   A(LHLFC),A(LAJM1),A(LAJM2),A(LCPA),A(LCPTV),A(LCPTL),A(LRHS),
     7   A(LVVX),A(LVVY),A(LVVZ),A(LVLX),A(LVLY),A(LVLZ),A(LDTW),
     8   A(LIHTR),A(LVISL), A(LHV), A(LFRAC),A(LHDZ),A(LSIJ),
     9   NZP2,NZP,NZ,NC)
        IF (LERR) RETURN
C
```

```
C  SOLVE FOR NEW PRESSURES
C
        CALL CLEAR (0., A(LDP), NZP2*NC)
      IF(ITAM.EQ.0)
     + CALL INNER (A(LDP),A(LAJM1),A(LAJM2),A(LRHS),A(LEND),A(LICC),
     1   NZ,NC,NZP2,NCP,EPSI,IITMAX,IIC,ERRI,A(LP) )
      IF(ITAM.NE.0) CALL INNBGS
        IITOT=IITOT+IIC
C
C  OBTAIN REMAINING VARIABLES AND COMPUTE ERROR
C
        CALL UPDATE(A(LICC),A(LIRC),A(LPN),A(LALPN),A(LTVN),A(LTLN),
     1A(LROVN),A(LROLN),A(LEVN),A(LELN),A(LDP),A(LRHS),A(LCPA),A(LCPTV),
     2   A(LCPTL),A(LTSAT),A(LTW),A(LDTW),A(LHLFC),A(LHLNB),A(LHVFC),
     3   A(LHVS),A(LHLS),NZ,NC,NZP,NZP2)
        IF (LERR) RETURN
        IF(NITMAX.EQ.1) GO TO 200
        CALL NEWERR(A(LPN),A(LDP),ERRN,NZP2*NC)
   20   CONTINUE
C
C  TEST ERROR
C
        IF(ERRN.LE.EPSN) GO TO 200
  100   CONTINUE
      IF (NITMAX.GT.0) GO TO 200
C
C  NEWTON ITERATIONS FAILED TO CONVERGE AS REQUIRED
C
      IERR = 9
      LERR = .TRUE.
      RETURN
C
C  COMPUTE VELOCITIES
C
  200 CALL VSET(A(LICC),A(LPN),A(LVVX),A(LVLX),A(LVVY),A(LVLY),A(LVVZ),
     1 A(LVLZ),A(LCPVX),A(LCPLX),A(LCPVY),A(LCPLY),A(LCPVZ),
     2 A(LCPLZ),A(LFVX),A(LFLX),A(LFVY),A(LFLY),A(LFVZ),A(LFLZ),
     3 NZP2,NZP,NZ)
C
C  DETERMINE QUANTITIES IN TOP AND BOTTOM FICTITIOUS CELLS
C
      CALL QSET(A(LPN),A(LALPN),A(LROVN),A(LROLN),A(LEVN),A(LELN),
     1          A(LTVN),A(LTLN),A(LVVZ),A(LVLZ),A(LTSAT),
     2          A(LDZ),A(LVISL),A(LVISV),A(LIWFZ),A(LHDZ),GRAV,
     3          NZP2,NZP,NC,ITB,IBB)
C
C  COMPUTE PROPERTIES
C
      CALL PSET(A(LPN),A(LROVN),A(LROLN),A(LEVN),A(LELN),A(LTVN),
     1 A(LTLN),A(LHV),A(LHL),A(LVISV),A(LVISL),NZP2)
      RETURN
      END
```

```
      SUBROUTINE NEWERR(PN,DP,ERRN,N)
C
C  FIND LARGEST RELATIVE PRESSURE CHANGE FOR THE PRECEDING
C   NEWTON ITERATION
C
      DIMENSION PN(1),DP(1)
C
      ERRN=0.0
      DO 10 I=1,N
        IF(PN(I).NE.0.0) ERRN=AMAX1(ERRN,ABS(DP(I)/PN(I)) )
   10   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE EDIT(PN,ALPN,ROVN,ROLN,EVN,ELN,TVN,TLN,
     1 VVX,VLX,VVY,VLY,VVZ,VLZ,TSAT,HV,HL,TRN,IHTR,QPP,DZ,ARZ,RN,
     2 FRACP,CHFR,M1,M2,M3,M4)
C
C  PRINTS OUT STATE OF FLOW AT THE END OF SPECIFIED TIME STEPS
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      COMMON /UNITS/ NTTY,NINP,NOUT,NTZC,NRES,NDUMP
      DIMENSION PN(M1,1),ALPN(M1,1),ROVN(M1,1),ROLN(M1,1),EVN(M1,1),
     1 ELN(M1,1),TVN(M1,1),TLN(M1,1),VVX(M1,1),VLX(M1,1),VVY(M1,1),
     2 VLY(M1,1),VVZ(M2,1),VLZ(M2,1),TSAT(M1,1),HV(M1,1),HL(M1,1),
     3 TRN(M3,M4,1),IHTR(M4,1),QPP(M4,1),DZ(1),ARZ(M2,1),RN(1),FRACP(1)
     4 ,CHFR(M4,1)
      LOGICAL LONG,SHORT
      IDON(V) = INT(.51 + SIGN(.5,V) )
C
C  OBTAIN CURRENT CPU TIME
C
      CALL TIMING(NCPU)
      CPU=.01*(NCPU-ICPU)
C
C  MONITOR PRINT
C
      SHORT=.TRUE.
      LONG=.TRUE.
      RTM=RTIME+0.5*DELT
      IF(ISS.NE.0) GO TO 300
      IF(LOUTPU) GO TO 300
C
C     CHECK THE ONSET OF CHF
C
      DO 400 I=1,NRODS
      DO 400 J=1,NZ
  400 IF(CHFR(J,I).LE.1.) GO TO 350
      GO TO 300
  350 LOUTPU=.TRUE.
      GO TO 19
  300 IF(NSTEP.GT.0.AND.ICPU.GT.0) GO TO 10
        WRITE(NTTY,1011)
        CPU=0.0
        KCPU = ICPU + 6000
        GO TO 19
C
   10 CONTINUE
C  SHORT PRINT
      IF(RTIME.GE.RTNSP)GO TO 11
```

```
      IF(RTNSP.LT.RTM)GO TO 11
      SHORT=.FALSE.
C  LONG PRINT
   11 CONTINUE
      IF(RTIME.GE.RTNLP)GO TO 12
      IF(RTNLP.LT.RTM)GO TO 12
      LONG=.FALSE.
   12 CONTINUE
      IF (NCPU.LT.KCPU) GO TO 15
        WRITE(NTTY,1018) RTIME,DELT,CPU,KRED
        KCPU = KCPU + 6000
   15 IF (.NOT.(LONG.OR.SHORT)) RETURN
C
C  HEADING FOR BOTH SHORT AND LONG PRINT
C
   19 HSUM = 0.
      QSUM = 0.
      WSUMI = 0.
      WSUMO = 0.
      DO 20 I=1,NC
        JI =    2 - IDON(VVZ(  1,I))
        JO = NZP2 - IDON(VVZ(NZP,I))
      WI = ALPN(JI,I)*ROVN(JI,I)*VVZ(  1,I)*ARZ(  1,I)
      WO = ALPN(JO,I)*ROVN(JO,I)*VVZ(NZP,I)*ARZ(NZP,I)
      WSUMI = WSUMI+WI
      WSUMO = WSUMO+WO
      HSUM = HSUM+HV(JO,I)*WO-HV(JI,I)*WI
        JI =    2 - IDON(VLZ(  1,I))
        JO = NZP2 - IDON(VLZ(NZP,I))
      WI = (1.-ALPN(JI,I))*ROLN(JI,I)*VLZ(  1,I)*ARZ(  1,I)
      WO = (1.-ALPN(JO,I))*ROLN(JO,I)*VLZ(NZP,I)*ARZ(NZP,I)
      WSUMI = WSUMI+WI
      WSUMO = WSUMO+WO
20    HSUM = HSUM+HL(JO,I)*WO-HL(JI,I)*WI
      DO 30 I=1,NRODS
        DO 30 J=1,NZ
   30    QSUM = QSUM + QPP(J,I)*DZ(J+1)*RN(I)*FRACP(I)
C
      KCPU = NCPU + 6000
      QKW = 0.001*Q
      HSUM = 0.001*HSUM
      PERIM = 6.2831853*RADR
      QSUM = 0.001*QSUM*PERIM
      WERR =WSUMI-WSUMO
      QERR = QKW-HSUM
      WRITE(NTTY,1000) NSTEP,RTIME,DELT,NITNO,IITOT,CPU,WERR,QERR
      WRITE (NOUT,1001) NSTEP,RTIME,DELT,CPU,NITNO,IITOT,KRED,
     1 QKW,WSUMI,QSUM,WSUMO,TWMAX,ITWMAX,JTWMAX,
     2 HSUM,TRMAX,ITRMAX,JTRMAX,AMCHFR,IMCHFR,JMCHFR
      KRED = 0
      IF (LONG) GO TO 200
C
C  SHORT PRINT
C
```

```
      RTNSP=RTNSP+DTSP
      WRITE(NOUT,1002)
      DO 110 I=1,NC
        WRITE(NOUT,1053) I,(PN(J,I),J=1,NZP2)
  110   CONTINUE
      WRITE(NOUT,1014)
      WRITE(NOUT,1004)
      DO 120 I=1,NC
        WRITE(NOUT,1003) I,(ALPN(J,I),J=1,NZP2)
  120   CONTINUE
      RETURN
C
C  LONG PRINT
C
  200 CONTINUE
      RTNLP=RTNLP+DTLP
      IF(SHORT)RTNSP=RTNSP+DTSP
      WRITE (NOUT,1006)
      DO 220 I=1,NC
      TMASS=0.
      WLEVEL=0.
        DO 210 J=1,NZP
        JJ=J+1
          JV = J + 1 - IDON(VVZ(J,I))
          JL = J + 1 - IDON(VLZ(J,I))
          QUAL = ALPN(JV,I)*ROVN(JV,I)*VVZ(J,I)
          G = QUAL + (1.-ALPN(JL,I))*ROLN(JL,I)*VLZ(J,I)
          IF (G.NE.0.)  QUAL = 100.*QUAL/G
          IF ((VVZ(J,I).LT.0.).OR.(VLZ(J,I).LT.0.))
     +    QUAL=ALPN(JJ,I)*ROVN(JJ,I)/(ALPN(JJ,I)*ROVN(JJ,I)+(1.-ALPN
     +          (JJ,I))*ROLN(JJ,I))
          HM = (1.-QUAL/100.)*HL(J,I) + QUAL/100.*HV(J,I)
        WRITE(NOUT,1007) I,J,PN(J,I),ALPN(J,I),QUAL,HM,HL(J,I),
     1      TVN(J,I),TLN(J,I),TSAT(J,I),VVZ(J,I),VLZ(J,I),ROVN(J,I),
     2      ROLN(J,I),G
  210 CONTINUE
        WRITE (NOUT,1017) I,NZP2,PN(NZP2,I),ALPN(NZP2,I),HM,
     1    HL(NZP2,I),TVN(NZP2,I),TLN(NZP2,I),TSAT(NZP2,I),
     2    ROVN(NZP2,I),ROLN(NZP2,I)
  220   CONTINUE
C
      IF (NC.EQ.1.OR.ITAM.EQ.0) GO TO 250
      WRITE (NOUT,1008)
      DO 240 I=1,NC,2
        IP = I+1
        IF (IP.GT.NC) GO TO 232
        WRITE (NOUT,1009) (I,VVX(J,I),VLX(J,I),VVY(J,I),VLY(J,I),J,
     1    IP,VVX(J,IP),VLX(J,IP),VVY(J,IP),VLY(J,IP), J=2,NZP)
        GO TO 233
  232     WRITE (NOUT,1015) (I,VVX(J,I),VLX(J,I),VVY(J,I),VLY(J,I), J,
     1      J=2,NZP)
  233   WRITE (NOUT,1014)
  240   CONTINUE
C
```

```
  250 IF (IHT.EQ.0.OR.IQSS.EQ.0) GO TO 280
      WRITE (NOUT,1012)
      DO 270 I=1,NRODS
        DO 260 J=1,NZ
          WRITE (NOUT,1013) I,J,IHTR(J,I),QPP(J,I),CHFR(J,I),
     1                          (TRN(K,J,I), K=1,NODES)
  260     CONTINUE
        WRITE (NOUT,1014)
  270   CONTINUE
C
  280 IF (.NOT.LERR) RETURN
      WRITE (NOUT,1016)
      RETURN
C
C
 1000 FORMAT(I5,E12.5,E10.3,2I4,F8.2,1X,E12.5,2X,E12.5)
 1001 FORMAT(15H1TIME STEP NO =,I5,10X,6HTIME =,F11.6,4H SEC,6X,
     1 16HTIME STEP SIZE =,E12.5,4H SEC,10X,10HCPU TIME =,F8.2,4H SEC,/
     2 30H NUMBER OF NEWTON ITERATIONS =, I4,/
     3 30H NUMBER OF INNER ITERATIONS = , I4,20X,I4,
     A   36H REDUCED TIME STEPS SINCE LAST PRINT//
     4 22H TOTAL REACTOR POWER =,F12.3,3H KW,10X,
     5 18H INLET FLOW RATE =,F12.3,5H KG/S,9X,
     6 29H MAXIMUM TEMPERATURES  IR  IZ,/
     7 22H TOTAL HEAT TRANSFER =,F12.3,3H KW,10X,
     8 18HOUTLET FLOW RATE =,F12.3,5H KG/S,9X,
     9 10H   WALL:  ,F8.2,3H AT,2I4,/
     1 22H FLUID ENERGY RISE   =,F12.3,3H KW,54X,
     2 10H   ROD:   ,F8.2,3H AT,2I4,/ 91X,
     3 12H MIN CHFR = ,F6.3,3H AT,2I4,//)
 1002 FORMAT(9H PRESSURE,/)
 1003 FORMAT(I4,10 F10.5,/(4X,10 F10.5) )
 1053 FORMAT(I4,-5P 10F10.5,/ (4X,10F10.5) )
 1004 FORMAT(6H ALPHA,/)

 1006 FORMAT (52H  IC  IZ  PRESSURE VOID    % QUAL     HM       HL    ,
     1  24H  T VAP   T LIQ   T SAT ,5X,3HVVZ,5X,3HVLZ,
     2  6X,3HROV,6X,3HROL,5X,9HMASS FLUX,/,10X,5H(MPA),20X,2(7H(KJ/KG),
     3  2X),2X,3(3H(K),5X),2X,2(5H(M/S),3X),2(7H(KG/M3),1X),
     4  2X,9H(KG/M2-S),//)
 1007 FORMAT (2I4, -6P F9.5, 0P F8.4,F7.2, -3P F11.3,  F9.3,
     1   0P 3F8.2, 2X,2F8.3,2F9.2,F10.1)
 1017 FORMAT (2I4, -6P F9.5, 0P F8.4, 7X , -3P F11.3,F9.3,
     1         0P 3F8.2,18X,2F9.2/)
 1008 FORMAT (//4H  IC, 4X,3HVVX,8X,3HVLX,8X,3HVVY,8X,3HVLY,4X,
     1  8H  IZ  IC, 4X,3HVVX,8X,3HVLX,8X,3HVVY,8X,3HVLY,//)
 1009 FORMAT (I4, 1P 4E11.3, 2I4, 1P 4E11.3)
C
 1011 FORMAT(41H STEP  REAL TIME   DELTA T  NIT IIT   CPU,
     1       29H    FLOW ERROR   ENERGY ERROR)
C
 1012 FORMAT (//13H  IR  IZ IHTR, 2X,17HHEAT FLUX(W/M**2), 2X,
     1   12HCHFR OR CPR ,2X,
     1  16HROD TEMPERATURES,8H (DEG K),//)
```

```
 1013 FORMAT (2I4,I5, F12.0,9X,F7.4,5X, 15F7.1, (30X,15F7.1) )
C
 1014 FORMAT (/)
 1015 FORMAT(I4,1P4E11.3,I4)
 1016 FORMAT (//38H STATE OF FLOW WHEN ERROR WAS DETECTED/)
 1018 FORMAT (5X,E12.5,E10.3,8X,F8.2, I8,8H REDUCED)
C
      END
```

```
      SUBROUTINE MOVE(PN,P,NM)
      DIMENSION PN(1),P(1)
C
      DO 10 I=1,NM
   10   P(I)=PN(I)
      RETURN
      END
```

```
      SUBROUTINE VSET(ICC,PN,VVX,VLX,VVY,VLY,VVZ,VLZ,CPVX,CPLX,CPVY,
     1  CPLY,CPVZ,CPLZ,FVX,FLX,FVY,FLY,FVZ,FLZ,M1,M2,M3)
C
C  COMPUTES VELOCITIES AFTER NEWTON ITERATIONS TERMINATE
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      DIMENSION ICC(4,1),PN(M1,1),VVX(M1,1),VLX(M1,1),VVY(M1,1),
     1  VLY(M1,1),VVZ(M2,1),VLZ(M2,1),CPVX(M3,1),CPLX(M3,1),CPVY(M3,1),
     2  CPLY(M3,1),CPVZ(M2,1),CPLZ(M2,1),FVX(M3,1),FLX(M3,1),
     3  FVY(M3,1),FLY(M3,1),FVZ(M2,1),FLZ(M2,1)
C
      DO 100 I=1,NC
        IXM=ICC(2,I)
        IYM=ICC(1,I)
        DO 50 J=1,NZ
          JJ=J+1
          VVX(JJ,I)=CPVX(J,I)*(PN(JJ,I)-PN(JJ,IXM))+FVX(J,I)
          VLX(JJ,I)=CPLX(J,I)*(PN(JJ,I)-PN(JJ,IXM))+FLX(J,I)
          VVY(JJ,I)=CPVY(J,I)*(PN(JJ,I)-PN(JJ,IYM))+FVY(J,I)
          VLY(JJ,I)=CPLY(J,I)*(PN(JJ,I)-PN(JJ,IYM))+FLY(J,I)
          VVZ(J,I)=CPVZ(J,I)*(PN(JJ,I)-PN(J,I))+FVZ(J,I)
          VLZ(J,I)=CPLZ(J,I)*(PN(JJ,I)-PN(J,I))+FLZ(J,I)
   50     CONTINUE
        VVZ(NZP,I)=CPVZ(NZP,I)*(PN(NZP2,I)-PN(NZP,I))+FVZ(NZP,I)
        VLZ(NZP,I)=CPLZ(NZP,I)*(PN(NZP2,I)-PN(NZP,I))+FLZ(NZP,I)
  100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PSET(PN,ROVN,ROLN,EVN,ELN,TVN,TLN,HV,HL,VISV,VISL,M1)
C
C  COMPUTES FLUID PROPERTIES (ENTHALPY, VISCOSITY) AT END OF
C   NEWTON ITERATIONS
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,QO,TO,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      DIMENSION PN(M1,1),ROVN(M1,1),ROLN(M1,1),EVN(M1,1),ELN(M1,1),
     1  TVN(M1,1),TLN(M1,1),HV(M1,1),HL(M1,1),VISV(M1,1),VISL(M1,1)
C
      DO 100 I=1,NC
        DO 100 J=1,NZP2
          HV(J,I)=EVN(J,I)+PN(J,I)/ROVN(J,I)
          HL(J,I)=ELN(J,I)+PN(J,I)/ROLN(J,I)
          VISV(J,I)=VISVP(TVN(J,I))
          VISL(J,I)=VISLQ(TLN(J,I))
  100     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE QSET(PN,ALPN,ROVN,ROLN,EVN,ELN,TVN,TLN,VVZ,VLZ,TSAT,
     1                DZ,VISL,VISV,IWFZ,HDZ,GRAV,NZP2,NZP,NC,ITB,IBB)
C
C  COMPUTES QUANTITIES FOR TOP AND BOTTOM LAYERS OF FICTITIOUS CELLS
C
      DIMENSION PN(NZP2,1),ALPN(NZP2,1),ROVN(NZP2,1),ROLN(NZP2,1),
     1          EVN(NZP2,1),ELN(NZP2,1),TVN(NZP2,1),TLN(NZP2,1),
     2          TSAT(NZP2,1),VVZ(NZP,1),VLZ(NZP,1),VISL(NZP2,1),
     3          VISV(NZP2,1),DZ(2),HDZ(2),IWFZ(1)
C
      IDON(I1,I2,V) = I1+(I2-I1)*INT(.51+SIGN(.5,V))
C                   = I1 IF V<0,  = I2 IF V>0
      DO 100 I=1,NC
        JDN = IDON(   2,    1,VVZ(   1,I))
        TVN(   1,I) = TVN(JDN,I)
        ALPN(   1,I) = ALPN(JDN,I)
        JDN = IDON(   2,    1,VLZ(   1,I))
        TLN(   1,I) = TLN(JDN,I)
        JDN = IDON(NZP2, NZP,VVZ(NZP,I))
        TVN(NZP2,I) = TVN(JDN,I)
        ALPN(NZP2,I) = ALPN(JDN,I)
        JDN = IDON(NZP2, NZP,VLZ(NZP,I))
        TLN(NZP2,I) = TLN(JDN,I)
C
C   COMPUTE PRESSURE IN FICTITOUS CELL IF IBB=0
C
        IF(IBB.NE.1) GO TO 30
        DZA=.5* (DZ(1) + DZ(2))
        RDZ = 0.5 /DZA
        RDZ2 = 2. * RDZ
        ROLA = RDZ*(ROLN(1,I)*DZ(1) + ROLN(2,I)*DZ(2))
        ROVA = RDZ*(ROVN(1,I)*DZ(1) + ROVN(2,I)*DZ(2))
        ALPA = RDZ*(ALPN(1,I)*DZ(1) + ALPN(2,I)*DZ(2))
        ALPA1 = 1.-ALPA
        VISVA = RDZ*(VISV(1,I)*DZ(1) + VISV(2,I)*DZ(2))
        VISLA = RDZ*(VISL(1,I)*DZ(1) + VISL(2,I)*DZ(2))
        PA = RDZ*(PN(1,I)*DZ(1) + PN(2,I)*DZ(2))
        CFV=0.0
        CFL=1.0
        CALL FWALL(FWV,FWL,HDZ(I),1.,CFV,CFL,PA,ALPA,ROVA,ROLA,
     1             VVZ(1,I),VLZ(1,I),VISVA,VISLA,RDZ2,IWFZ(1),I,1)
        CONV=0.0
        IF(VLZ(1,I).LT.0.) CONV=(VLZ(2,I)-VLZ(1,I))*VLZ(1,I)/DZ(2)
        PN(1,I) = PN(2,I) + DZA*(ROLA*(CONV-GRAV)+FWL*VLZ(1,I)/ALPA1)
   30   CONTINUE

        CALL STATE(PN(   1,I),TVN(   1,I),TLN(   1,I),ROVN(   1,I),
     1             ROLN(   1,I),EVN(   1,I),ELN(   1,I),TSAT(   1,I),
     2             D0,D00,D1,D2,D3,D4,D5,D6,D7,D8,D9,2,IERR)
        CALL STATE(PN(NZP2,I),TVN(NZP2,I),TLN(NZP2,I),ROVN(NZP2,I),
     1             ROLN(NZP2,I),EVN(NZP2,I),ELN(NZP2,I),TSAT(NZP2,I),
     2             D0,D00,D1,D2,D3,D4,D5,D6,D7,D8,D9,2,IERR)
  100 CONTINUE
      RETURN
```

END

```
      SUBROUTINE EXPLCT(ICC,IRC,DX,DY,DZ,VVX,VVY,VVZ,
     1  VLX,VLY,VLZ,P,ALP,ROV,ROL,CPVX,CPLX,CPVY,CPLY,
     2  CPVZ,CPLZ,FVX,FLX,FVY,FLY,FVZ,FLZ,ARX,ARY,ARZ,IWFZ,VISV,VISL,
     3  IHTR,QV,QL, HDZ,FRACP,SIJ,M4,M3,M2,M1)
C
C  COMPUTES THE COEFFICIENTS OF P AND OF VELOCITIES IN LINEAR
C   MOMENTUM EQUATIONS
C
C  SINCE ALL TERMS ARE ASSUMED TO BE LINEAR IN IMPLICIT VARIABLES, THIS
C   CALCULATION IS ONLY DONE ONCE PER TIME STEP
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      DIMENSION ICC(4,1),IRC(4,1),DX(1),DY(1),DZ(1),HDZ(1),VVX(M1,1),
     1  VVY(M1,1),VVZ(M2,1),P(M1,1),ALP(M1,1),ROV(M1,1),ROL(M1,1),
     2  CPVX(M3,1),CPLX(M3,1),CPVY(M3,1),CPLY(M3,1),
     3  CPVZ(M2,1),CPLZ(M2,1),FVX(M3,1),FLX(M3,1),
     4  FVY(M3,1),FLY(M3,1),FVZ(M2,1),FLZ(M2,1),
     5  VLX(M1,1),VLY(M1,1),VLZ(M2,1),ARX(M3,1),ARY(M3,1),ARZ(M2,1),
     6  IWFZ(1),VISV(M1,1),VISL(M1,1),IHTR(M3,1),QV(M3,1),QL(M3,1)
     7   ,FRACP(1)
       DIMENSION SIJ(4,1)
      DATA  ITRNS / 5 /
C--VALUE OF IHTR FOR TRANSITION BOILING REGIME. IT IS ASSUMED THAT
C  FOR IHTR<5, LIQUID COATS RODS, FOR IHTR>5, VAPOR CONTACTS RODS
      IDON(I1,I2,V)=I1+(I2-I1)*INT(.51+SIGN(.5,V))
C                   =I1 IF V<0,   =I2 IF V>0
C
      JSTART=1
      JSTOP=NZP
      IF(IBB.EQ.1)JSTART=2
      IF(ITB.EQ.1)JSTOP=NZ
C
C  MOMENTUM EQUATIONS
C
      DO 1000 I=1,NC
        IYM=ICC(1,I)
        IXM=ICC(2,I)
        IXP=ICC(3,I)
        IYP=ICC(4,I)
        IF(IXM.EQ.NCP) GO TO 200
        IF(ITAM.EQ.0)  GO TO 200
        IXMYP = ICC(4,IXM)
C
C  X DIRECTION
C
        DO 100 J=1,NZ
```

```
      IF(ARX(J,I).EQ.0.0) GO TO 100
      JJ=J+1
      RDX=1./(DX(I)+DX(IXM))
      RDX2=2.*RDX
      PA=RDX*(P(JJ,I)*DX(I)+P(JJ,IXM)*DX(IXM))
      ALPA=RDX*(ALP(JJ,I)*DX(I)+ALP(JJ,IXM)*DX(IXM))
      ROVA=RDX*(ROV(JJ,I)*DX(I)+ROV(JJ,IXM)*DX(IXM))
      ROLA=RDX*(ROL(JJ,I)*DX(I)+ROL(JJ,IXM)*DX(IXM))
      ARV=ALPA*ROVA
      ARL=(1.-ALPA)*ROLA
      VISVA=RDX*(VISV(JJ,I)*DX(I)+VISV(JJ,IXM)*DX(IXM))
      VISLA=RDX*(VISL(JJ,I)*DX(I)+VISL(JJ,IXM)*DX(IXM))
C--SET LIQUID AND VAPOR WALL CONTACT FRACTIONS FOR FWALL
      CFV=0.
      CFL=1.
      IF (IHT.EQ.0) GO TO 90
      IDN = IDON(I,IXM,VLX(JJ,I))
      ITEST = 0
      DO 20 N=1,4
      NN = IRC(N,IDN)
      IF(NN.EQ.0) GO TO 30
      IF(ITEST.LT.IHTR(J,NN)) ITEST = IHTR(J,NN)
 20   CONTINUE
 30   CONTINUE
      IF(ITEST-ITRNS) 40,50,80
 40   GO TO 90
 50   QLSAVE = 0.0
      QVSAVE = 0.0
      DO 60 N=1,4
      NN = IRC(N,IDN)
      IF(NN.EQ.0) GO TO 70
      QLSAVE = QLSAVE + QL(J,NN)*FRACP(NN)
      QVSAVE = QVSAVE + QV(J,NN)*FRACP(NN)
 60   CONTINUE
 70   CFL = QLSAVE/(QLSAVE+QVSAVE)
      CFV = 1.0- CFL
      GO TO 90
 80   CFV=1.
      CFL=0.
 90   IWF = IWFT + 30
      IF (IWFZ(J).EQ.0) IWF = 30
      IF (IVEC.EQ.0) GO TO 95
     VZV = .25*(VVZ(JJ,I) + VVZ(J,I) +VVZ(JJ,IXM) + VVZ(J,IXM))
     VZL = .25*(VLZ(JJ,I) + VLZ(J,I) +VLZ(JJ,IXM) + VLZ(J,IXM))
     VYV = .25*(VVY(JJ,I)+VVY(JJ,IXM)+VVY(JJ,IYP) +VVY(JJ,IXMYP))
     VYL = .25*(VLY(JJ,I)+VLY(JJ,IXM)+VLY(JJ,IYP)+VLY(JJ,IXMYP))
 95  VV=VVX(JJ,I)
     VL=VLX(JJ,I)
      CALL FWALL (FWV,FWL,HDT,VELX,CFV,CFL,PA,ALPA,ROVA,ROLA,
     1  VV,VL,VISVA,VISLA,RDX2,IWF,I,JJ)
      VR=ABS(VV-VL)
      CALL FINTER(FIV,FIL,ALPA,ROVA,ROLA,VR,VISVA,VISLA,HDT,IFINTR)
      CALL CVECX(TCVX,DX,DY,DZ,ICC,IWFZ,VVX,VVY,VVZ,JJ,I,
     1  IXM,IXP,IYM,IYP,NZP,NZP2)
```

```
         CALL CVECX(TCLX,DX,DY,DZ,ICC,IWFZ,VLX,VLY,VLZ,JJ,I,
     1    IXM,IXP,IYM,IYP,NZP,NZP2)
         FEXVX=(RDELT*VVX(JJ,I)-TCVX)*ARV
         FEXLX=(RDELT*VLX(JJ,I)-TCLX)*ARL
         AA=RDELT*ARV+FIV+FWV
         BB=RDELT*ARL+FIL+FWL
         RD=1./(AA*BB-FIL*FIV)
         RVDX=RDX2*ALPA
         RLDX=RDX2*(1.-ALPA)
         CPVX(J,I)=-RD*(BB*RVDX+FIV*RLDX)
         CPLX(J,I)=-RD*(AA*RLDX+FIL*RVDX)
         FVX(J,I)=RD*(BB*FEXVX+FIV*FEXLX)
         FLX(J,I)=RD*(AA*FEXLX+FIL*FEXVX)
  100    CONTINUE
  200  CONTINUE
       IF(IYM.EQ.NCP) GO TO 400
       IF(ITAM.EQ.0)  GO TO 400
       IYMXP=ICC(3,IYM)
C
C  Y DIRECTION
C
       DO 300 J=1,NZ
         IF(ARY(J,I).EQ.0.0) GO TO 300
         JJ=J+1
         RDY=1./(DY(I)+DY(IYM))
         RDY2=2.*RDY
         PA=RDY*(P(JJ,I)*DY(I)+P(JJ,IYM)*DY(IYM))
         ALPA=RDY*(ALP(JJ,I)*DY(I)+ALP(JJ,IYM)*DY(IYM))
         ROVA=RDY*(ROV(JJ,I)*DY(I)+ROV(JJ,IYM)*DY(IYM))
         ROLA=RDY*(ROL(JJ,I)*DY(I)+ROL(JJ,IYM)*DY(IYM))
         ARV=ALPA*ROVA
         ARL=(1.-ALPA)*ROLA
         VISVA=RDY*(VISV(JJ,I)*DY(I)+VISV(JJ,IYM)*DY(IYM))
         VISLA=RDY*(VISL(JJ,I)*DY(I)+VISL(JJ,IYM)*DY(IYM))
C--SET LIQUID AND VAPOR WALL CONTACT FRACTIONS FOR FWALL
         CFV=0.
         CFL=1.
         IF (IHT.EQ.0) GO TO 290
         IDN = IDON(I,IYM,VLY(JJ,I))
         ITEST = 0
         DO 220 N=1,4
         NN = IRC(N,IDN)
         IF(NN.EQ.0) GO TO 230
         IF(ITEST.LT.IHTR(J,NN)) ITEST = IHTR(J,NN)
 220     CONTINUE
 230     CONTINUE
         IF(ITEST -ITRNS) 240,250,280
 240     GO TO 290
 250     QLSAVE = 0.0
         QVSAVE = 0.0
         DO 260 N=1,4
         NN = IRC(N,IDN)
         IF(NN.EQ.0) GO TO 270
         QLSAVE = QLSAVE + QL(J,NN)*FRACP(NN)
```

```
          QVSAVE = QVSAVE + QV(J,NN)*FRACP(NN)
260       CONTINUE
270       CFL = QLSAVE/(QLSAVE+QVSAVE)
          CFV = 1.0 - CFL
          GO TO 290
  280     CFV=1.
          CFL=0.
  290     IWF = IWFT + 30
          IF (IWFZ(J).EQ.0) IWF = 30
          IF(IVEC.EQ.0) GO TO 295
          VZV= .25*(VVZ(JJ,I) + VVZ(JJ,IYM) + VVZ(J,I) + VVZ(J,IYM))
          VZL= .25*(VLZ(JJ,I) + VLZ(JJ,IYM) + VLZ(J,I) + VLZ(J,IYM))
          VXV= .25*(VVX(JJ,IYM)+VVX(JJ,I)+VVX(JJ,IYMXP)+VVX(JJ,IXP))
          VXL= .25*(VLX(JJ,IYM)+VLX(JJ,I)+VLX(JJ,IYMXP)+VLX(JJ,IXP))
 295      VV=VVY(JJ,I)
          VL=VLY(JJ,I)
          CALL FWALL (FWV,FWL,HDT,VELX,CFV,CFL,PA,ALPA,ROVA,ROLA,
     1      VV,VL,VISVA,VISLA,RDY2,IWF,I,JJ)
          VR=ABS(VV-VL)
          CALL FINTER(FIV,FIL,ALPA,ROVA,ROLA,VR,VISVA,VISLA,HDT,IFINTR)
          CALL CVECY(TCVY,DX,DY,DZ,ICC,IWFZ,VVX,VVY,VVZ,JJ,I,
     1      IXM,IXP,IYM,IYP,NZP,NZP2)
          CALL CVECY(TCLY,DX,DY,DZ,ICC,IWFZ,VLX,VLY,VLZ,JJ,I,
     1      IXM,IXP,IYM,IYP,NZP,NZP2)
          FEXVY=(RDELT*VVY(JJ,I)-TCVY)*ARV
          FEXLY=(RDELT*VLY(JJ,I)-TCLY)*ARL
          AA=RDELT*ARV+FIV+FWV
          BB=RDELT*ARL+FIL+FWL
          RD=1./(AA*BB-FIL*FIV)
          RVDY=RDY2*ALPA
          RLDY=RDY2*(1.-ALPA)
          CPVY(J,I)=-RD*(BB*RVDY+FIV*RLDY)
          CPLY(J,I)=-RD*(AA*RLDY+FIL*RVDY)
          FVY(J,I)=RD*(BB*FEXVY+FIV*FEXLY)
          FLY(J,I)=RD*(AA*FEXLY+FIL*FEXVY)
  300     CONTINUE
  400   CONTINUE
C
C  Z DIRECTION
C
        DO 500 J=JSTART,JSTOP
          IF(ARZ(J,I).EQ.0.0) GO TO 500
          JP=J+1
          RDZ=1./(DZ(J)+DZ(JP))
          RDZ2=2.*RDZ
          PA=RDZ*(P(J,I)*DZ(J)+P(JP,I)*DZ(JP))
          ALPA=RDZ*(ALP(J,I)*DZ(J)+ALP(JP,I)*DZ(JP))
          ROVA=RDZ*(ROV(J,I)*DZ(J)+ROV(JP,I)*DZ(JP))
          ROLA=RDZ*(ROL(J,I)*DZ(J)+ROL(JP,I)*DZ(JP))
          ARV=ALPA*ROVA
          ARL=(1.-ALPA)*ROLA
          VISVA=RDZ*(VISV(J,I)*DZ(J)+VISV(JP,I)*DZ(JP))
          VISLA=RDZ*(VISL(J,I)*DZ(J)+VISL(JP,I)*DZ(JP))
C--SET LIQUID AND VAPOR WALL CONTACT FRACTIONS FOR FWALL
```

```
      CFV=0.
      CFL=1.
      IF (IHT.EQ.0) GO TO 490
      JDN = IDON(JP,J,VLZ(J,I)) - 1
      IF ((JDN.EQ.0).OR.(JDN.EQ.NZP)) GO TO 490
      ITEST=0
      DO 420 N=1,4
      NN = IRC(N,I)
      IF(NN.EQ.0) GO TO 430
      IF(ITEST.LT.IHTR(JDN,NN)) ITEST = IHTR(JDN,NN)
420   CONTINUE
430   CONTINUE
      IF(ITEST -ITRNS) 440,450,480
 440  GO TO 490
450   QLSAVE = 0.0
      QVSAVE = 0.0
      DO 460 N=1,4
      NN = IRC(N,I)
      IF(NN.EQ.0) GO TO 470
      QLSAVE = QLSAVE + QL(JDN,NN)*FRACP(NN)
      QVSAVE = QVSAVE + QV(JDN,NN)*FRACP(NN)
460   CONTINUE
470   CFL = QLSAVE/(QLSAVE+QVSAVE)
      GO TO 490
 480  CFV=1.
      CFL=0.
 490  IWF = IWFZ(J)
      CALL FWALL (FWV,FWL,HDZ(I),1.   ,CFV,CFL,PA,ALPA,ROVA,ROLA,
     1  VVZ(J,I),VLZ(J,I),VISVA,VISLA,RDZ2,IWF,I,J)
      VR=ABS(VVZ(J,I)-VLZ(J,I))
    CALL FINTER(FIV,FIL,ALPA,ROVA,ROLA,VR,VISVA,VISLA,HDZ(I),IFINTR)
      CALL CVECZ(TCVZ,DX,DY,DZ,ICC,VVX,VVY,VVZ,J,I,
     1  IXM,IXP,IYM,IYP,NZP,NZP2)
      CALL CVECZ(TCLZ,DX,DY,DZ,ICC,VLX,VLY,VLZ,J,I,
     1  IXM,IXP,IYM,IYP,NZP,NZP2)
C
C   CALCULATE TURBULENT MIXING PRESSURE GRADIENT
C
      DPDZTV=0.0
      DPDZTL=0.0
      IF(ITAM.EQ.0.OR.IMIXM.EQ.0) GO TO 496
      DO 495 IJ=1,4
      IC=ICC(IJ,I)
      IF(IC.EQ.NCP.OR.SIJ(IJ,I).EQ.0.) GO TO 495
      ALPAJ=RDZ*(ALP(J,IC)*DZ(J)+ALP(JP,IC)*DZ(JP))
      ROVAJ=RDZ*(ROV(J,IC)*DZ(J)+ROV(JP,IC)*DZ(JP))
      ROLAJ=RDZ*(ROL(J,IC)*DZ(J)+ROL(JP,IC)*DZ(JP))
      ARVJ=ALPAJ*ROVAJ
      ARLJ=(1.-ALPAJ)*ROLAJ
      VISLAJ=RDZ*(VISL(J,IC)*DZ(J)+VISL(JP,IC)*DZ(JP))
      CALL MIXING(ROVA,ROVAJ,ROLA,ROLAJ,VISLA,VISLAJ,HDZ(I),
     1        HDZ(IC),ARZ(J,I),ARZ(J,IC),VVZ(J,I),VVZ(J,IC),
     2        VLZ(J,I),VLZ(J,IC),SIJ(IJ,I),ARV,ARVJ,ARL,ARLJ,
     3        D1,D2,D3,D4,DPDZV,DPDZL,D5,D6,D7,D8,D9,D10,D11,D12,
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    4           D13,D14,D15,D16,D17,D18,D19,D20,D21,D22,D23,
    5           D24,D25,D26,D27,D28,D29,D30,D31,RADR,1)
          DPDZTV=DPDZTV+DPDZV
          DPDZTL=DPDZTL+DPDZL
  495     CONTINUE
          RARZ=1./ARZ(J,I)
          DPDZTV=DPDZTV*RARZ
          DPDZTL=DPDZTL*RARZ
  496     CONTINUE
          FEXVZ=(RDELT*VVZ(J,I)-TCVZ+GRAV)*ARV-DPDZTV
          FEXLZ=(RDELT*VLZ(J,I)-TCLZ+GRAV)*ARL-DPDZTL
          AA=RDELT*ARV+FIV+FWV
          BB=RDELT*ARL+FIL+FWL
          RD=1./(AA*BB-FIL*FIV)
          RVDZ=RDZ2*ALPA
          RLDZ=RDZ2*(1.-ALPA)
          CPVZ(J,I)=-RD*(BB*RVDZ+FIV*RLDZ)
          CPLZ(J,I)=-RD*(AA*RLDZ+FIL*RVDZ)
          FVZ(J,I)=RD*(BB*FEXVZ+FIV*FEXLZ)
          FLZ(J,I)=RD*(AA*FEXLZ+FIL*FEXVZ)
  500     CONTINUE
 1000   CONTINUE
C
C  SET TOP AND BOTTOM VELOCITY BOUNDARY CONDITIONS
C
      IF(IBB.EQ.0) GO TO 1200
      DO 1100 I=1,NC
        FVZ(1,I)=VVZ(1,I)
        FLZ(1,I)=VLZ(1,I)
 1100   CONTINUE
 1200 CONTINUE
      IF(ITB.EQ.0) GO TO 1400
      DO 1300 I=1,NC
        FVZ(NZP,I)=VVZ(NZP,I)
        FLZ(NZP,I)=VLZ(NZP,I)
 1300   CONTINUE
 1400 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CVECX(TCX,DX,DY,DZ,ICC,IWFZ,VX,VY,VZ,IZP,IC,
     1    IXM,IXP,IYM,IYP,NZP,NZP2)
C
C  CALCULATES (EXPLICIT) CONVECTIVE TERMS IN X DIRECTION MOMENTUM
C   EQUATIONS      (ONE CALL FOR EACH PHASE)
C
C  INCLUDES AXIAL FUNNEL EFFECT WHERE IWFZ >= 20
C
      DIMENSION DX(1),DY(1),DZ(1),ICC(4,1),IWFZ(1),
     1          VX(NZP2,1),VY(NZP2,1),VZ(NZP,1)
C
      IXMYP = ICC(4,IXM)
C
      VY1 = 0.5*(VY(IZP  ,IXM  )+VY(IZP  ,IC ))
      VY4 = 0.5*(VY(IZP  ,IXMYP)+VY(IZP  ,IYP))
      VZ5 = 0.5*(VZ(IZP-1,IXM  )+VZ(IZP-1,IC ))
      VZ6 = 0.5*(VZ(IZP  ,IXM  )+VZ(IZP  ,IC ))
C
      VXA = VX(IZP,IC)
      VYA = 0.5*(VY1+VY4)
      VZA = 0.5*(VZ5+VZ6)
C
      DVXXM = (VX(IZP  ,IC )-VX(IZP  ,IXM))/ DX(IXM)
      DVXXP = (VX(IZP  ,IXP)-VX(IZP  ,IC ))/ DX(IC )
      DVXYM = (VX(IZP  ,IC )-VX(IZP  ,IYM))/(DY(IC )+DY(IYM  ))*2.0
      DVXYP = (VX(IZP  ,IYP)-VX(IZP  ,IC ))/(DY(IYP)+DY(IC   ))*2.0
      VXINZ =                VX(IZP-1,IC )
      IF (IWFZ(IZP-1).GE.20) VXINZ=0.
      DVXZM = (VX(IZP  ,IC )-VXINZ        )/(DZ(IZP)+DZ(IZP-1))*2.0
      VXINZ =  VX(IZP+1,IC )
      IF (IWFZ(IZP  ).GE.20) VXINZ=0.
      DVXZP = (VXINZ        -VX(IZP  ,IC ))/(DZ(IZP)+DZ(IZP+1))*2.0
C
      TCXXD = 0.5*((VXA+ABS(VXA))*DVXXM+(VXA-ABS(VXA))*DVXXP)
      TCXYD = 0.5*((VYA+ABS(VYA))*DVXYM+(VYA-ABS(VYA))*DVXYP)
      TCXZD = 0.5*((VZA+ABS(VZA))*DVXZM+(VZA-ABS(VZA))*DVXZP)
C
      TCX = TCXXD+TCXYD+TCXZD
      RETURN
      END
```

```
      SUBROUTINE CVECY(TCY,DX,DY,DZ,ICC,IWFZ,VX,VY,VZ,IZP,IC,
     1    IXM,IXP,IYM,IYP,NZP,NZP2)
C
C  CALCULATES (EXPLICIT) CONVECTIVE TERMS IN Y DIRECTION MOMENTUM
C   EQUATIONS      (ONE CALL FOR EACH PHASE)
C
C  INCLUDES AXIAL FUNNEL EFFECT WHERE IWFZ >= 20
C
      DIMENSION DX(1),DY(1),DZ(1),ICC(4,1),IWFZ(1),
     1          VX(NZP2,1),VY(NZP2,1),VZ(NZP,1)
C
      IYMXP = ICC(3,IYM)
C
      VX2 = 0.5*(VX(IZP  ,IYM  )+VX(IZP  ,IC ))
      VX3 = 0.5*(VX(IZP  ,IYMXP)+VX(IZP  ,IXP))
      VZ5 = 0.5*(VZ(IZP-1,IYM  )+VZ(IZP-1,IC ))
      VZ6 = 0.5*(VZ(IZP  ,IYM  )+VZ(IZP  ,IC ))
C
      VXA = 0.5*(VX2+VX3)
      VYA = VY(IZP,IC)
      VZA = 0.5*(VZ5+VZ6)
C
      DVYXM = (VY(IZP  ,IC )-VY(IZP  ,IXM))/(DX(IC )+DX(IXM  ))*2.0
      DVYXP = (VY(IZP  ,IXP)-VY(IZP  ,IC ))/(DX(IXP)+DX(IC   ))*2.0
      DVYYM = (VY(IZP  ,IC )-VY(IZP  ,IYM))/ DY(IYM)
      DVYYP = (VY(IZP  ,IYP)-VY(IZP  ,IC ))/ DY(IC )
      VYINZ =              VY(IZP-1,IC )
      IF (IWFZ(IZP-1).GE.20) VYINZ=0.
      DVYZM = (VY(IZP  ,IC )-VYINZ        )/(DZ(IZP)+DZ(IZP-1))*2.0
      VYINZ =  VY(IZP+1,IC )
      IF (IWFZ(IZP  ).GE.20) VYINZ=0.
      DVYZP = (VYINZ        -VY(IZP  ,IC ))/(DZ(IZP)+DZ(IZP+1))*2.0
C
      TCYXD = 0.5*((VXA+ABS(VXA))*DVYXM+(VXA-ABS(VXA))*DVYXP)
      TCYYD = 0.5*((VYA+ABS(VYA))*DVYYM+(VYA-ABS(VYA))*DVYYP)
      TCYZD = 0.5*((VZA+ABS(VZA))*DVYZM+(VZA-ABS(VZA))*DVYZP)
C
      TCY = TCYXD+TCYYD+TCYZD
      RETURN
      END
```

```
      SUBROUTINE CVECZ(TCZ,DX,DY,DZ,ICC,VX,VY,VZ,IZ,IC,
     1    IXM,IXP,IYM,IYP,NZP,NZP2)
C
C  CALCULATES (EXPLICIT) CONVECTIVE TERMS IN Z DIRECTION MOMENTUM
C   EQUATIONS      (ONE CALL FOR EACH PHASE)
C
      DIMENSION DX(1),DY(1),DZ(1),ICC(4,1),
     1          VX(NZP2,1),VY(NZP2,1),VZ(NZP,1)
C
      VX2 = 0.5*(VX(IZ,IC )+VX(IZ+1,IC ))
      VX3 = 0.5*(VX(IZ,IXP)+VX(IZ+1,IXP))
      VY1 = 0.5*(VY(IZ,IC )+VY(IZ+1,IC ))
      VY4 = 0.5*(VY(IZ,IYP)+VY(IZ+1,IYP))
C
      VXA = 0.5*(VX2+VX3)
      VYA = 0.5*(VY1+VY4)
      VZA = VZ(IZ,IC)
C
      DVZXM = (VZ(IZ,IC )-VZ(IZ,IXM))/(DX(IC )+DX(IXM))*2.0
      DVZXP = (VZ(IZ,IXP)-VZ(IZ,IC ))/(DX(IXP)+DX(IC ))*2.0
      DVZYM = (VZ(IZ,IC )-VZ(IZ,IYM))/(DY(IC )+DY(IYM))*2.0
      DVZYP = (VZ(IZ,IYP)-VZ(IZ,IC ))/(DY(IYP)+DY(IC ))*2.0
      DVZZM =  VZ(IZ,IC)/DZ(IZ)
      IF(IZ.NE.  1) DVZZM = (VZ(IZ,IC)-VZ(IZ-1,IC))/DZ(IZ  )
      DVZZP = -VZ(IZ,IC)/DZ(IZ)
      IF(IZ.NE.NZP) DVZZP = (VZ(IZ+1,IC)-VZ(IZ,IC))/DZ(IZ+1)
C
      TCZXD = 0.5*((VXA+ABS(VXA))*DVZXM+(VXA-ABS(VXA))*DVZXP)
      TCZYD = 0.5*((VYA+ABS(VYA))*DVZYM+(VYA-ABS(VYA))*DVZYP)
      TCZZD = 0.5*((VZA+ABS(VZA))*DVZZM+(VZA-ABS(VZA))*DVZZP)
C
      TCZ = TCZXD+TCZYD+TCZZD
      RETURN
      END
```

```
      SUBROUTINE JACOB(ICC,ICR,IRC,DZ,VOL,ROV,ROL,ALP,P,EV,EL,
     1  ROVN,ROLN,ALPN,PN,EVN,ELN,TVN,TLN,TW,ARX,ARY,ARZ,
     2  CPVX,CPLX,CPVY,CPLY,CPVZ,CPLZ,FVX,FLX,FVY,FLY,
     3  FVZ,FLZ,RN,QV,HVFC,HLNB,HLFC,
     4  AJM1,AJM2,CPA,CPTV,CPTL,RHS,VVX,VVY,VVZ,VLX,VLY,VLZ,DTW,
     5  IHTR,VISL, HV,FRACP,HDZ,SIJ,
     6  M1,M2,M3,M4 )
C
C  OBTAIN JACOBIAN MATRIX BY LINEARIZING MASS AND ENERGY EQUATIONS,
C   SUBSTITUTING IN THE MOMENTUM EQUATIONS TO ELIMINATE VELOCITIES,
C   REDUCE TO PRESSURE PROBLEM
C
      DOUBLE PRECISION CA,C,CP,F,T,RD
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      DIMENSION ICC(4,1),ICR(1),IRC(4,1),ROV(M1,1),ROL(M1,1),
     1  ALP(M1,1),P(M1,1),EV(M1,1),EL(M1,1),
     2  ROVN(M1,1),ROLN(M1,1),ALPN(M1,1),
     3  PN(M1,1),EVN(M1,1),ELN(M1,1),TVN(M1,1),TLN(M1,1),
     4  TW(M3,1),DTW(M3,1),ARX(M3,1),ARY(M3,1),ARZ(M2,1)
      DIMENSION QV(M3,1),HVFC(M3,1),HLNB(M3,1),HLFC(M3,1)
      DIMENSION DZ(1),VOL(M3,1),RN(1),
     1  VVX(M1,1),VVY(M1,1),VVZ(M2,1),VLX(M1,1),VLY(M1,1),VLZ(M2,1)
      DIMENSION CPVX(M3,1),CPLX(M3,1),CPVY(M3,1),CPLY(M3,1),
     1  CPVZ(M2,1),CPLZ(M2,1),FVX(M3,1),FLX(M3,1),
     2  FVY(M3,1),FLY(M3,1),FVZ(M2,1),FLZ(M2,1)
      DIMENSION AJM1(3,M3,1),AJM2(4,M3,1),CPA(6,M3,1),
     1  CPTV(6,M3,1),CPTL(6,M3,1),RHS(M3,M4,4)
      DIMENSION IHTR(M3,1),VISL(M1,1),FRACP(1),HDZ(1),HV(M1,1)
C
      DIMENSION ARB(6),VVB(6),VLB(6),CC(4,6),CP(4,11),F(4),
     1  TC(4),C(4,4),IJA(6),CA(4,11)
      DIMENSION SIJ(4,1)
      EQUIVALENCE (CA(1,1),C(1,1)),(CA(1,5),CP(1,1)),(CA(1,11),F(1))
      DATA IJA/0,0,0,0,-1,1/
      DATA PI2/6.2831853/
       DATA  HL0,HL1,HL2,HL3,HL4,HL5/5.7474718E5,2.0920624E-1,
     1    -2.8051070E-8,2.3809828E-15,-1.0042660E-22,1.6586960E-30/
       DATA  HV0,HV1,HV2,HV3,HV4/2.7396234E6,3.758844E-2,
     1       -7.1639909E-9,4.2002319E-16,-9.8507521E-24 /
C
C
C
      DO 1000 I=1,NC
C
        IYM=ICC(1,I)
        IXM=ICC(2,I)
```

```
        IXP=ICC(3,I)
        IYP=ICC(4,I)
C
        DO 1000 J=1,NZ
          JJ=J+1
      GAM=0.0
      DGDP=0.0
      DGDA=0.0
      DGDTV=0.0
      DGDTL=0.0
      QI=0.0
      DQDA=0.0
      DQDP=0.0
      DQDTV=0.0
      DQDTL=0.0
C
C  DETERMINE HEAT TRANSFER AREA PER UNIT VOLUME
C
      IF(VOL(J,I).GT.0.) GO TO 22
      AREA=0.
      GO TO 24
 22       RVOL=1./VOL(J,I)
          AREA=PI2*RADR*DZ(JJ)*RVOL
C
C  SET DONOR CELL QUANTITIES FOR DIVERGENCE TERMS
C
 24       ARB(1)=ARY(J,I)
          ARB(2)=ARX(J,I)
          ARB(3)=ARX(J,IXP)
          ARB(4)=ARY(J,IYP)
          ARB(5)=ARZ(J,I)
          ARB(6)=ARZ(JJ,I)
          VVB(1)=VVY(JJ,I)
          VLB(1)=VLY(JJ,I)
          VVB(2)=VVX(JJ,I)
          VLB(2)=VLX(JJ,I)
          VVB(3)=VVX(JJ,IXP)
          VLB(3)=VLX(JJ,IXP)
          VVB(4)=VVY(JJ,IYP)
          VLB(4)=VLY(JJ,IYP)
          VVB(5)=VVZ(J,I)
          VLB(5)=VLZ(J,I)
          VVB(6)=VVZ(JJ,I)
          VLB(6)=VLZ(JJ,I)
C
          DO 150 K=1,6
            JA=JJ+IJA(K)
            IA=I
            IF(K.LE.4)IA=ICC(K,I)
            RVA=RVOL*ARB(K)
            WTV=0.5+SIGN(0.5,VVB(K))
            WTL=0.5+SIGN(0.5,VLB(K))
C             FOR SIDES 1,2,5, POSITIVE VELOCITY MEANS INCOMING
            IF(K.EQ.3.OR.K.EQ.4.OR.K.EQ.6) GO TO 110
```

```
C            FOR SIDES 3,4,6, POSITIVE VELOCITY MEANS OUTGOING
           WTV=1.-WTV
           WTL=1.-WTL
  110      CC(1,K)=RVA*(WTV*ALP(JJ,I)*ROV(JJ,I)+(1.-WTV)*ALP(JA,IA)
    1        *ROV(JA,IA))
           CC(2,K)=RVA*(WTL*(1.-ALP(JJ,I))*ROL(JJ,I)+(1.-WTL)*
    1        (1.-ALP(JA,IA))*ROL(JA,IA))
           CC(3,K)=RVA*(WTV*ALP(JJ,I)*(ROV(JJ,I)*EV(JJ,I)+P(JJ,I))
    1        +(1.-WTV)*ALP(JA,IA)*(ROV(JA,IA)*EV(JA,IA)+P(JJ,I)))
           CC(4,K)=RVA*(WTL*(1.-ALP(JJ,I))*(ROL(JJ,I)*EL(JJ,I)+P(JJ,I))
    1        +(1.-WTL)*(1.-ALP(JA,IA))*(ROL(JA,IA)*EL(JA,IA)+P(JJ,I)))
  150      CONTINUE
C
C  ELIMINATE SURROUNDING LIQUID VELOCITIES FOR PRESSURES
C
         DO 200 L=2,4,2
           CP(L,1) = CC(L,1)*CPLY(J,I)
           CP(L,2) = CC(L,2)*CPLX(J,I)
           CP(L,3) = CC(L,3)*CPLX(J,IXP)
           CP(L,4) = CC(L,4)*CPLY(J,IYP)
           CP(L,5) = CC(L,5)*CPLZ(J,I)
           CP(L,6) = CC(L,6)*CPLZ(J+1,I)
          F(L) =
    +       CC(L,1)*(FLY(J,I)   +CPLY(J,I)  *(PN(JJ,I)-PN(JJ,IYM))) -
    -       CC(L,4)*(FLY(J,IYP) +CPLY(J,IYP)*(PN(JJ,IYP)-PN(JJ,I))) +
    +       CC(L,2)*(FLX(J,I)   +CPLX(J,I)  *(PN(JJ,I)-PN(JJ,IXM))) -
    -       CC(L,3)*(FLX(J,IXP) +CPLX(J,IXP)*(PN(JJ,IXP)-PN(JJ,I))) +
    +       CC(L,5)*(FLZ(J,I)   +CPLZ(J,I)  *(PN(JJ,I)-PN(JJ-1,I))) -
    -       CC(L,6)*(FLZ(J+1,I) +CPLZ(J+1,I)*(PN(JJ+1,I)-PN(JJ,I)))
  200      CONTINUE
C
C  ELIMINATE SURROUNDING VAPOR VELOCITIES FOR PRESSURES
C
         DO 201 L=1,3,2
           CP(L,1) = CC(L,1)*CPVY(J,I)
           CP(L,2) = CC(L,2)*CPVX(J,I)
           CP(L,3) = CC(L,3)*CPVX(J,IXP)
           CP(L,4) = CC(L,4)*CPVY(J,IYP)
           CP(L,5) = CC(L,5)*CPVZ(J,I)
           CP(L,6) = CC(L,6)*CPVZ(J+1,I)
           F(L) =
    +       CC(L,1)*(FVY(J,I)   +CPVY(J,I)  *(PN(JJ,I)-PN(JJ,IYM))) -
    -       CC(L,4)*(FVY(J,IYP) +CPVY(J,IYP)*(PN(JJ,IYP)-PN(JJ,I))) +
    +       CC(L,2)*(FVX(J,I)   +CPVX(J,I)  *(PN(JJ,I)-PN(JJ,IXM))) -
    -       CC(L,3)*(FVX(J,IXP) +CPVX(J,IXP)*(PN(JJ,IXP)-PN(JJ,I))) +
    +       CC(L,5)*(FVZ(J,I)   +CPVZ(J,I)  *(PN(JJ,I)-PN(JJ-1,I))) -
    -       CC(L,6)*(FVZ(J+1,I) +CPVZ(J+1,I)*(PN(JJ+1,I)-PN(JJ,I)))
  201      CONTINUE
C
         TC(1)=CP(1,1)+CP(1,2)+CP(1,3)+CP(1,4)+CP(1,5)+CP(1,6)
         TC(2)=CP(2,1)+CP(2,2)+CP(2,3)+CP(2,4)+CP(2,5)+CP(2,6)
         TC(3)=CP(3,1)+CP(3,2)+CP(3,3)+CP(3,4)+CP(3,5)+CP(3,6)
         TC(4)=CP(4,1)+CP(4,2)+CP(4,3)+CP(4,4)+CP(4,5)+CP(4,6)
C
```

```
C  OBTAIN THERMODYNAMIC DERIVATIVES
C
          CALL STATE(PN(JJ,I),TVN(JJ,I),TLN(JJ,I),D1,D2,D3,D4,TSATN,
     1 HVSN,HLSN,DTSDP,DELDP,DEVDP,DELDT,DEVDT,DRLDP,DRVDP,DRLDT,DRVDT,
     2     1,IERR )
      HVS=HVO + P(JJ,I)*(HV1 + P(JJ,I)*(HV2 + P(JJ,I)*(HV3 + P(JJ,I)
     1     *HV4)))
      HLS = HLO + P(JJ,I)*(HL1 + P(JJ,I)*(HL2 + P(JJ,I)*(HL3 +
     1      P(JJ,I)*(HL4 + P(JJ,I)*HL5))))
      DHLSDP = HL1 + PN(JJ,I)*(2.*HL2 + PN(JJ,I)*(3.*HL3 + PN(JJ,I)
     1         *(4.*HL4 + PN(JJ,I)*5.*HL5)))
      DHVSDP = HV1 + PN(JJ,I)*(2.*HV2 + PN(JJ,I)*(3.*HV3 + PN(JJ,I)
     1         *4.*HV4))
C
C  HEAT TRANSFER TERMS IN ENERGY EQUATION
      QWL=0.
      QWV=0.
      DQWDTV=0.
      DQWDTL=0.
      DQWDP=0.
      ATOTAL = 0.
      ITEST = 0
      DO 205 JR=1,4
      IR=IRC(JR,I)
      IF(IR.EQ.0) GO TO 206
      AREAH=AREA*FRACP(IR)*RN(IR)
      QWV= QWV+ AREAH*(QV(J,IR)+HVFC(J,IR)*(TW(J,IR)-TVN(JJ,I)))
      QWL= QWL+AREAH*(QV(J,IR+NRODS)+HLFC(J,IR)*(TW(J,IR)-TLN(JJ,I))
     1                 + HLNB(J,IR)*(TW(J,IR)-TSATN))
      DQWDTV= DQWDTV+ AREAH*HVFC(J,IR)*(1.-HVFC(J,IR)*DTW(J,IR))
      DQWDTL= DQWDTL+ AREAH*HLFC(J,IR)*(1.-(HLFC(J,IR)+HLNB(J,IR))*
     1                        DTW(J,IR))
      DQWDP= DQWDP+AREAH*HLNB(J,IR)*DTSDP*(1.-(HLFC(J,IR)+HLNB(J,IR))*
     1                     DTW(J,IR))
      ATOTAL = ATOTAL + AREAH
      IF(ITEST.LT.IHTR(J,IR)) ITEST = IHTR(J,IR)
 205   CONTINUE
 206    CONTINUE
C
C   TURBULENT MIXING MASS AND ENERGY TERMS
C
      VV=0.5*(VVZ(J,I)+VVZ(JJ,I))
      VL=0.5*(VLZ(J,I)+VLZ(JJ,I))
      QVTM=0.
      QLTM=0.
      WVTM=0.
      WLTM=0.
      DWVDP=0.
      DWVDA=0.
      DWVDTV=0.
      DWLDP=0.
      DWLDA=0.
      DWLDTL=0.
      DQVDP=0.
```

```
      DQVDA=0.
      DQVDTV=0.
      DQLDP=0.
      DQLDA=0.
      DQLDTL=0.
      IF(ITAM.EQ.0.OR.IMIXE.EQ.0) GO TO 208
      RARZ=1./ARZ(J,I)
      ARV=ALP(JJ,I)*ROV(JJ,I)
      ARL=(1.-ALP(JJ,I))*ROL(JJ,I)
      DO 207 IJ=1,4
      IC=ICC(IJ,I)
      IF(IC.EQ.NCP.OR.SIJ(IJ,I).EQ.0.) GO TO 207
      VVJ=0.5*(VVZ(J,IC)+VVZ(JJ,IC))
      VLJ=0.5*(VLZ(J,IC)+VLZ(JJ,IC))
      ARVJ=ALP(JJ,IC)*ROV(JJ,IC)
      ARLJ=(1.-ALP(JJ,IC))*ROL(JJ,IC)
      CALL MIXING(ROV(JJ,I),ROV(JJ,IC),ROL(JJ,I),ROL(JJ,IC),
     1      VISL(JJ,I),VISL(JJ,IC),HDZ(I),HDZ(IC),ARZ(J,I),ARZ(J,IC),
     2           VV,VVJ,VL,VLJ,SIJ(IJ,I),ARV,ARVJ,ARL,ARLJ,EVN(JJ,I),
     3           EV(JJ,IC),ELN(JJ,I),EL(JJ,IC),D1,D2,
     4           EVIJ,ELIJ,WVIJ,WLIJ,DRVDT,DRLDT,DRVDP,DRLDP,DEVDT,
     5           DELDT,DEVDP,DELDP,ROVN(JJ,I),ROLN(JJ,I),ALPN(JJ,I),
     6           DQV1,DQV2,DQV3,DQL1,DQL2,DQL4,DWV1,DWV2,DWV3,DWL1,
     7           DWL2,DWL4,RADR,2)
      QVTM=QVTM+EVIJ*RARZ
      QLTM=QLTM+ELIJ*RARZ
      WVTM=WVTM+WVIJ*RARZ
      WLTM=WLTM+WLIJ*RARZ
      DWVDP=DWVDP+DWV1*RARZ
      DWVDA=DWVDA+DWV2*RARZ
      DWVDTV=DWVDTV+DWV3*RARZ
      DWLDP=DWLDP+DWL1*RARZ
      DWLDA=DWLDA+DWL2*RARZ
      DWLDTL=DWLDTL+DWL4*RARZ
      DQVDP=DQVDP+DQV1*RARZ
      DQVDA=DQVDA+DQV2*RARZ
      DQVDTV=DQVDTV+DQV3*RARZ
      DQLDP=DQLDP+DQL1*RARZ
      DQLDA=DQLDA+DQL2*RARZ
      DQLDTL=DQLDTL+DQL4*RARZ
  207 CONTINUE
  208 CONTINUE
      IF(IFLASH.EQ.1) GO TO 310
      IF(IFLASH.EQ.0.AND.ITEST.LT.5)
     T     CALL GAMMA (GAM, DGDP,DGDA,DGDTV,DGDTL, ALP(JJ,I),
     1       ALPN(JJ,I),TVN(JJ,I),TLN(JJ,I),ROV(JJ,I),ROL(JJ,I),
     2       TSATN,DTSDP )
      IF(IFLASH.EQ.2.AND.ITEST.LT.5)
     T     CALL GAMSUB (GAM, DGDP,DGDA,DGDTV,DGDTL, P(JJ,I),
     1      ALP(JJ,I),TVN(JJ,I),TLN(JJ,I),TSATN,PN(JJ,I),ALPN(JJ,I),
     2      TVN(JJ,I),TLN(JJ,I),TSATN,DTSDP,DELDT, ROV(JJ,I),
     3      ROL(JJ,I),VV,VL,HDZ(I),ATOTAL,VISL(JJ,I),HVS,HLS,
     4      QWL,QWV,DQWDTL,DQWDP,ITEST)
C
```

```
C      SAHA POST-CHF VAPOR GENERATION RATE CORR.
C
      IF (ITEST.GE.5)
     +   CALL GAMSUP (GAM,DGDP,DGDA,DGDTV,DGDTL,P(JJ,I),
     1   ROV(JJ,I),TVN(JJ,I),TLN(JJ,I),VV,ALPN(JJ,I),TVN(JJ,I),
     2   TSATN,HVS,HLS,DTSDP,HDZ(I) )
C
C     CALCULATE INTERFACIAL ENERGY EXCHANGE RATE
C
 310  CALL QINTER(QI,DQDP,DQDA,DQDTV,DQDTL,GAM,DGDP,DGDA,
     1                  DGDTV,DGDTL,HLSN,HVSN,DHLSDP,DHVSDP,
     2                 TVN(JJ,I),TLN(JJ,I),TSATN,DTSDP,ITEST,IFLASH)
C
C      VAPOR MASS EQUATION
C
  320     C(1,1) = ALPN(JJ,I)*DRVDP*RDELT - DGDP +DWVDP
          C(1,2) = ROVN(JJ,I)*RDELT - DGDA +DWVDA
          C(1,3) = ALPN(JJ,I)*DRVDT*RDELT - DGDTV +DWVDTV
          C(1,4) = -DGDTL
          F(1) = F(1) - RDELT*( ALPN(JJ,I)*ROVN(JJ,I) -
     -                ALP( JJ,I)*ROV(JJ,I)  )    + GAM - WVTM
          C(1,1) = C(1,1) - TC(1)
C
C   LIQUID MASS EQUATION
C
          ALPN1 = 1.- ALPN(JJ,I)
          C(2,1) = ALPN1*DRLDP*RDELT + DGDP + DWLDP
          C(2,2) = -ROLN(JJ,I)*RDELT + DGDA +DWLDA
          C(2,3) = DGDTV
          C(2,4) = ALPN1*DRLDT*RDELT + DGDTL +DWLDTL
          F(2) = F(2) - RDELT*( ALPN1*ROLN(JJ,I) -
     -                    (1.-ALP(JJ,I))*ROL(JJ,I)  )  - GAM - WLTM
          C(2,1) = C(2,1) - TC(2)
C
C   VAPOR ENERGY EQUATION
C
          C(3,1) = ALPN(JJ,I) *(ROVN(JJ,I)*DEVDP + EVN(JJ,I)*DRVDP) *
     *                            RDELT - DQDP +DQVDP
          C(3,2) = (ROVN(JJ,I)*EVN(JJ,I) + P(JJ,I)) *RDELT -DQDA+DQVDA
          C(3,3) = ALPN(JJ,I)* (ROVN(JJ,I)*DEVDT + EVN(JJ,I)*DRVDT) *
     *                RDELT - DQDTV +
     +      DQWDTV + DQVDTV
          C(3,4) = -DQDTL
          F(3) = F(3) - RDELT*( ALPN(JJ,I)*ROVN(JJ,I)*EVN(JJ,I) -
     -                       ALP(JJ,I)*ROV(JJ,I)*EV(JJ,I) +
     +            P(JJ,I) * (ALPN(JJ,I) - ALP(JJ,I))  )  + QI +
     +         QWV - QVTM
          C(3,1) = C(3,1) - TC(3)
C
C   LIQUID ENERGY EQUATION
C
          C(4,1) = ALPN1* (ROLN(JJ,I)*DELDP + ELN(JJ,I)*DRLDP) *
     *                       RDELT + DQDP +
     +      DQWDP + DQLDP
```

```
        C(4,2) = (-ROLN(JJ,I)*ELN(JJ,I) - P(JJ,I))* RDELT +DQDA+DQLDA
        C(4,3) = DQDTV
        C(4,4) = ALPN1* (ROLN(JJ,I)*DELDT + ELN(JJ,I)*DRLDT)  *
     *                        RDELT + DQDTL +
     +     DQWDTL + DQLDTL
C--NOTE: ABOVE ASSUMES HVFC=0 IF HLFC+HLNB>0 AND VICE VERSA
        F(4) = F(4) - RDELT*( ALPN1*ROLN(JJ,I)*ELN(JJ,I) -
     -                         (1.-ALP(JJ,I))*ROL(JJ,I)*EL(JJ,I) +
     +             P(JJ,I) * (ALP(JJ,I) - ALPN(JJ,I))  )  - QI +
     +       QWL - QLTM
C
        C(4,1) = C(4,1) - TC(4)
C
C  INVERT 4X4 TO ELIMINATE AL, TV, TL, FOR PRESSURE ALONE
C
        RD=1./(C(1,1)*C(2,2)-C(1,2)*C(2,1))
        DO 210 K=3,11
          T=RD*(C(2,2)*CA(1,K)-C(1,2)*CA(2,K))
          CA(2,K)=RD*(-C(2,1)*CA(1,K)+C(1,1)*CA(2,K))
  210     CA(1,K)=T
        DO 220 K=3,11
          CA(4,K)=CA(4,K)-C(4,1)*CA(1,K)-C(4,2)*CA(2,K)
  220     CA(3,K)=CA(3,K)-C(3,1)*CA(1,K)-C(3,2)*CA(2,K)
        RD=1./(C(3,3)*C(4,4)-C(4,3)*C(3,4))
        DO 230 K=5,11
          T=RD*(C(4,4)*CA(3,K)-C(3,4)*CA(4,K))
          CA(4,K)=RD*(-C(4,3)*CA(3,K)+C(3,3)*CA(4,K))
  230     CA(3,K)=T
        DO 240 K=5,11
          CA(1,K)=CA(1,K)-C(1,4)*CA(4,K)-C(1,3)*CA(3,K)
  240     CA(2,K)=CA(2,K)-C(2,4)*CA(4,K)-C(2,3)*CA(3,K)
C
C  SET UP JACOBIAN MATRIX, STORE PRESSURE COEFFICIENTS
C
        AJM1(1,J,I)=1.0
        AJM1(2,J,I)=CP(1,5)
        AJM1(3,J,I)=CP(1,6)
        AJM2(1,J,I)=CP(1,1)
        AJM2(2,J,I)=CP(1,2)
        AJM2(3,J,I)=CP(1,3)
        AJM2(4,J,I)=CP(1,4)
        DO 270 K=1,4
  270     RHS(J,I,K)=F(K)
        DDOM = 0.
        DO 300 K=1,6
          DDOM = DDOM + CP(1,K)
          CPA(K,J,I)=CP(2,K)
          CPTV(K,J,I)=CP(3,K)
  300     CPTL(K,J,I)=CP(4,K)
        IF (DDOM.LT.-1.) GO TO 903
C
 1000   CONTINUE
      RETURN
C
```

```
C  ERROR DETECTED, PRESSURE PROBLEM IS NOT DIAGONALLY DOMINANT
C
  903 IERR = 3
      LERR = .TRUE.
      RETURN
      END
```

```
      SUBROUTINE INNER (DP,AJM1,AJM2,RHS,T,ICC,NZ,NC,NZP2,NCP,
     1                   EPSI,INITMX,INITCT,ERRI,PREF)
      DIMENSION DP(NZP2,NCP),AJM1(3,NZ,NC),AJM2(4,NZ,NC),RHS(NZ,NC),
     1          T(NZ),ICC(4,NC)
C
C  SOLVE THE PRESSURE PROBLEM, OF THE FORM
C         ([AJM1] + [AJM2]) * [DP] = [RHS]
C   BY BLOCK GAUSS-SEIDEL ITERATION
C
C     ARGUMENTS:
C            DP = NEW PRESSURE INCREMENT (FOR THIS NEWTON ITERATION)
C          AJM1 = TRIDIAGONAL PORTION OF PRESSURE COEFFICIENT MATRIX
C          AJM2 = REMAINDER OF PRESSURE COEFFICIENT MATRIX
C           RHS = RIGHT HAND SIDE OF EQUATION
C             T = TEMPORARY STORAGE (VIRTUAL RHS)
C           ICC = INDICATOR FOR CHANNEL COUPLING
C            NZ = NUMBER OF AXIAL LEVELS
C            NC = NUMBER OF CHANNELS
C          NZP2 = NUMBER OF AXIAL LEVELS INCLUDING BOUNDARIES
C           NCP = NUMBER OF CHANNELS PLUS ONE
C          EPSI = CONVERGENCE CRITERION
C        INITMX = MAXIMUM NUMBER OF INNER ITERATIONS ALLOWED
C        INITCT = ACTUAL NUMBER OF INNER ITERATIONS (COUNT)
C          ERRI = INNER ITERATION ERROR
C
C     * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C  PERFORM "LU" DECOMPOSITION
C
      DO 10 IC=1,NC
        AJM1(1, 1,IC) = 1.0/AJM1(1, 1,IC)
        AJM1(3, 1,IC) = AJM1(3, 1,IC)*AJM1(1, 1,IC)
C
        DO 10 IZ=2,NZ
          AJM1(1,IZ,IC) = 1.0/
     1       (AJM1(1,IZ,IC) - AJM1(2,IZ,IC)*AJM1(3,IZ-1,IC))
          AJM1(3,IZ,IC) = AJM1(3,IZ,IC)*AJM1(1,IZ,IC)
   10     CONTINUE
C
      INITCT = 0
C
C  ENTER ITERATIVE PROCESS
C
   20 CONTINUE
      ERRI = 0.0
      INITCT = INITCT+1
C
C  FORM VIRTUAL RHS AND PERFORM FORWARD ELIMINATION
C
      DO 40 IC=1,NC
        IYM = ICC(1,IC)
        IXM = ICC(2,IC)
        IXP = ICC(3,IC)
        IYP = ICC(4,IC)
```

```
C
      T( 1) = -AJM2(1, 1,IC)*DP(  2,IYM)-AJM2(2, 1,IC)*DP(  2,IXM)
     1        -AJM2(3, 1,IC)*DP(  2,IXP)-AJM2(4, 1,IC)*DP(  2,IYP)
     2        +RHS( 1,IC)                -AJM1(2, 1,IC)*DP(  1, IC)
      T( 1) = T( 1)*AJM1(1, 1,IC)
C
      DO 30 IZ=2,NZ
        IZP = IZ+1
        T(IZ) = -AJM2(1,IZ,IC)*DP(IZP,IYM)-AJM2(2,IZ,IC)*DP(IZP,IXM)
     1          -AJM2(3,IZ,IC)*DP(IZP,IXP)-AJM2(4,IZ,IC)*DP(IZP,IYP)
     2          +RHS(IZ,IC)
        T(IZ) = (T(IZ)-AJM1(2,IZ,IC)*T(IZ-1))*AJM1(1,IZ,IC)
   30   CONTINUE
C
C PERFORM BACKWARD SUBSTITUTION AND COMPUTE MAXIMUM ERROR
C
      DO 40 IZ=1,NZ
        JZ = NZ+1-IZ
        JZP  = JZ+1
        DPOLD = DP(JZP,IC)
        DP(JZP,IC) = T(JZ)-AJM1(3,JZ,IC)*DP(JZP+1,IC)
        ERRI = AMAX1(ERRI, ABS(DPOLD-DP(JZP,IC)) )
   40   CONTINUE
C
      ERRI = ERRI / PREF
      IF(ERRI.LE.EPSI.OR.INITCT.GE.INITMX) RETURN
      GO TO 20
      END
```

```
      SUBROUTINE UPDATE(ICC,IRC,PN,ALPN,TVN,TLN,ROVN,ROLN,
     1 EVN,ELN,DP,RHS,CPA,CPTV,CPTL,TSAT,TW,DTW,HLFC,HLNB,HVFC,
     2 HVS,HLS,M1,M2,M3,M4)
C
C  DETERMINE VALUES OF ALPHA, TL, TV  FROM NEW PRESSURES
C   EVALUATE NEW FUNCTIONS OF STATE
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      DIMENSION ICC(4,1),IRC(4,1),PN(M4,1),ALPN(M4,1),TVN(M4,1),
     1 TLN(M4,1),ROVN(M4,1),ROLN(M4,1),EVN(M4,1),
     2 ELN(M4,1),DP(M4,1),RHS(M1,M2,4),CPA(6,M1,1),
     3 CPTV(6,M1,1),CPTL(6,M1,1),TSAT(M4,1),TW(M1,1),
     4 DTW(M1,1),HLFC(M1,1),HLNB(M1,1),HVS(M4,1),HLS(M4,1),HVFC(M1,1)
C
      DO 200 I=1,NC
        IYM=ICC(1,I)
        IXM=ICC(2,I)
        IXP=ICC(3,I)
        IYP=ICC(4,I)
        DO 200 J=1,NZ
          JJ=J+1
          PN(JJ,I) = PN(JJ,I) + DP(JJ,I)
          ALPN(JJ,I) = ALPN(JJ,I)+RHS(J,I,2)-CPA(1,J,I)*DP(JJ,IYM)-
     1      CPA(2,J,I)*DP(JJ,IXM)-CPA(3,J,I)*DP(JJ,IXP)-
     2      CPA(4,J,I)*DP(JJ,IYP)-CPA(5,J,I)*DP(J,I)-
     3      CPA(6,J,I)*DP(JJ+1,I)
          DTVN = RHS(J,I,3)-CPTV(1,J,I)*DP(JJ,IYM)-
     1      CPTV(2,J,I)*DP(JJ,IXM)-CPTV(3,J,I)*DP(JJ,IXP)-
     2      CPTV(4,J,I)*DP(JJ,IYP)-CPTV(5,J,I)*DP(J,I)-
     3      CPTV(6,J,I)*DP(JJ+1,I)
          TVN(JJ,I) = TVN(JJ,I) + DTVN
          DTLN = RHS(J,I,4)-CPTL(1,J,I)*DP(JJ,IYM)-
     1      CPTL(2,J,I)*DP(JJ,IXM)-CPTL(3,J,I)*DP(JJ,IXP)-
     2      CPTL(4,J,I)*DP(JJ,IYP)-CPTL(5,J,I)*DP(J,I)-
     3      CPTL(6,J,I)*DP(JJ+1,I)
          TLN(JJ,I) = TLN(JJ,I) + DTLN
          TSOLD = TSAT(JJ,I)
          CALL STATE(PN(JJ,I),TVN(JJ,I),TLN(JJ,I),ROVN(JJ,I),
     1  ROLN(JJ,I),EVN(JJ,I),ELN(JJ,I),TSAT(JJ,I),HVS(JJ,I),HLS(JJ,I),
     2      D1,D2,D3,D4,D5,DRLDP,DRVDP,D8,D9,2,IERR)
          IF (IERR.NE.0) GO TO 904
          DTSAT = TSAT(JJ,I) - TSOLD
          DO 100 N=1,4
          IR=IRC(N,I)
          IF(IR.EQ.0) GO TO 105
          CHTW= DTW(J,IR)*(HVFC(J,IR)*DTVN+HLFC(J,IR)*DTLN
     1    + HLNB(J,IR)*DTSAT)
 100      TW(J,IR)=TW(J,IR)+CHTW
 105      CONTINUE
```

```
          TS = 0.1*ROVN(JJ,I)/ROLN(JJ,I)
          IF (ALPN(JJ,I).LT.-TS*DRLDP/DRVDP) GO TO 907
          IF (ALPN(JJ,I).LT.1.E-10) ALPN(JJ,I)=0.
          IF (ALPN(JJ,I).GT.1.+TS) GO TO 908
          IF (ALPN(JJ,I).GT.1.) ALPN(JJ,I)=1.
  200     CONTINUE
      RETURN
C
C  RANGE OF STATE FUNCTIONS OR VOID FRACTION EXCEEDED
C
  904 IERR = IERR + 3
      GO TO 999
  907 IERR = 7
      GO TO 999
  908 IERR = 8
  999 LERR = .TRUE.
      RETURN
      END
```

```
      SUBROUTINE HCONDO (TRN,QPP,QV,QL,HVFC,HLNB,HLFC,TSAT,TLN,TVN,
     1 QPPP,TR,QZ,QT,QR,DTRN,DTW,IHTR,ICR,TW,M1,M2,M3,M4)
C
C  FIRST PHASE OF ROD TEMPERATURE AND HEAT TRANSFER;
C   SET UP AND FORWARD ELIMINATE ROD TEMPERATURE PROBLEM TO OBTAIN
C   INITIAL HEAT FLUX AND ITS VARIATION WITH FLUID TEMPERATURES
C
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR,  LICR,LIRC,LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      DIMENSION TRN(M1,M2,1),QPP(M2,1),QV(M2,1),QL(M2,1),HVFC(M2,1),
     1 HLNB(M2,1),HLFC(M2,1),TSAT(M3,1),TLN(M3,1),TVN(M3,1),
     2 QPPP(1),QZ(1),QT(1),QR(1),DTRN(M4,M2,1),DTW(M2,1),TW(M2,1),
     3 IHTR(M2,1),ICR(1),TR(M1,M2,1)
C
      DATA ITRNS /5/
C
      NDP1=NODES+1
      TRDT=RDELT
      IF(ISS.GT.0)TRDT=0.0
C
      DO 100 I=1,NRODS
        DO 100 J=1,NZ
      IF(TW(J,I).LT.0.) GO TO 1000
          IF (TW(J,I).EQ.0.0) GO TO 100
          JJ=J+1
          IF(IHT.LE.1) GO TO 10
          CALL RPROP(TRN(1,J,I),A(LRCP),A(LCND),A(LRAD),NCF,NG,
     1     NDM1,IHT,NRODS)
   10     CONTINUE
C
C  SET POWER DISTRIBUTION
C
          DO 50 K=1,NDM1
   50       QPPP(K)=Q*QZ(J)*QT(I)*QR(K)
C
C  FORWARD ELIMINATION OF ROD TEMPERATURE PROBLEM
C
```

```
      II=ICR(I)
C
      IF(IHTR(J,I).NE.ITRNS) GO TO 80
        QMAX = QL(J,I)
        QMIN= QV(J,I)
        EPS2= HLNB(J,I)
        HLNB(J,I)=0.
      QL(J,I) = QL(J,I)*EPS2- HLFC(J,I)*(TW(J,I)-TLN(JJ,II))
      QV(J,I) = QV(J,I)*(1.-EPS2) - HVFC(J,I)*(TW(J,I)-TVN(JJ,II))
C
 80   CONTINUE
         CALL RTEMPF (TRN(1,J,I),A(LCND),A(LRCP),A(LQPPP),A(LRRDR),
     1    A(LVP),A(LVM),A(LEND),A(LEND+NDP1),A(LEND+2*NDP1),
     2    A(LEND+3*NDP1),TRDT,RADR,QV(J,I),QL(J,I),HVFC(J,I),
     3    HLNB(J,I),HLFC(J,I),TSAT(JJ,II),TLN(JJ,II),TVN(JJ,II),
     4    TW(J,I),DTW(J,I),DTRN(1,J,I),NODES,NDM1)
C
C  FOR TRANSITION BOILING, HEAT FLUXES DEPEND ON NEW TWALL BUT
C   ON OLD TL, TV
C
         IF (IHTR(J,I).NE.ITRNS) GO TO 100
           QL(J,I) = QL(J,I) + HLFC(J,I)*(TW(J,I)-TLN(JJ,II))
           HLFC(J,I) = 0.
           QV(J,I) = QV(J,I) + HVFC(J,I)*(TW(J,I)-TVN(JJ,II))
           HVFC(J,I) = 0.
           QHTR=QL(J,I) + QV(J,I)
          IF(QHTR.LE.QMAX.AND.QHTR.GE.QMIN) GO TO 100
          IF(QMAX.LT.QMIN) QMIN=QMAX - 10.
            QL(J,I) = QMAX* EPS2
            QV(J,I) = QMIN* (1.-EPS2)
            DO 90 K=1,NODES
            TRN(K,J,I)= TR(K,J,I)
 90         CONTINUE
            GO TO 80
 100     CONTINUE
      RETURN
 1000 LERR=.TRUE.
      IERR=110
      RETURN
      END
```

```
      SUBROUTINE HCOND1 (TRN,QPP,QV,QL,HVFC,HLNB,HLFC,TSAT,TLN,TVN,
     1 DTRN,DTW,TW,ICR,M1,M2,M3,M4)
C
C  FINAL PHASE OF HEAT TRANSFER CALCULATION; COMPUTE FINAL
C   ROD TEMPERATURES
C
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
      DIMENSION TRN(M1,M2,1),QPP(M2,1),QV(M2,1),QL(M2,1),HVFC(M2,1),
     1 HLNB(M2,1),HLFC(M2,1),TSAT(M3,1),TLN(M3,1),TVN(M3,1),
     2 DTRN(M4,M2,1),DTW(M2,1),TW(M2,1),ICR(1)
C
C
      TWMAX = 0.0
      TRMAX = 0.0
C
      DO 200 I = 1,NRODS
        DO 200 J = 1,NZ
        II=ICR(I)
        IF (IQSS.EQ.0) GO TO 160
          IF (TW(J,I).EQ.0.0) GO TO 200
          JJ=J+1
          TRN(NODES,J,I) = TW(J,I)
C
C  BACKWARD SUBSTITUTION FOR FINAL ROD TEMPERATURES
C
          DO 100 KK = 1,NDM1
            K = NDM1 + 1 - KK
            TRN(K,J,I) = TRN(K,J,I) - DTRN(K,J,I)*TRN(K+1,J,I)
            IF (TRMAX.GE.TRN(K,J,I)) GO TO 100
              TRMAX = TRN(K,J,I)
              ITRMAX = I
              JTRMAX = J
  100       CONTINUE
          IF (TWMAX.GE.TW(J,I)) GO TO 150
            TWMAX = TW(J,I)
            ITWMAX = I
            JTWMAX = J
  150     CONTINUE
 160      CONTINUE
C
C  COMPUTE TOTAL LINEAR HEAT FLUX FOR PRINTOUT
C
          QPP(J,I) = QV(J,I) + HVFC(J,I)*(TW(J,I)-TVN(JJ,II)) +
     +               QL(J,I) + HLNB(J,I)*(TW(J,I)-TSAT(JJ,II)) +
     +                         HLFC(J,I)*(TW(J,I)-TLN(JJ,II))
C
```

```
200     CONTINUE
      RETURN
      END
```

```
      SUBROUTINE RPROP(TRN,RCP,CND,RAD,NCF,NG,NDM1,IHT,NRODS)
C
C  GET MATERIAL AND GAP PROPERTIES FOR ROD CONDUCTION CALCULATION
C
      COMMON /PROP/ FTD,FPUO2,FPRESS,CPR,EXPR,GRGH,PGAS,GMIX(4),
     1   HGAP,BURN,EFFB,FRAC
      DIMENSION TRN(1),RCP(1),CND(1),RAD(1)
C
C  COMPUTE FUEL PROPERTIES
C
      DO 100 K=1,NCF
        TEMP=0.5*(TRN(K+1)+TRN(K))
        CALL MPF(TEMP,FTD,FPUO2,RCP(K),CND(K))
  100   CONTINUE
C
C  COMPUTE CLAD PROPERTIES
C
      KSTART=NG+1
      DO 200 K=KSTART,NDM1
        TEMP=0.5*(TRN(K+1)+TRN(K))
        CALL MPC(TEMP,RCP(K),CND(K))
  200   CONTINUE
C
C  CALCULATE GAP HEAT TRANSFER COEFFICIENT
C
      IF(IHT.LT.3) GO TO 300
      TGAP=(TRN(NG)+TRN(NG+1))*0.5
      CALL MPG(.FALSE.,BURN,EFFB,FRAC,FPRESS,CPR,EXPR,GRGH,RAD(NG),
     1 RAD(NG+1),PGAS,TGAP,GMIX,TRN(NG),TRN(NG+1),HGAP)
  300 CONTINUE
      CND(NG)=HGAP
      RCP(NG)=0.0
      RETURN
      END
```

```
      SUBROUTINE MPF (TEM, FTD, FPUO2, RCP, COND)
C
C  CALCULATES HEAT CAPACITY AND CONDUCTIVITY OF UO2 AND PUO2 FUELS AS
C    FUNCTIONS OF TEMPERATURE, FRACTION OF THEORETICAL DENSITY, AND
C    PLUTONIUM CONTENT
C
C  ARGUMENTS
C    INPUT      TEM      TEMPERATURE (DEG K)
C               FTD      FRACTION OF THEORETICAL DENSITY
C               FPUO2    PLUTONIUM FRACTION BY VOLUME
C    RETURN     RCP     HEAT CAPACITY (J/M**3-DEG K)
C               COND     CONDUCTIVITY (W/M-DEG K)
C
C  THIS SUBROUTINE IS BASED ON EXPRESSIONS USED IN MATPRO; SEE
C    TREE-NUREG-1005, APPENDIX A. THOSE EXPRESSIONS HAVE BEEN APPROXI-
C    MATED BY POLYNOMIAL FITS WHOSE MAXIMUM ERRORS ARE ABOUT ONE
C    STANDARD DEVIATION IN EXPERIMENTAL DATA.
C       RCP ERROR =  2 PER CENT        300 < TEM < 3000 DEG K
C       COND ERROR = 10 PER CENT       400 < TEM < 2500 DEG K
C
      DIMENSION RC(4), RCM(4), CN(3), CNM(3)
      DATA  RC /1.78E6, 3.62E3, -2.61, 6.59E-4/
      DATA RCM /1.81E6, 3.72E3, -2.57, 6.13E-4/
      DATA  CN /10.8, -8.84E-3, 2.25E-6/
      DATA CNM /9.88, -8.44E-3, 2.25E-6/
C
C--------------------------------------------------
C
      IF (FPUO2.GT.1.E-7)  GO TO 20
C
C  UO2 FUEL
C
   10 RCP = FTD*( RC(1)+ TEM*(RC(2) +TEM*(RC(3) +TEM*RC(4))) )
      BT = 2.74 - TEM * 5.8E-4
      POR = 1.- BT*(1.- FTD)
C--THE FACTOR  /(1.-BT*(1.-.95)) IS INCORPORATED IN THE FIT CN(3)
      COND = POR*( CN(1)+ TEM*(CN(2)+ TEM*CN(3)) )
      GO TO 100
C
C  MIXED OXIDE FUEL
C
   20 RCP = FTD *(1.+.045+FPUO2) *
     *        (RCM(1)+ TEM*(RCM(2)+ TEM*(RCM(3)+ TEM*RCM(4))) )
      BT = 2.74 - TEM * 5.8E-4
      POR = FTD / (1.+ BT*(1.-FTD))
C          THE FACTOR (1.+BT*(1.-.96))/.96 IS INCORPORATED IN CNM(3)
      COND = POR*( CNM(1)+ TEM*(CNM(2)+ TEM*CNM(3)) )
C
C
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MPC (TEM, RCP, COND)
C
C  CALCULATES HEAT CAPACITY AND CONDUCTIVITY OF ZIRCALOY AS A FUNCTION
C    OF TEMPERATURE
C
C  ARGUMENTS
C    INPUT      TEM      TEMPERATURE (DEG K)
C    RETURN     RCP     HEAT CAPACITY (J/M**3-DEG K)
C               COND     CONDUCTIVITY (W/M-DEG K)
C
C  THIS SUBROUTINE IS BASED ON DATA IN TREE-NUREG-1005, APPENDIX B.
C    CONDUCTIVITY IS USED UNCHANGED. HEAT CAPACITY HAS BEEN FIT
C    LINEARLY IN THE ALPHA PHASE (TEM < 1190), BY A CONSTANT IN THE
C    BETA PHASE (TEM > 1254), AND BY AN INVERTED VEE IN THE TRANSITION.
C    ERROR IS 5 PER CENT IN THE ALPHA PHASE, 300 < TEM < 1190 DEG K.
C
      DIMENSION CN(4)
      DATA CN /7.51, 2.09E-2, -1.45E-5, 7.67E-9 /
C
C--------------------------------------------------
C
C  HEAT CAPACITY
C
      IF (TEM.GT.1090.)  GO TO 20
C  ALPHA PHASE:    (0 < TEM < 1090 DEG K, USUAL CASE)
      RCP = 1673456. + TEM * 721.6
      GO TO 50
C
   20 IF (TEM.GE.1254.)  GO TO 30
        RCP = 5346400. - 36080.*ABS(TEM-1170.)
        GO TO 50
   30   RCP = 2315680.
C
   50 CONTINUE
C
C  CONDUCTIVITY
C
      COND = CN(1)+ TEM*(CN(2)+ TEM*(CN(3)+ TEM*CN(4)))
C
      RETURN
      END
```

```
      SUBROUTINE  MPG (INIT, BURN, EFFB, FRAC, PRESS, CPR, EXPR, ROUGH,
     1      RADFU, RADCL, PGAS, TGAS, GMIX, TFUEL, TCLAD, HGAP)
C
C  CALULATES GAP HEAT TRANSFER COEFFICIENT, IN THREE PARTS:
C     1. OPEN GAP COMPONENT, BASED ON CONDUCTIVITY OF A MIXTURE OF FOUR
C         NOBLE GASES; A SMALL GAP CORRECTION IS APPLIED IF PGAS > 0.
C     2. CONTRIBUTION FROM PARTIAL FUEL-CLAD CONTACT
C     3. RADIATION COMPONENT
C  IF RADFU > RADCL - ROUGH, THEN IN ADDITION TO THE ABOVE:
C     4. CLOSED GAP LAW = CPR * (PRESS**EXPR)
C
C  PARTS 1 & 2 ARE BASED ON TREE-NUREG-1005, APPENDIX C, WITH CRACKED
C    PELLET MODEL; PART 4 IS USER-SUPPLIED.
C
C  MPG IS CALLED WITH INIT = .TRUE. TO PERFORM INITIALIZATION
C   NORMAL CALLS HAVE INIT = .FALSE.
C
C  ARGUMENTS: INIT = .TRUE.
C    INPUT       BURN     BURNUP (MWD/MTU)
C                ROUGH    ROOT MEAN SQUARE OF FUEL PELLET AND CLADDING
C                          SURFACE ROUGHNESSES
C                RADFU    RADIUS OF FUEL PELLET (M)
C                RADCL    RADIUS OF CLADDING INNER SURFACE (M)
C    RETURN      ROUGH    IF ROUGH = 0 ON INPUT, A DEFAULT VALUE OF
C                          4.4E-6 METERS IS RETURNED
C                EFFB     FRACTIONAL EFFECT OF BURNUP, USED IN PARTIAL
C                          FUEL-CLAD CONTACT MODEL
C                FRAC     FRACTION OF FUEL PERIMETER IN LIGHT CONTACT
C                          WITH CLAD
C
C  ARGUMENTS: INIT = .FALSE. (NORMAL ENTRY)
C    INPUT       FRAC     FRACTION OF FUEL PERIMETER TOUCHING CLAD
C                PRESS    PRESSURE OF FUEL AGAINST CLAD FOR CLOSED GAP
C                CPR      COEFFICIENT OF PRESS
C                EXPR     EXPONENT OF PRESS
C                ROUGH    RMS OF FUEL AND CLAD ROUGHNESSES (M)
C                RADFU    FUEL PELLET RADIUS (M)
C                RADCL    INNER CLADDING RADIUS (M)
C                PGAS     PRESSURE OF GAS MIXTURE IN GAP, FOR SMALL GAP
C                          CORRECTION FACTOR (N/M**2)
C                TGAS     TEMPERATURE OF GAS MIXTURE IN GAP (DEG K)
C                GMIX     FOUR MOLE FRACTIONS OF NOBLE GASES
C                          1. HELIUM
C                          2. ARGON
C                          3. KRYPTON
C                          4. ZENON
C                            THE FOUR ELEMENTS OF GMIX MUST SUM TO 1
C                TFUEL    TEMPERATURE OF FUEL PELLET SURFACE (DEG K)
C                TCLAD    TEMPERATURE OF INNER CLAD SURFACE (DEG K)
C    RETURN      HGAP     GAP HEAT TRANSFER COEFFICIENT (W/M**2-DEG K)
C
      LOGICAL  INIT
      DIMENSION  GMIX(4)
C
```

```
      DIMENSION AM(4,4), BM(4,4)
C       COMBINING FACTORS WHICH ARE FUNCTIONS ONLY OF THE MOLECULAR
C       WEIGHTS OF THE FOUR NOBLE GASES
      DATA AM / 0.,   .295, .232, .194,
     2          .362, 0.,   .309, .332,
     3          .413, .235, 0.,   .286,
     4          .435, .260, .232, 0.   /
      DATA BM / 0.,   1.78, 2.14, 2.39,
     2          .563, 0.,   1.20, 1.35,
     3          .467, .831, 0.,   1.12,
     4          .418, .743, .894, 0.   /
      DIMENSION CC(4), EE(4), CON(4), CSR(4)
      DATA CC / 3.366E-3, 3.421E-4, 4.029E-5, 4.726E-5 /
      DATA EE / .668, .701, .872, .923 /
C
C-----------------------------------------------------
C
      DGAP = RADCL - RADFU
      IF (INIT) GO TO 200
C
C  NOBLE GAS CONDUCTIVITIES
C
      CON(1) = 0.
      DO  10  I = 1, 4
        IF (GMIX(I).LT.1.E-6)  GO TO 10
        CON(I) = CC(I) *(TGAS**EE(I))
        CSR(I) = SQRT(CON(I))
   10   CONTINUE
C  SMALL GAP CORRECTION FOR HELIUM:
      GAP = AMAX1  (ROUGH, DGAP)
      FAC = PGAS * GAP
      IF (FAC.LT.1.E-9)  GO TO 15
        CON(1) = CON(1) / (1.+ CON(1)*.2103*SQRT(TGAS)/FAC)
        CSR(1) = SQRT(CON(1))
   15 CONTINUE
C
C  MIXTURE CONDUCTIVITY
C
      GCOND = 0.
      DO  30  I = 1, 4
        IF (GMIX(I).LT.1.E-6) GO TO 30
        XSUM = GMIX(I)
        DO  20  J = 1, 4
          IF (J.EQ.I) GO TO 20
          IF (GMIX(J).LT.1.E-6) GO TO 20
          TS = CSR(J) + CSR(I)*BM(I,J)
          XSUM = XSUM + GMIX(J)*AM(I,J)*TS*TS/CON(J)
   20     CONTINUE
        GCOND = GCOND + CON(I)*GMIX(I)/XSUM
   30 CONTINUE
C
      HGAP = GCOND /(DGAP + ROUGH)
C
C  PARTIAL FUEL-CLAD CONTACT MODEL
```

```
C
      HGAP = (1.-FRAC)*HGAP + FRAC*GCOND/ROUGH
C
C  RADIATION HEAT TRANSFER CONTRIBUTION
C
      REMISF = AMAX1(1.1485, AMIN1(2.451, -.154+TFUEL*1.3025E-3 ))
      REMISC = 1.33
      RFVIEW = REMISF + (REMISC-1.)*RADFU/RADCL
C
      HGAP = HGAP +
     +   5.279E-8*(TFUEL+TCLAD)*(TFUEL*TFUEL+TCLAD*TCLAD)/RFVIEW
C
C  CLOSED GAP CONTACT HEAT TRANSFER
C
      IF (DGAP .GE. ROUGH)  GO TO 100
      HGAP = HGAP +  CPR * (PRESS **EXPR)
C
C
  100 RETURN
C
C  INITIALIZATION OF MPG, CALLED ONLY ONCE
C
  200 IF (ROUGH.LE.0.)  ROUGH = 4.4E-6
C
C  FRACTION OF FUEL IN LIGHT CONTACT WITH CLAD, A FUNCTION OF BURNUP
C
C--FRACTIONAL EFFECT OF BURNUP, INDEPENDENT OF FUEL RADIUS
      IF (BURN-600.) 210,210,220
  210   EFFB = 0.
        GO TO 230
  220 CONTINUE
        TS = .001*BURN - .6
        TS = TS*TS
        EFFB = 1.- 1./(TS*TS + 1.)
  230 CONTINUE
C--FRACTION OF CIRCUMFERENCE OF FUEL IN LIGHT CONTACT WITH CLAD
      A1 = 100. - 98.*EFFB
      A2 = 4. - .5*EFFB
      FRAC = 1./ (A1*(100.*DGAP/RADFU)**A2 + 1.42857) + .3
      RETURN
      END
```

```
      SUBROUTINE RTEMPF (TR,CND,RCP,QPPP,RRDR,VP,VM,A1,A2,A3,B,RDELT,
     1 RADR,QV,QL,HVFC,HLNB,HLFC,TSAT,TL,TV,TW,DTW,DTRN,NODES,NDM1)
C
C  FORWARD ELIMINATION OF TRIDIAGONAL TEMPERATURE PROBLEM IN FUEL ROD
C
      DIMENSION TR(1),CND(1),RCP(1),QPPP(1),RRDR(1),VP(1),VM(1),
     1 A1(2),A2(1),A3(1),B(1),DTRN(1)
C
C  SET UP COEFFICIENTS OF TRIDIAGONAL MATRIX
C
      A1(1)=0.0
      A2(1)=RRDR(1)*CND(1)+RDELT*VP(1)*RCP(1)
      B(1)=VP(1)*QPPP(1)+RDELT*VP(1)*RCP(1)*TR(1)
      DO 100 K=2,NDM1
        A1(K)=-RRDR(K-1)*CND(K-1)
        A2(K)=-A1(K)+RRDR(K)*CND(K)+RDELT*(VP(K)*RCP(K)+VM(K)*RCP(K-1))
        B(K)=VP(K)*QPPP(K)+VM(K)*QPPP(K-1)+RDELT*(VP(K)*RCP(K)+VM(K)*
     1   RCP(K-1))*TR(K)
  100   CONTINUE
      A1(NODES)=-RRDR(NDM1)*CND(NDM1)
      A2(NODES) = -A1(NODES) + RDELT*VM(NODES)*RCP(NDM1) +
     + RADR*(HVFC+HLNB+HLFC)
      B(NODES) = VM(NODES)*QPPP(NDM1) +
     +  RDELT*VM(NODES)*RCP(NDM1)*TR(NODES) +
     +  RADR*(HVFC*TV +HLFC*TL +HLNB*TSAT -QV-QL)
      A1(NODES+1)=0.0
C
C  FORWARD ELIMINATION
C
      A2(1)=1./A2(1)
      A3(1)=A1(2)*A2(1)
      B(1)=B(1)*A2(1)
      DO 200 K=2,NODES
        A2(K)=1./(A2(K)-A1(K)*A3(K-1))
        A3(K)=A1(K+1)*A2(K)
        B(K)=(B(K)-A1(K)*B(K-1))*A2(K)
  200   CONTINUE
C
C  VALUE OF TW  IF HLFC*TL, HVFC*TV, HLNB*TS DO NOT CHANGE
C
      TW = B(NODES)
C
C  INCREMENTAL CHANGE IN TW PER UNIT CHANGE IN HLFC*TL, ETC.
C
      DTW = A2(NODES) * RADR
C
C  SAVE INTERMEDIATE RESULTS
C
      DO 250 K = 1,NDM1
        TR(K) = B(K)
  250   DTRN(K) = A3(K)
C
      RETURN
      END
```

```
      SUBROUTINE HTCOR(IHTR,QV,QL,HVFC,HLNB,HLFC,TW,TL,TV,P,ALP,ROV,ROL,
     1                 VV,VL,HDZ,HDH,ISS,CHFR,HLIN,HLS,HVS,
     2                    FTONG,BL,ICHF,HV,HL,TOTZ,QW,Q,RADR)
C
C  THIS ROUTINE COMPUTES HEAT TRANSFER COEFFICIENTS AND/OR HEAT
C  FLUXES
C
C  THE TOTAL HEAT FLUX IS ASSUMED TO BE OF THE FORM:
C  Q=QV+QL+HVFC(TW-TV)+HLNB(TW-TSAT)+HLFC(TW-TL)
C
C  NORMALLY QV AND QL WILL BE ZERO AND ONE OR MORE OF THE HEAT
C  TRANSFER COEFFICIENTS HVFC, HLNB, AND HLFC WILL BE NON-ZERO.
C  IN TRANSITION BOILING, HOWEVER, THE HEAT TRANSFER COEFFICIENTS ARE
C  ZERO AND Q=QV+QL.
C
C  NOMENCLATURE:
C
C  QV     HEAT FLUX TO VAPOR (W/M**2)
C  QL     HEAT FLUX TO LIQUID (W/M**2)
C  HVFC   CONVECTION HEAT TRANSFER COEFFICIENT TO VAPOR (W/M**2 K)
C  HLNB   NUCLEATE BOILING HEAT TRANSFER COEFFICIENT (W/M**2 K)
C  HLFC   CONVECTION HEAT TRANSFER COEFFICIENT TO LIQUID (W/M**2 K)
C  TW     WALL TEMPERATURE (K)
C  TL     LIQUID TEMPERATURE (K)
C  TV     VAPOR TEMPERATURE (K)
C  P      PRESSURE (P)
C  ALP    VAPOR VOLUME FRACTION
C  ROV    VAPOR DENSITY (KG/M**3)
C  ROL    LIQUID DENSITY (KG/M**3)
C  VV     VAPOR VELOCITY (M/S)
C  VL     LIQUID VELOCITY (M/S)
C
C
C  NOTE: THE FOLLOWING QUANTITIES ARE AVAILABLE AND,
C  IF DESIRED, COULD BE ADDED TO THE ARGUMENT LIST OF
C  HTCOR AND THE CORRESPONDING CALL STATEMENT:
C
C  TCHF   TEMPERATURE AT CRITICAL HEAT FLUX
C  TMSFB  MINIMUM STABLE FILM BOILING TEMPERATURE
C  QCHF   CRITICAL HEAT FLUX
C  QMSFB  HEAT FLUX AT TMSFB
C
C
      DATA GCON/9.8066/
      DATA PI/3.1416/
      HVFC=0.0
      HLFC=0.0
      HVFILM=0.0
      HLNB=0.0
      CHFR=1.0
      QCHF = 0.
      QV=0.0
      QL=0.0
      IHTR=0
```

```
      IF (TW.EQ.0.0) RETURN
      VVA=ABS(VV)
      VLA=ABS(VL)
      RHD=1./HDZ
C
C  OBTAIN FLUID PROPERTIES
C  (RUNNING TIME COULD BE SHORTENED BY REPLACING THE
C  FOLLOWING CALL TO STATE AND THE SUBSEQUENT COMPUTATION OF
C  HFG, BETAV, BETAL, CPV, AND CPL BY APPROPRIATE FITS TO
C  THESE QUANTITIES)
      CALL STATE(P,TV,TL,ROVS,ROLS,EV,EL,TSAT,DO,DOO,DTSDP,
     1 DELDP,DEVDP,DELDT,DEVDT,DRLDP,DRVDP,DRLDT,DRVDT,2,IERR)
      TVF = (TW+TV)*.5
      SPVV = 1./ROVS
      SPVL = 1./ROLS
      HFG = HVS - HLS
      BETAV = -DRVDT*SPVV
      BETAL = -DRLDT*SPVL
      CPV = DEVDT -P*DRVDT*SPVV*SPVV
      CPL = DELDT -P*DRLDT*SPVL*SPVL
      VISV = VISVP(TV)
      VISVF = VISVP(TVF)
      VISL = VISLQ(TL)
      CNDV = CONDV(P,TV)
      CNDVF = CONDV(P,TVF)
      CNDL = CONDL(P,TL)
      SIG = SURTEN(TL)
C
C  COMPUTE QUALITY ASSUMING VL=VV IF FLOW IS COUNTERCURRENT OR IF
C  ABS(VV) .LT. ABS(VL)
C
      GV = ALP*ROV*VVA
      GL = (1.-ALP)*ROL*VLA
      G = GV + GL
      IF((VV-VL)*VL.LE.0.0)GO TO 5
      X = GV / G
      GO TO 10
    5 CONTINUE
      X=ALP*ROV/(ALP*ROV+(1.-ALP)*ROL)
   10 CONTINUE
      HM=X*HV+(1.-X)*HL
      XEQUIL=(HM-HLS)/HFG
C
C          ... DETERMINE HEAT TRANSFER REGIME ...
C
C  TEST QUALITY
C
      IF(X.LE.0.) GO TO 200
      IF(X.GE.0.99)GO TO 301
      GO TO 41
  301 QCHEN=QW*Q
      GO TO 50
C
C  TEST FOR COLD WALL
```

```
C
   41 IF(TW.LE.TSAT) GO TO 200
      IF(ISS.NE.0) GO TO 30
C
C
C  COMPUTE MINIMUM STABLE FILM BOILING TEMPERATURE
C
      IF (P.GT.68.96E5) GO TO 20
      THN = 581.5 + .01876*SQRT( AMAX1(P-1.0345E5,0.) )
      GO TO 25
   20 THN = 630.37 + .00432*SQRT(P-68.96E5)
   25 CONTINUE
      PSI=0.0
      IF (P.LT.4.827E5) PSI = 127.3 - 26.37E-5*P
C     CALL MPC(TW,RCP,COND)
C     RRKCPW = 1./(RCP*COND)
C  INVERSE OF ROCP OF ZIRCALOY TIMES CONDUCTIVITY OF OXIDE
      RRKCPW = 3.1E-7 - 1.3E-10*TW
      RKCPL=ROL*CNDL*CPL
      T1 = RRKCPW*RKCPL
CRRKCPW BECOMES NEGATIVE FOR TW>2384.6 DEG K
      IF(T1.LT.0.0) T1=0.0
C
      TMSFB = THN + (THN-TL)*POW(T1,.5) - PSI
C
C  TEST WHETHER TWALL EXCEEDS TMSFB
C
      IF(TW.LT.TMSFB)GO TO 30
C
C  COMPUTE FILM BOILING HEAT TRANSFER COEFFICIENT
C
      GO TO 300
C
   30 CONTINUE
C
C
C  DETERMINE HEAT TRANSFER COEFFICIENTS USING CHEN CORRELATION
C
      RVISL = 1./VISL
      XTTI=POW(X/(1.-X),.9) *POW(ROL/ROV,.5) *POW(VISV*RVISL,.1)
      F=1.0
      GX = G
      IF(TL.LT.TSAT) GO TO 32
      IF(XTTI.GT.0.1)F=2.35*POW(XTTI+.213,.736)
      GX = GL
   32 PRL = VISL*CPL/CNDL
      REL = GX*HDZ*RVISL
      HLF = .023*F*CNDL*RHD* POW(REL,.8) *POW(PRL,.4)
      RETP = REL *POW(F,1.25)*1.E-4
      S=.1
      IF(RETP.LT.70.0.AND.RETP.GE.32.5) S=1./(1.+.42*POW(RETP,.78))
      IF(RETP.LT.32.5) S=1./(1.+.12*POW(RETP,1.14))
      HS = .00122*S* POW(CNDL*CPL/(SIG*GCON),.5) *POW(PRL,-.29) *
     *        POW(ROL,.25) *POW(CPL*ROL/(HFG*ROV),.24)
```

```
      PWALL = (.11062558*(TW-255.2))**4.4843049
      HLN = HS*POW(TW-TSAT,.24)*POW(PWALL-P,.75)
      QCHEN = HLF*(TW-TL) + HLN*(TW-TSAT)
C
C  CALCULATE CRITICAL HEAT FLUX
C
   50 IF(ICHF.NE.3) CALL CHF(QCHF,ALP,ROV,ROL,G,P,X,HDH,HFG,SIG,
     1          HLIN,XEQUIL,GBRIT,ICHF,HLS,FTONG,RADR,TOTZ,HDZ)
      IF(ICHF.EQ.3) CALL CISE(CPR,X,G,P,HDZ,HDH,BL,HLS,HLIN,HFG,HM)
      IF(ICHF.EQ.3) QCHF=QCHEN*CPR
      IF(ISS.EQ.2) GO TO 400
      IF(QCHEN.LE.QCHF) GO TO 400
      IF(ISS.EQ.1) GO TO 300
C
C
C  SOLVE THE EQUATION
C        HLFC*(TCHF-TL) +HLNB*(TCHF-TSAT)**1.24*(PWALL-P)**.75  = QCHF
C  FOR TCHF USING NEWTON'S ITERATION
C
      TCHF=AMAX1(TW,TSAT+.1)
      DO 35 K=1,10
      IF(TCHF.GT.TSAT) GO TO 31
      TCHF=TSAT
      GO TO 40
   31   TCS=AMAX1(TCHF-TSAT,0.0)
        PWALL=(.11062558*(TCHF-255.2))**4.4843049
        DQ = QCHF - HLF*(TCHF-TL) - HS*POW(TCS,1.24)*POW(PWALL-P,.75)
        DQDT = HLF + HS*POW(TCS,.24)*POW(PWALL-P,.75) *
     *    (1.24 + 3.3632287*TCS*PWALL/((TCHF-255.2)*(PWALL-P)) )
        DTCHF = DQ/DQDT
        TCHF = TCHF + DTCHF
        IF(ABS(DTCHF).LE.0.1)GO TO 40
   35   CONTINUE
   40 CONTINUE
      GO TO 500
C
C          ... INDIVIDUAL CORRELATIONS FOLLOW ...
C
C
C  CONVECTION TO SINGLE PHASE LIQUID
C  MAX OF SIEDER-TATE AND MCADAMS CORRELATIONS
C
C  NOTE: MCADAMS SHOULD EVALUATE PROPERTIES AT A LIQUID FILM TEMP
C
  200 CONTINUE
      T1=ROL*ROL*GCON*BETAL*CPL*ABS(TW-TL)/(VISL*CNDL)
      HMA=.13*CNDL*POW(T1,.333333)
      REL=ROL*VLA*HDZ/VISL
      PRL=VISL*CPL/CNDL
      VISW=VISLQ(TW)
      HST=.023*CNDL*RHD *POW(REL,.8) *POW(PRL,.33) *POW(VISL/VISW,.14)
      HLFC=AMAX1(HMA,HST)
      CHFR=99.0
      IHTR=1
```

```
      IF(HMA.GT.HST) IHTR=2
      GO TO 1000
C
C  CONVECTION TO SINGLE PHASE VAPOR
C  MAX OF SIEDER-TATE AND MCADAMS CORRELATIONS
C
C  NOTE:  MCADAMS SHOULD EVALUATE PROPERTIES AT A VAPOR FILM TEMP
C
  300 CONTINUE
      T1=ROV*ROV*GCON*BETAV*CPV*ABS(TW-TV)/(VISV*CNDV)
      HMA=.13*CNDV*POW(T1,.333333)
      REV=ROV*VVA*HDZ/VISV
      PRV=VISV*CPV/CNDV
      VISW=VISVP(TW)
      HST=.023*CNDV*RHD *POW(REV,.8) *POW(PRV,.33) *POW(VISV/VISW,.14)
      HVFC=AMAX1(HMA,HST)
      IHTR=9
      IF(HMA.GT.HST) IHTR=10
C
C
C     THE WALLIS SLUG-ANNULAR TRANSITION CORRELATION IS USED
C     HERE TO DISTINGUISH FILM BOILING FROM DISPERSED FLOW
C
      IF(G.LE.0.) GO TO 1000
      XM=(.4*SQRT(ROL*HDZ*(ROL-ROV))/G+.6)/(SQRT(ROL/ROV)+.6)
      IF(X.GE.XM) GO TO 1000
C
C     LOW QUALITY FILM BOILING:
C     BROMLEY PLUS SIEDER-TATE
C
      CLAM=2*PI*SQRT(SIG/(ROL-ROV))
      HFGP=HFG+.5*CPV*(TW-TSAT)
      T1=GCON*(ROL-ROV)*ROV*(CNDV**3)*HFGP/(CLAM*VISV*(TW-TSAT))
      HMB=.62*POW(T1,.25)
      HVFC=(1.-ALP)*HMB+ALP*HST
      IHTR=6
      GO TO 1000
C
C  SUBCOOLED OR SATURATED NUCLEATE BOILING
C  CHEN CORRELATION
C
  400 CONTINUE
      HLFC = HLF
      HLNB = HLN
      IF(ICHF.NE.3) CHFR=QCHF/QCHEN
      IF(ICHF.EQ.3) CHFR=CPR
      IHTR=4
      IF((TL+0.5).LT.TSAT) IHTR=3
      IF(CHFR.GE.100.) CHFR=99.
      GO TO 1000
C
C
C  TRANSITION BOILING
C
```

```
 500 CONTINUE
     IF(TV.GE.TMSFB) GO TO 300
     CALL FILM(HVTB,ALP,ROV,ROL,VVA,VLA,HDZ,RHD,TL,TV,TMSFB,TSAT,HFG,
    1 CPV,CPL,P,VISV,VISL,BETAV,SIG,IHTR,X)
     RDTMC = 1./(TMSFB-TCHF)
     EPS = (TMSFB-TW)*RDTMC
     EPS2 = EPS*EPS
     QMSFB=HVTB*(TMSFB-TV)
     QV= QMSFB
     QL= QCHF
     HLNB= EPS2
     DQLDTW = -2.*EPS*QCHF*RDTMC
     DQVDTW = 2.*EPS*QMSFB*RDTMC
     HLFC = DQLDTW
     HVFC = DQVDTW
     IHTR=5
     GO TO 1000
1000 CONTINUE
     RETURN
     END
```

```
      SUBROUTINE FILM(H,ALP,ROV,ROL,VVA,VLA,HD,RHD,TL,TV,TW,TSAT,HFG,
     1  CPV,CPL,P,VISV,VISL,BETAV,SIG,IHTR,X)
      DATA GCON,PI2/9.8066,6.2831853/
C
C  NOTE: IN BROMLEY'S AND MCADAMS' CORRELATIONS VAPOR PROPERTIES
C        ARE EVALUATED AT BULK VAPOR TEMPERATURE AND NOT
C        AT VAPOR FILM TEMPERATURE.
C        IN GROENEVELD'S CORRELATION THE VAPOR PRANDTL NUMBER
C        IS EVALUATED AT BULK VAPOR TEMPERATURE AND NOT
C        AT WALL TEMPERATURE.
C
C
C   HIGH FLOW FILM BOILING
C   GROENEVELD 5.7 OR MODIFIED DITTUS-BOELTER (FOR LOW PRESSURE)
C
      CNDV = CONDV(P,TV)
      REV = HD*ROV*(VLA+ALP*(VVA-VLA))/VISV
      PRV = VISV*CPV/CNDV
      IF(P.LT.1.33E6) GO TO 10
      Y = 1.-.1*POW((1.-X)*((ROL/ROV)-1.),.4)
      HGDB = .052*CNDV*RHD *POW(REV,.688)*POW(PRV,1.26)*POW(Y,-1.06)
      IHTR = 6
      GO TO 20
   10 HGDB = .023*CNDV*RHD *POW(REV,.800)*POW(PRV,0.40)
      IHTR = 7
   20 CONTINUE
      H = HGDB
C
C   TEST FOR LOW OR HIGH FLOW
C
      AJG =      ALP *ROV*VVA/SQRT(GCON*HD*ROV*(ROL-ROV))
      AJF = (1.-ALP)*ROL*VLA/SQRT(GCON*HD*ROL*(ROL-ROV))
      AJ = SQRT(AJG)+SQRT(AJF)
      IF(AJ.GE.2.0) RETURN
C
C   LOW FLOW FILM BOILING
C   BROMLEY PLUS MAX OF MCADAMS AND FORCED CONVECTION(AS FOR HIGH FLOW)
C
      CLAM = PI2*SQRT(SIG/(ROL-ROV))
      HFGP = HFG+0.5*CPV*(TW-TSAT)
      T1 = GCON*(ROL-ROV)*ROV*(CNDV**3)*HFGP/(CLAM*VISV*(TW-TSAT))
      HMB = .62*POW(T1,.25)
C
      T1 = ROV*ROV*GCON*BETAV*CPV*ABS(TW-TV)/(VISV*CNDV)
      HMA = .13*CNDV*POW(T1,.333333)
C
      H = (1.-ALP)*HMB + ALP*AMAX1(HGDB,HMA)
      IHTR = 8
C
      RETURN
      END
```

```
      SUBROUTINE CHF(QCHF,ALP,ROV,ROL,G,P,X,HDH,HFG,SIG,HLIN,
     1      XEQUIL,ICHF,HLS,FTONG,RADR,TOTZ,HDZ)
C
C  DETERMINES CRITICAL HEAT FLUX
C
C     ICHF = 1, BIASI AND CHF-VOID CORRELATIONS
C            2, W-3
C            4, BARNETT
C            5, BOWRING
C            6, HENCH-LEVY
C
      DATA GCON/9.8066/
      DATA GCONV/7.3733E-4/
      DATA HCONVT/4.302E-4/
      DATA EE /2.7182818/
      DATA PU/1020./,PL/980./
      IF(G.LE.0.) GO TO 50
      IF(ICHF.EQ.2) GO TO 200
      IF(ICHF.EQ.4) GO TO 300
      IF(ICHF.EQ.5) GO TO 400
      IF(ICHF.EQ.6) GO TO 500
C
50    PBAR=1.0E-5*P
      GHI=135.0
      GLO=27.0
      IF(PBAR.GE.83.0.AND.X.GE.0.5)GHI=270.0
      IF(G.LT.GLO)GO TO 20
C
C  BIASI CORRELATION FOR HIGH FLOW
C
      EN=-0.4
      IF(HDH.LT.0.01)EN=-0.6
      GT=AMAX1(G,GHI)
      Q10=0.0
      IF(GT.LT.300.0)GO TO 10
      F=.7249 + .099*PBAR*POW(EE,-.032*PBAR)
      G6=POW(GT,-.166667)
      Q10=2.764E7*POW(100.*HDH,EN)*G6*(1.468*F*G6-X)
   10 CONTINUE
      H=-1.159 + .149*PBAR*POW(EE,-.019*PBAR) + 8.99*PBAR/
     1 (10.+PBAR*PBAR)
      Q11=15.048E7*H*POW(100.*HDH,EN)*POW(GT,-.6)*(1.-X)
      QB=AMAX1(Q10,Q11)
      QCHF=QB
C
C
      IF(G.GE.GHI)GO TO 100
   20 CONTINUE
C
C  CHF-VOID CORRELATION FOR LOW FLOW
C
      T1=SIG*GCON*GCON*(ROL-ROV)*ROV*ROV
      QVC=.1178*(1.-ALP)*HFG*POW(T1,.25)
      QCHF=QVC
```

```
C
C
      IF(G.LE.GLO)GO TO 100
C
C  LINEAR INTERPOLATION BETWEEN BIASI AND CHF-VOID
C
      WT=(G-GLO)/(GHI-GLO)
      QCHF=WT*QB+(1.-WT)*QVC
C
  100 CONTINUE
      RETURN
  200 CONTINUE
      HF = HLS * HCONVT
      PBRIT = P* 1.45036 84E-4
      GBRIT=G*GCONV
      DH = HDH * 39.370079
      HIN = HLIN * HCONVT
C
C     W-3 FOR UNIFORM HEAT FLUX
C
      CHFW3 = ((2.022 - .0004302*PBRIT) + (.1722 - .0000984*PBRIT)*
     1        EXP((18.177-0.004129*PBRIT)*XEQUIL)) * ((0.1484 -
     2        1.596* XEQUIL + 0.1729*XEQUIL* ABS(XEQUIL))* GBRIT +
     3        1.037 ) * (1.157-0.869*XEQUIL) * (0.2664+0.8357 *
     4        EXP( -3.151 *DH)) * (0.8258 + 0.000794*(HF-HIN))
C    W-3 CHF WITH NON-UNIFORM AXIAL HEAT FLUX CORRECTION
C
      QCHF = CHFW3 * 3.1546031E6 / FTONG
      QCHF= AMAX1(QCHF,2.84E5)
       RETURN
C
C     BARNETT CHF CORRELATION
C
300   DR=2.*RADR
      D1=DR*(DR+HDH)
      DO=POW(D1,0.5)
      DE=DO-DR
      D=(DO**2-DR**2)/DR
      A=2.0524979E2*POW(D,.68)*POW(G,.192)*(1.-
     1  .744*EXP(-.18902747*DE*G))
      B=7.331046E-2*POW(D,1.261)*POW(G,.817)
      C=7.248908E3*POW(DE,1.415)*POW(G,.212)
      QCHF=3.1546E6*(A+4.299E-4*B*(HLS-HLIN))/(C+39.37*TOTZ)
      RETURN
C
C     BOWRING CHF CORRELATION
C
400   PR=.14504E-6*P
      PN=2.-.5*PR
      IF(PR.GT.0.98.AND.PR.LT.1.02) GO TO 430
      IF(PR.GT.1.) GO TO 410
      F1=(PR**18.942*EXP(20.89*(1.-PR))+.917)/1.917
      F2=F1/((PR**1.316*EXP(2.444*(1.-PR))+.309)/1.309)
      F3=(PR**17.023*EXP(16.658*(1.-PR))+.667)/1.667
```

```
      F4=F3*PR**1.649
      GO TO 420
  410 F1=PR**(-.368)*EXP(.648*(1.-PR))
      F2=F1/(PR**(-.448)*EXP(.245*(1.-PR)))
      F3=PR**.219
      F4=F3*PR**1.649
      GO TO 420
  430 F1=1.
      F2=1.
      F3=1.
      F4=1.
  420 A=.57925*HFG*HDH*G*F1/(1.+.0143*F2*HDH**.5*G)
      B=.25*HDH*G
      C=.077*F3*HDH*G/(1.+.347*F4*(G/1356.)**PN)
      QCHF=(A-B*X*HFG)/C
      RETURN
C
C     HENCH-LEVY CHF CORRELATION
C
500   G1=G*737.3
      X1=0.273-0.212*(TANH(G1*3.E-6))**2
      X2=0.5-0.269*(TANH(G1*3.E-6))**2+0.0346*(TANH(G1*2.E-6))**2
      IF(XEQUIL.LE.X1) QPPC=1.E6
      IF(XEQUIL.GT.X2) GO TO 510
      QPPC=1.E6*(1.9-3.3*XEQUIL-0.7*(TANH(G1*3.E-6))**2)
      GO TO 520
510   QPPC=1.E6*(0.6-0.7*XEQUIL-0.09*(TANH(G1*2.E-6))**2)
520   QCHF=QPPC*3.1546
      P1=P*1.45037E-4
      IF(P1.LE.PU.AND.P1.GE.PL) RETURN
      IF(P1.LT.600.) P1=600.
      QCHF=QCHF*(1.1-0.1*((P1-600.)/400.)**1.25)
      RETURN
       END
```

```
      SUBROUTINE CISE(CPR,XEQUIL,G,P,HDZ,HDH,BL,HLS,HLIN,HFG,HM)
C
C
C     CALCULATES THE CRITICAL QUALITY AND APPROXIMATES THE CRITICAL
C     POWER.
C
      DATA PCR/2.2106E7/
C
C     CISE-4 CORRELATION
C     DETERMINES CRITICAL QUALITY
C     XCRIT = CRITICAL QUALITY
C     BL    = BOILING LENGTH
C
      GSTAR=3375.*(1-P/PCR)**3
      A=1./(1.+1.481E-4*(1.-P/PCR)**(-3)*G)
      IF(G.GT.GSTAR) A=(1.-P/PCR)/(G*.001)**.33333333
      B=0.199*(PCR/P-1)**0.4*G*HDZ**1.4
      XCRIT=(HDZ/HDH)*A*BL/(B+BL)
      CPR=1.+(XCRIT-XEQUIL)/(XEQUIL+(HLS-HLIN)/HFG)
      IF(XEQUIL.LE.0.) CPR=99.
      IF(BL.LE.0.) CPR=99.
      RETURN
      END
```

```
      FUNCTION POW(A,B)
C
C  THIS FUNCTION IS CALLED WHENEVER A LOW ACCURACY EXPONENTIATION
C   WOULD BE ADEQUATE
C
      POW=A**B
      RETURN
      END
```

```
      FUNCTION  CONDL (P, TL)
C
C  THERMAL CONDUCTIVITY OF LIQUID WATER
C    W/M DEG K    FUNCTION OF    PASCAL,  DEG K
C
C  ERROR OF APPROXIMATION < 5 PERCENT FOR  273 < TL < 573 DEG K
C  VALUE AT 150 BAR, 300 DEG C = .55
C
      TS = TL - 415.
      CONDL = .686 - 5.87E-6*TS*TS + 7.3E-10*P
      RETURN
      END
```

```
      FUNCTION  CONDV (P, TV)
C
C  THERMAL CONDUCTIVITY OF DRY STEAM
C    W/M DEG K    FUNCTION OF    PASCAL,  DEG K
C
C  ERROR OF APPROXIMATION < 10 PERCENT FOR  373 < TV < 623 AND
C    P IN SUPERHEATED REGION
C  FOR LOW P, CONDV DEPENDS MORE ON TV, FOR P > 50 BAR CONDV DEPENDS
C    MORE ON P.
C  VALUE AT SATURATION FOR 70 BAR = .061
C
      CONDV = -.0123 + P*(7.8E-9 + P*2.44E-16) +
     +            1.25E-11*TV*(80.E5 - P)
      RETURN
      END
```

```
      FUNCTION VISLQ (TL)
C
C  VISCOSITY OF SATURATED LIQUID WATER
C    KG/M SEC    FUNCTION OF    DEG K
C
C  ERROR OF APPROXIMATION = 6 PERCENT FOR  273 < TL < 623 DEG K
C    MAY ALSO BE USED FOR NON-SATURATED CONDITIONS AT SAME TL
C    THIS FIT HAS A SINGULARITY AT TL = 251 DEG K
C  VALUE AT 250 DEG C = .107E-3
C
      VISLQ = 25.3 / (-8.58E4 + TL*(91.+ TL))
      RETURN
      END
```

```
      FUNCTION  VISVP (TV)
C
C  VISCOSITY OF SATURATED STEAM
C    KG/M SEC    FUNCTION OF    DEG K
C
C  ERROR OF APPROXIMATION = 3 PERCENT FOR  373 < TV < 623 DE K
C    MAY ALSO BE USED FOR NON-SATURATED CONDITIONS AT SAME TV
C    THIS FIT HAS A SINGULARITY AT TV = 822 DEG K
C  VALUE AT 250 DEG C = .174E-4
C
      IF(TV.GT.623) GO TO 50
      VISVP = 11.4 / (1.37E6 - TV*(844.+ TV))
      RETURN
 50    VISVP=4.07E-8*TV -3.7E-7
      RETURN
      END
```

```
      FUNCTION SURTEN (TL)
C
C   SURFACE TENSION OF LIQUID WATER
C     KG(F)/M    FUNCTION OF    DEG K
C   ( 1 KG(F)= 9.80665 KG M/SEC**2 )
C   ALSO EQUAL TO SURFACE TENSION / GRAVITATIONAL ACCELERATION CONSTANT
C   IN UNITS OF KG/M
C
C   ERROR OF APPROXIMATION = 2 PERCENT FOR 373 < TL < 623 DEG K
C   VALUE AT 250 DEG C = .0026
C
      SURTEN = (80.72 - TL*.126) / (5140.+ TL)
      IF(SURTEN.LT.0.0) SURTEN=0.0
      RETURN
      END
```

```
      SUBROUTINE FWALL (FWV,FWL,HDIAM,VELX,CFV,CFL,
     1  P,ALP,ROV,ROL,VV,VL,VISV,VISL,RD,IWF,I,J)
C
C  COMPUTES WALL FRICTION FOR LIQUID AND VAPOR MOMENTUM EQUATIONS
C
C  RETURN VALUES  FWV,FWL  SHOULD APPEAR IN THE MOMENTUM EQUATIONS
C    FOR ONE OF THE THREE DIRECTIONS, MULTIPLIED BY THE APPROPRIATE
C    VELOCITY
C
C  INPUT:
C    HDIAM    HYDRAULIC DIAMETER
C    VELX     VELOCITY MULTIPLIER, CONVERTS TRANSVERSE VELOCITY TO
C               MAXIMUM VALUE (IN GAP)
C    CFV,CFL  WALL CONTACT FRACTIONS FOR VAPOR AND LIQUID;
C               NORMALLY  CFV+CFL=1  AND  CFV=0 BELOW CHF
C    RD       INVERSE OF DZ; USED FOR FORM LOSS
C    IWF      SELECTS FORMULA TO BE USED:
C      TENS DIGIT = 0: AXIAL FRICTION ONLY
C                 = 1 OR 2: FORM LOSS + AXIAL FRICTION
C                 = 3: TRANSVERSE FRICTION
C      IWF = 01: 2 PHASE MARTINELLI WITH XTT PARAMETER
C          = 02: 2 PHASE MARTINELLI-NELSON WITH MASS FLUX EFFECT (JONES)
C          = 03: 2 PHASE LEVY
C          = 04: ROUGH WALL CORRELATION
C          = 05: HOMOGENOUS 2 PHASE MODEL
C          = 10: FORM LOSS WITHOUT AXIAL FRICTION
C          = 1N: FORM LOSS + ON AXIAL FRICTION
C          = 2N: SAME AS 1N (CONVECTION FUNNEL EFFECT)
C          = 31: GUNTER AND SHAW LATERAL WITH MARTINELLI 2 PHASE
C
C  N.B.: IN TWO-PHASE FLOW, A FRICTION MULTIPLIER IS APPLIED ASSUMING
C    BOTH PHASES TO BE TURBULENT IF ONE IS. NO TWO-PHASE MULTIPLIER IS
C    USED IF BOTH PHASES ARE LAMINAR.
C
      COMMON /FRICMD/ FCON(4,4)
      DIMENSION GFAC(9)
C
      LOGICAL TT
      DATA GFAC/1.,1.,1.,1.,1.,1.,1.,1.,1./
      DATA  CAX, CT /20., 8./
C
C---------------------------------------------------
C
      AL1 = 1.- ALP
      RHD = 1./HDIAM
      GV = ABS(ALP*ROV*VV*VELX)
      GL = ABS(AL1*ROL*VL*VELX)
      G = GV + GL
      REV = GV/(VISV*RHD)
      REL = GL/(VISL*RHD)
      IT = INT (FLOAT(IWF)*.1)
      IU = IWF - IT*10
      FWV = 0.
      FWL = 0.
```

```
C
    5 AO = FCON(1,IT+1)
      REX = FCON(2,IT+1)
      A = FCON(3,IT+1)
      B = FCON(4,IT+1)
      TT = (REL.GT.REX) .OR. (REV.GT.REX)
      REYL = REL
      IF (TT) REYL = AMAX1(REL,REX)
      REYV = REV
      IF (TT) REYV = AMAX1(REV,REX)
C
      IF (IT.EQ.0) GO TO 10
      GO TO (100,100,200),IT
   10 IF (IU.EQ.0) RETURN
C
C  AXIAL FRICTION
C
      IF (TT) GO TO 20
        FWV = FWV + .5*AO*CFV*VISV*RHD*RHD
        FWL = FWL + .5*AO*CFL*VISL*RHD*RHD
        RETURN
   20 CONTINUE
      GO TO (30,40,50,60,80),IU
   30 FWL = FWL + .5*RHD*A*CFL*( (REYL**B)*AL1*GL +
     +              CAX *SQRT((ROL/ROV)*(REYV*REYL)**B) *AL1*GV  )
      FWV = FWV + .5*RHD*A*(REYV**B)*ALP*GV*CFV
      RETURN
C
   40 XQ = GV / G
      GO = G/950. - 1.
      IF (GO) 41,42,42
   41   FGP = 1.43 + GO*(.07 - 7.35E-8*P)
        GO TO 43
   42   FGP = 1.43 + (950./G -1.)*(.17 - 6.E-8*P)
   43 FWL = FWL + .5*RHD*A*(REYL**B)*AL1*G*CFL*
     *               (1.+ FGP*1.2*(ROL/ROV -1.)*(XQ**.824) )
      FWV = FWV + .5*RHD*A*(REYV**B)*GV*CFV
      RETURN
C
   50 REYL = ABS(ROL*VL)/(VISL*RHD)
      REYV = ABS(ROV*VV)/(VISV*RHD)
      FWL = FWL + .5*RHD*A*(REYL**B)*GL*CFL
      FWV = FWV + .5*RHD*A*(REYV**B)*GV*CFV
      RETURN
  60  RREL=18.7/G*RHD*VISL
      T=6.5
      DO 65 K=1,10
      IF(T.LE.0.) T=10.
      DF= T- 1.74 + .868589*LOG(.02+RREL*T)
      DFDT= 1+ .868589/(.02 + RREL*T)*RREL
      DT= -DF/DFDT
      T= T + DT
      IF(ABS(DT).LE. 0.01) GO TO 70
  65  CONTINUE
```

```
   70  CONTINUE
       F= 1/T**2
       FWL=FWL + .5*RHD*F*G**.2*(ROL*ABS(VL))**.8*CFL
       FWV=FWV + .5*RHD*F*G**.2*(ROV*ABS(VV))**.8*CFV
       RETURN
C
C      HOMOGENEOUS MODEL
C
   80  XQ = GV/G
       REY = G*RHD/VISL
       PHI = 1.+XQ*(ROL-ROV)/ROV
       FWL = FWL+0.5*RHD*A*REY**B*G*CFL*PHI
       FWV = FWV+0.5*RHD*A*REY**B*G*CFV*PHI
       RETURN
C
C
C  AXIAL FORM LOSS
C
  100  REY = AMAX1 (REX, G/(VISL*RHD) )
       TS = .5*RD*A*(REY**B)*GFAC(I)
       FWV = TS*ALP*GV
       FWL = TS*(AL1*G + ALP*AL1*ROL*ABS(VV) )
       IT = 0
       IF (IU.LE.0) RETURN
       GO TO 5
C
C  TRANSVERSE FRICTION
C
  200  CONTINUE
       IF (IU.EQ.0) RETURN
       IF (TT) GO TO 220
         FWV = .5*A0*ALP*CFV*VISV*RHD*RHD*VELX
         FWL = .5*A0*AL1*CFL*VISL*RHD*RHD*VELX
         RETURN
  220  FWV = .5*RHD*A*(REYV**B)*ALP*CFV*GV*VELX
       FWL = .5*RHD*A*CFL*( (REYL**B)*AL1*GL +
     +            CT *SQRT((ROL/ROV)*(REYV*REYL)**B) *AL1*GV )*VELX
       RETURN
       END
```

```
      SUBROUTINE FINTER(FIV,FIL,ALP,ROV,ROL,VR,VISV,VISL,HD,IFINTR)
      DATA AN/4.1888E7/
C
C  THIS SUBROUTINE COMPUTES THE INTERFACIAL MOMENTUM EXCHANGE COEFS.
C
      TS = AMAX1(ALP, 0.1)
      RRB = (1.01-TS)/(TS*HD)
      FIL = RRB*(RRB*VISL + 0.5*ROV*VR)
      IF(ALP.GE.1.) FIL=0.
      FIV=FIL
      IF(ALP.LE.0.) GO TO 50
      IF(IFINTR.EQ.0) GO TO 50
      IF(ALP.GE.1.) GO TO 50
C
C     ALTERNATE INTERFACIAL MODEL
C
      RHO =ALP*ROV + (1.-ALP)*ROL
      VISC = ALP*VISV/ROV + (1.-ALP)*VISL/ROL
      ALPHA=ALP
      IF(ALP.GT.0.5) ALPHA=1.-ALP
      A= AN**.33333 * ALPHA**.666667
      RB = (ALPHA/AN)**.33333
      FIL= .375*RHO*(.5*VR+12*VISC/RB)*A
 50   FIV=FIL
      RETURN
      END
```

```
      SUBROUTINE GAMMA(GAM,DGDP,DGDA,DGDTV,DGDTL,
     1                 ALP,ALPN,TVN,TLN,ROV,ROL,TSATN,DTSDP)
      DATA AN,SRRG/1.33333E+14,21.4942/
C
C  FUNCTION: CALCULATES GAMMA AND ITS DERIVATIVES
C
C   NOTE: AN=4/3*NR. OF BUBBLES(OR DROPLETS) PER CUBIC METRE
C         SRRG=SQRT OF THE GAS CONSTANT FOR WATER VAPOR
C
      TALP=AMAX1(ALP,.0001)
      TALP=AMIN1(TALP,.9999)
      WT = .5+SIGN(.5,TALP-.5)
      TALPX = TALP*(1.-WT)+(1.-TALP)*WT
      AREA = AN**.333333 * TALPX**.666667
      CE = AREA*ROL*     TALP *SRRG
      CC = AREA*ROV*(1.-TALP)*SRRG
C
      ALAME = .05+SIGN(.05,TLN-TSATN)
      ALAMC = .05+SIGN(.05,TSATN-TVN)
      CLAME = CE*ALAME
      CLAMC = CC*ALAMC
      RRTSAT = 1./SQRT(TSATN)
      DTL = (TLN-TSATN)*RRTSAT
      DTV = (TVN-TSATN)*RRTSAT
C
      GAM = CLAME*(1.-ALPN)*DTL+CLAMC*ALPN*DTV
      DGDP = -.5*(CLAME*(1.-ALPN)*(TSATN+TLN)+CLAMC*ALPN*(TSATN+TVN))
     1      *RRTSAT/TSATN*DTSDP
      DGDA = -CLAME*DTL+CLAMC*DTV
      DGDTV = CLAMC*     ALPN *RRTSAT
      DGDTL = CLAME*(1.-ALPN)*RRTSAT
      RETURN
      END
```

```
      SUBROUTINE QINTER(QI,DQDP,DQDA,DQDTV,DQDTL,GAM,DGDP,
     +            DGDA,DGDTV,DGDTL,HLSN,HVSN,DHLSDP,DHVSDP,TVN,
     1            TLN,TSATN,DTSDP,ITEST,IFLASH)
C
C     CALCULATE INTERFACIAL ENERGY EXCHANGE RATE.
C               KAO, 5-22-80
C                    6-24-80 (REVISED)
C                    2-21-81 (REVISED)
C                    4-8-81 (REVISED)
C
      DATA HINTER/1.0E11/
      IF(IFLASH.EQ.1) GO TO 200
      IF (ITEST.LT.5) GO TO 100
      IF((TLN+0.5).LT.TSATN) GO TO 100
C
C     POST-CHF INTERFACIAL ENERGY EXCHANGE RATE;
C     THE MODEL HAS THE EFFECT OF FORCING TL=TSAT.
C
      QI=+GAM*HLSN-HINTER*(TSATN-TLN)
      DQDP=+HLSN*DGDP+GAM*DHLSDP-HINTER*DTSDP
      DQDA=+HLSN*DGDA
      DQDTV=+HLSN*DGDTV
      DQDTL=+HLSN*DGDTL+HINTER
      RETURN
C
C     PRE-CHF OR SUBCOOLED POST-CHF INTERFACIAL ENERGY EXCHANGE RATE;
C     THE MODEL HAS THE EFFECT OF FORCING TV=TSAT.
C
100   QI=HINTER*(TSATN-TVN)+GAM*HVSN
      DQDP=HINTER*DTSDP+HVSN*DGDP+GAM*DHVSDP
      DQDA=HVSN*DGDA
      DQDTV=-HINTER+HVSN*DGDTV
      DQDTL=HVSN*DGDTL
      RETURN
C
C     CLCULATE QI AS SUCH THAT TV=TL.
C
200   QI=HINTER*(TLN-TVN)
      DQDP=0.
      DQDA=0.
      DQDTV=-HINTER
      DQDTL=HINTER
      RETURN
      END
```

```
      SUBROUTINE GAMSUB (GAM,DGDP,DGDA,DGDTV,DGDTL,P,ALP,TV,TL,TSAT,
     1  PN,ALPN,TVN,TLN,TSATN,DTSDP,DELDT,ROV,ROL,VV,VL,DH,AREA,VISL,
     2  HV,HL,QLEFF,QVEFF,DQWDTL,DQWDP,IHTR)
C
C  PHASE CHANGE RATE GAMMA, INCLUDING A MODEL FOR SUBCOOLED BOILING
C
      DATA ALPBF,CBF /0.1, 9./
      DATA ITRNS /5/
      DATA THIRD /0.3333333/
C
      CPL = DELDT
      CNDL = CONDL(P,TL)
      TST = 9.0395*POW(P,.223) + 255.2
      RHVL = 1./(HV-HL)
C
C  SUBCOOLED OR NUCLEATE BOILING PHASE CHANGE
C
      HH = 0.
      IF (TLN.GE.TSATN) GO TO 10
        G = ALP*ROV*ABS(VV) + (1.-ALP)*ROL*ABS(VL)
        RE = G*DH/VISL
        PRL = VISL*CPL/CNDL
        XNUAH = 2.44*POW(RE,.5)*POW(PRL*(HV-HL)/HL,THIRD)
        HH = CNDL*XNUAH/DH
   10 QBL = QLEFF - HH *(TSATN-TLN)*AREA
      W = (.5 + SIGN(.5,QBL)) * RHVL
C--W IS ZERO WHEN TLN < BUBBLE DETACHMENT TEMPERATURE
C
   20 GAM = QBL*W
      DGDP  = -W*(DQWDP + HH*DTSDP*AREA)
      DGDA  = 0.
      DGDTV = 0.
      DGDTL = -W*(DQWDTL - HH*AREA)
C
C  CONDENSATION OR VAPORIZATION AT LIQUID-VAPOR INTERFACE
C
      SURFB = 0.
      SURFA = 0.
      RH = 0.5*DH
        RB = RH
        VE = POW( (1.-ALP)*ABS(VL), THIRD)
        RB0 = 0.45 * POW( SURTEN(TST)/(ROL-ROV), .5) / (1.+ 1.34*VE)
        IF(IHTR.GT.ITRNS) GO TO 120
        IF (ALP.GE.1.) GO TO 110
        RB = RB0
        IF (ALP.GT.ALPBF) RB = RB0*POW(CBF*ALP/(1.-ALP), THIRD)
        RB = AMIN1(RB, RH)
  110   SURFB = 3./ RB
      IF (IHTR.LT.ITRNS) GO TO 140
  120   SURFA = 1./DH
  130 IF (IHTR.NE.ITRNS) GO TO 140
        EPS = QLEFF/(QLEFF+QVEFF)
        SURFB = SURFB*EPS
        SURFA = SURFA*(1.-EPS)
```

```
  140 DL = RBO * 0.015
      IF (TVN.GT.TLN)  GO TO 150
C  VAPORIZATION
        CND = CNDL /DL
        GO TO 160
C  CONDENSATION
  150   CNDV = CONDV(P,TV)
      DV = RBO * 0.010
        CND = CNDV*CNDL /(CNDL*DV + CNDV*DL)
C
  160 CND = CND*RHVL
      S = SURFB*ALPN + SURFA*(1.-ALPN)
      SCND = S*CND
      DTLV = TLN-TVN
      GAM = GAM + SCND*DTLV
      DGDP = DGDP
      DGDA = DGDA + (SURFB-SURFA)*CND*DTLV
      DGDTV = DGDTV - SCND
      DGDTL = DGDTL + SCND
C
      RETURN
      END
```

```
      SUBROUTINE GAMSUP(GAM,DGDP,DGDA,DGDTV,DGDTL,P,ROV,TV,TL,VV,
     1                  ALPN,TVN,TSATN,HG,HF,DTSDP,D)
C
C    POST-CHF GAMMA MODEL OF SAHA
C
      DATA GCON,PCRIT/9.80665,2.2105E7/
C
      SIG=SURTEN(TL)*GCON
      A=80.72-0.126*TL
      B=5140.+TL
      DSDTL=-(0.126*B+A)/B**2
      CONV=CONDV(P,TV)
      RD=1./D
      HFG=HG-HF
      W=6300.*(1.-P/PCRIT)**2*(ROV*VV*VV*D/SIG)**0.5*RD*RD*CONV/HFG
      GAM=W*(TVN-TSATN)*(1.-ALPN)
      IF(GAM.LT.0.) GAM=0.
      DGDP=-W*(1.-ALPN)*DTSDP-2.*GAM/(PCRIT*(1.-P/PCRIT))
      DGDA=-W*(TVN-TSATN)
      DGDTV=W*(1.-ALPN)
      DGDTL=-0.5*GAM*DSDTL/SIG
      RETURN
      END
```

```
      SUBROUTINE STATE(P,TV,TL,ROV,ROL,EV,EL,TSAT,HVS,HLS,DTSDP,
     1   DELDP,DEVDP,DELDT,DEVDT,DRLDP,DRVDP,DRLDT,DRVDT,IOP,IERR)
C
C
C     SUBROUTINE STATE CALCULATES THE STATE DYNAMIC PROPERTIES OF
C     WATER. THE PRESENT VERSION USES FITS DUE TO BILL RIVARD OF
C     GROUP T-3 OF THE LASL THEORETICAL DIVISION.
C     TAKEN FROM TRAC AND RECODED TO IMPROVE EFFICIENCY.
C     THE COMPRESSED LIQUID PROPERTIES HAVE BEEN REPROGRAMMED
C     BY JOHN KELLY OF MIT(5,79).
C     SI UNITS ARE USED
C
C     INPUT VARIABLES
C        1. P   PRESSURE
C        2. TL  TEMPERATURE OF THE LIQUID
C        3. TV  TEMPERATURE OF THE VAPOR
C        4. IOP OPTION SELECTOR - NOT IN PRESENT VERSION
C
C     OUTPUT VARIABLES
C        1. EV     INTERNAL ENERGY OF THE VAPOR
C        2. EL     INTERNAL ENERGY OF THE LIQUID
C        3. TSAT   SATURATION TEMPERATURE
C        4. HVS    VAPOR SATURATION ENTHALPY
C        5. HLS    LIQUID SATURATION ENTHALPY
C        6. ROL    DENSITY OF THE LIQUID
C        5. ROV    DENSITY OF THE VAPOR
C        6. DTSDP  DERIVATIVE OF TSAT WRT PRESSURE
C        7. DELDP  DERIVATIVE OF TL WRT PRESSURE
C        8. DEVDP  DERIVATIVE OF TV WRT PRESSURE
C        9. DELDT  DERIVATIVE OF EL WRT TL
C       10. DEVDT  DERIVATIVE OF EV WRT TV
C       11. DRLDP  DERIVATIVE OF ROL WRT PRESSURE
C       12. DRVDP  DERIVATIVE OF ROV WRT PRESSURE
C       13. DRLDT  DERIVATIVE OF ROL WRT TL
C       14. DRVDT  DERIVATIVE OF ROV WRT TV
C       15. IERR   ERROR FLAG (INPUT VARIABLE OUT OF RANGE)
C
C     CONSTANTS USED IN FITS
C
C     FOR TSAT, CPS
      DATA TSC1,TSC2, TSEXP  /9.0395, 255.2, 0.223/
      DATA CPS1,CPS2, CPSEXP  /9.5875E2, .00132334, -0.8566/
C       CPS2 = -CPSEXP * TCRINV
C     FOR ES, GAMS  IF P < 20 BARS
      DATA G11,G12,G13  /2.6194106E6, -4.995E10, 3.403E5/
      DATA G14,G15,G16  /1.066554, 1.02E-8, -2.548E-15/
C          G11,G14 ARE ADJUSTED SO THAT ES RESP. GAMS JUMPS LESS THAN
C             1 PART IN 1.E-8 ACROSS P = 20 BARS.
      DATA G17 /-5.096E-15/
C       G17 = 2.* G16
C     FOR ES, GAMS  IF P > 20 BARS
      DATA G21,G22,G23  /2.5896E6, 6.350E-3, -1.0582E-9/
      DATA G24,G25,G26  /1.0764, 3.625E-10, -9.063E-17/
      DATA G27,G28  /-2.1164E-9, -18.126E-17/
```

```
C        G27 = 2.* G23,    G28 = 2.* G26
C
C    FOR HLS AND HVS
       DATA  HL0,HL1,HL2,HL3,HL4,HL5/5.7474718E5,2.0920624E-1,
     1    -2.8051070E-8,2.3809828E-15,-1.0042660E-22,1.6586960E-30/
       DATA  HV0,HV1,HV2,HV3,HV4/2.7396234E6,3.758844E-2,
     1        -7.1639909E-9,4.2002319E-16,-9.8507521E-24 /
C
      DATA P20B /2.0E6/
      DATA TCRIT /647.3/
      DATA TCRINV /.00154488/
      DATA CC,CCI,CCM  /1.3, .76923, 0.3/
C
C      FOR ROL IF T < 576.5 DEG K
C
      DATA RL0,RL1,RL2,RL3 /1735.3320,-4.6406842,1.0431090E-2,
     1                         -9.4367085E-6/
      DATA RL22,RL33 /2.086218E-2,-2.8310126E-5 /
C       RL22 = 2.*RL2       RL33 =3.*RL3
C
C       FOR ROL   IF T > 576.5 DEG K
C

      DATA RH0,RH1,RH2,RH3,RH4 /-1.1755984E6,8.1437361E3,-2.1136559E1,
     1         2.4381598E-2,-1.0549747E-5 /
      DATA RH22,RH33,RH44 /-4.2273118E1,7.3144794E-2,-4.2198988E-5/
C       RH22 = 2.*RH2    RH33 = 3.*RH3     RH44 = 4.*RH4
C
      DATA RP0,RP1,RP2 /-14.643890,1.1283357E-3,1.2670366E-2/
C
      DATA SP0,SP1,SP2,SP3 / -42.0218,.2116,-4.4587E-4,3.251E-7/
      DATA SP22,SP33 /-8.9174E-4,9.753E-7/
C
C    FOR EL  IF TL < 576.5 DEG K
      DATA SL0,SL1,SL2,SL3,SL4 /-460.26818E3,-2.8634045E3,27.450693,
     1         -4.8108323E-2,3.2059316E-5/
      DATA SL22,SL33,SL44 /54.901386,-.14432497,1.2823726E-4/
C      SL22 = 2.* SL2,    SL33 = 3.* SL3
C    FOR EL  IF TL > 576.5 DEG K
      DATA SH0,SH1,SH2,SH3,SH4 /1.2426455E9,-8.6082251E6,2.2364564E4,
     1         -2.5815959E1,1.1178766E-2/
      DATA SH22,SH33,SH44 /4.4729128E4,-77.447877,4.4715064E-2/
C      SH22 = 2.* SH2,   SH33 = 3.* SH3
C
C    FOR VAPOR
      DATA A11,A12,A13 /1.2959E-3,  593.59, 1.6847E-3/
C
      DATA  HALF,ZERO,ONE,TWO  /0.5, 0., 1., 2./
C
C ----------------------------------------
C
C     CHECK THAT P, TL, TV, ARE WITHIN RANGE OF FITS
C
       TLSAVE = TL
```

```
      IF(TL.GT.647.) TL = 647.
     IF (P.GE.1.0E+3.AND.P.LE.190.0E+5) GO TO 5
       IERR = 1
       RETURN
   5 IF (TL.GE.280.0.AND.TL.LE.647.0) GO TO 10
       IERR = 2
       RETURN
  10 IF(TV.GE.280.0) GO TO 20
       IERR = 3
       RETURN
  20 IERR = 0
C
C    CALCULATE SATURATION PROPERTIES
C
C       1. TSAT    SATURATION TEMPERATURE
C       2. DTSDP    DERIVATIVE OF TSAT WRT PRESSURE
C       3. ES      SATURATION INTERNAL ENERGY
C       4. DPES    DERIVATIVE OF ES WRT PRESSURE
C       5. GAMS    GAMMA SUB S
C       6. DPGAMS  DERIVATIVE OF GAMS WRT PRESSURE
C       7. CPS     C SUB PS
C       8. DPCPS   DERIVATIVE OF CPS WRT PRESSURE
C       9. GAMSM   GAMS-ONE
C      10. HVS     VAPOR SATURATION ENTHALPY
C      11. HLS     LIQUID SATURATION ENTHALPY
C
     TSAT = TSC1* P**TSEXP
     HVS = HVO + P*(HV1 + P*(HV2 + P*(HV3 + P*HV4)))
     HLS = HLO + P*(HL1 + P*(HL2 + P*(HL3 + P*(HL4 + P*HL5))))
     PINV = ONE/ P
     DTSDP = TSAT*TSEXP*PINV
     TSAT = TSAT + TSC2
C
     T1 = ONE - TSAT*TCRINV
     CPS = CPS1* T1**CPSEXP
     DPCPS = CPS2*CPS/T1 *DTSDP
C
     IF (P.GT.P20B) GO TO 150
       T2 = ONE/ (G13+P)
       T1 = T2*G12
       ES = G11 + T1
       DPES = -T1*T2
       GAMS = G14 + P*(G15 + P*G16)
       DPGAMS = G15+G17*P
       GO TO 200
 150 CONTINUE
       ES = G21+(G23*P+G22)*P
       DPES = G22+G27*P
       GAMS = G24+(G26*P+G25)*P
       DPGAMS = G25 + G28*P
 200 GAMSM = GAMS - ONE
C
C
C     CALCULATE LIQUID PROPERTIES
```

```
C
C
C        1. INTERNAL ENERGY AND ITS DERIVATIVES
C
      DP=P - 150.E5
      DELDP = -EXP(SP0+TL*(SP1+TL*(SP2+TL*SP3)))
      DEL = DELDP * DP
      IF (TL.GE.576.5) GO TO 210
        EL = SL0 + TL*(SL1 + TL*(SL2 + TL*(SL3+TL*SL4))) + DEL
        DELDT = SL1 + TL*(SL22 + TL*(SL33+TL*SL44))
     1              + DEL * (SP1 + TL*(SP22 + TL*SP33))
        GO TO 220
  210 CONTINUE
        EL =(SH0 + TL*(SH1 + TL*(SH2 + TL*(SH3+ TL*SH4)))) + DEL
        DELDT = (SH1 + TL*(SH22 + TL*(SH33 + TL*SH44)))
     1            + DEL * (SP1 + TL*(SP22 +TL*SP33))
  220 CONTINUE
C
C        2. DENSITY AND ITS DERIVATIVES
C
      DRLDP = EXP(RP0 + RP1*EXP(RP2 * TL))
      DRL = DRLDP * DP
          IF (TL.GE.576.5) GO TO 230
      ROL = RL0 + TL*(RL1 + TL*(RL2+ TL*RL3)) + DRL
      DRLDT = RL1 + TL*(RL22 + TL*RL33) + DRL*RP1*RP2*EXP(RP2*TL)
      GO TO 240
 230  CONTINUE
      ROL = RH0 + TL*(RH1 + TL*(RH2 + TL*(RH3 + TL*RH4))) + DRL
      DRLDT = RH1 + TL*(RH22 + TL*(RH33 + TL*RH44)) +
     1          DRL*RP1*RP2*EXP(RP2*TL)
240   CONTINUE
       TL = TLSAVE
C
C     CALCULATE VAPOR PROPERTIES
C
      DT = TV-TSAT
      IF (DT.LE.ZERO) GO TO 250
C
C     SUPERHEATED VAPOR
C
C        1. BETA A WORKING PARAMETER
C        2. CAPK A WORKING PARAMETER
C        3. DBETAP  DERIVATIVE OF BETA WRT PRESSURE
C        4. DCAPKP  DERIVATIVE OF CAPK WRT PRESSURE
C        5. DEVDT
C        6. DEVDP
C        7. ROV
C        8. DRVDE
C        9. DRVDP
C
      T1 = ONE/(A11*CPS-ONE)
      T1SQ = T1*T1
      BETA = TSAT*TSAT*(ONE - T1SQ)
      T2 = TSAT*T1
```

```
      DE = A12*(DT+SQRT(TV*TV-BETA)-T2)
      EV = ES + DE
      CAPK = A13*DE+TSAT+T2
      DBETAP = TWO*(BETA*DTSDP+T2*T2*T2*A11*DPCPS)/TSAT
      DCAPKP = -A13*DPES + (ONE + T1)*DTSDP
     1  -TSAT*A11*T1SQ*DPCPS
      T3 = ONE-BETA/(CAPK*CAPK)
      DEVDT = ONE/(HALF*T3*A13)
      DEVDP = -HALF*(T3*DCAPKP+DBETAP/CAPK)*DEVDT
      T4 = ONE/(GAMSM*ES+CCM*DE)
      ROV = P*T4
      DRVDE = -ROV*CCM*T4
      DRVDT = DRVDE*DEVDT
      DRVDP = ROV*(PINV-(ES*DPGAMS+(GAMSM-CCM)*DPES)*T4)
     1   + DRVDE*DEVDP
      GO TO 300
  250 CONTINUE
C
C     SUBCOOLED VAPOR
C
      DEVDT = CPS * CCI
      DE = DT * DEVDT
      EV = ES + DE
      T1 = ONE/ CPS
      DEVDP = -(DTSDP -CC*T1*(DPES +DE*DPCPS*T1) )*DEVDT
      T1 = ONE/ GAMSM
      T2 = ONE/ EV
      ROV = P *T1*T2
      DRVDE = -ROV *T2
      DRVDT = DRVDE * DEVDT
      DRVDP = ROV *(PINV - DPGAMS*T1) + DRVDE*DEVDP
C
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MIXING(ROVI,ROVJ,ROLI,ROLJ,VISLI,VISLJ,HDI,HDJ,AI,AJ,
     1                  VVI,VVJ,VLI,VLJ,SIJ,ARVI,ARVJ,ARLI,ARLJ,EVI,
     2                  EVJ,ELI,ELJ,DPDZTV,DPDZTL,EVIJ,ELIJ,WVIJ,WLIJ,
     3                  DRVDT,DRLDT,DRVDP,DRLDP,DEVDT,DELDT,DEVDP,
     4                  DELDP,ROVNI,ROLNI,ALPI,DQVDP,DQVDA,DQVDTV,DQLDP,
     5                  DQLDA,DQLDTL,DWVDP,DWVDA,DWVDTV,DWLDP,DWLDA,
     6                  DWLDTL,RADR,IPART)
C
C   COMPUTE AVERAGES
C
       DFS=RADR*2
       IF(DFS.EQ.0.) DFS=.015
      C1= 1.4
      GVI=ARVI*ABS(VVI)
      GLI=ARLI*ABS(VLI)
      GVJ=ARVJ*ABS(VVJ)
      GLJ=ARLJ*ABS(VLJ)
      GI=GVI+GLI
      GJ=GVJ+GLJ
      GFD=1.-C1*(GI-GJ)/(GI+GJ)
      XI=GVI/GI
      XJ=GVJ/GJ
      X=0.5*(XI+XJ)
      G=0.5*(GI+GJ)
      D=0.5*(HDI+HDJ)
      A=AI+AJ
      VISL=0.5*(VISLI+VISLJ)
      RHO=0.5*(ARVI+ARVJ+ARLI+ARLJ)
      ROV=0.5*(ROVI+ROVJ)
      ROL=0.5*(ROLI+ROLJ)
      VV=0.5*(VVI+VVJ)
      VL=0.5*(VLI+VLJ)
C
C   CALCULATE TURBULENT VELOCITY
C
      IF(HDI.GT.HDJ) GO TO 50
      RE=GI*HDI/VISLI
      WIJSP=0.5*.0058*(SIJ/DFS)**(-1.46)*RE**(-.1)*
     1      (1.+(HDJ/HDI)**1.5)*HDI/DFS*GI*SIJ
      GO TO 60
 50   CONTINUE
      RE=GJ*HDJ/VISLJ
      WIJSP=0.5*.0058*(SIJ/DFS)**(-1.46)*RE**(-.1)*
     1      (1.+(HDI/HDJ)**1.5)*HDJ/DFS*GJ*SIJ
 60   CONTINUE
      VTURB=WIJSP/(SIJ*RHO)*THETA(ROL,ROV,G,VV,VL,RE,A,D,SIJ,WIJSP,X)
C
C   CALCULATE MOMENTUM EXCHANGE DUE TO MIXING
C
      IF(IPART.EQ.2) GO TO 100
      GVEQ=C1*(GVI+GVJ)*(GI-GJ)/(GI+GJ)
      GLEQ=C1*((ARLI-ROLI)*VLI+(ARLJ-ROLJ)*VLJ)*(GI-GJ)/(GI+GJ)
      GVEQ=0.
      GLEQ=0.
```

```
      DPDZTV=VTURB*(GVI-GVJ-GVEQ)*SIJ
      DPDZTL=VTURB*(GLI-GLJ-GLEQ)*SIJ
      RETURN
  100 CONTINUE
      ARVNI=ALPI*ROVNI
      ARLNI=(1.-ALPI)*ROLNI
      AREVI=ARVNI*EVI
      ARELI=ARLNI*ELI
      AREVJ=ARVJ*EVJ
      ARELJ=ARLJ*ELJ
C
C   CALCULATE MASS EXCHANGE DUE TO MIXING
C
      ARVEQ=C1*(ARVNI+ARVJ)*(GI-GJ)/(GI+GJ)
      ARLEQ=C1*(ARLNI-ROLNI+ARLJ-ROLJ)*(GI-GJ)/(GI+GJ)
      WVIJ=VTURB*(ARVNI-ARVJ-ARVEQ)*SIJ
      WLIJ=VTURB*(ARLNI-ARLJ-ARLEQ)*SIJ
      IF(X.LE.0.) WLIJ=0.
      DWVDA=SIJ*VTURB*GFD*ROVNI
      DWVDTL=0.
      DWVDTV=SIJ*VTURB*GFD*ALPI*DRVDT
      DWVDP=SIJ*VTURB*GFD*ALPI*DRVDP
      DWLDA=-SIJ*VTURB*GFD*ROLNI
      DWLDTL=SIJ*VTURB*(1.-GFD*ALPI)*DRLDT
      DWLDTV=0.
      DWLDP=SIJ*VTURB*(1.-GFD*ALPI)*DRLDP
      IF(X.LE.0.) DWLDP=0.
      IF(X.LE.0.) DWLDTL=0.
C
C   CALCULATE ENERGY EXCHANGE DUE TO MIXING
C
      AREVEQ=C1*(AREVI+AREVJ)*(GI-GJ)/(GI+GJ)
      ARELEQ=C1*(ARELI-ROLNI*ELI+ARELJ-ROLJ*ELJ)*(GI-GJ)/(GI+GJ)
      EVIJ=VTURB*(AREVI-AREVJ-AREVEQ)*SIJ
      ELIJ=VTURB*(ARELI-ARELJ-ARELEQ)*SIJ
      DQVDA=SIJ*VTURB*GFD*ROVNI*EVI
      DQVDTL=0.
      DQVDTV=SIJ*VTURB*GFD*ALPI*(EVI*DRVDT+ROVNI*DEVDT)
      DQVDP=SIJ*VTURB*GFD*ALPI*(EVI*DRVDP+ROVNI*DEVDP)
      DQLDA=-SIJ*VTURB*GFD*ROLNI*ELI
      DQLDTL=SIJ*VTURB*(1.-GFD*ALPI)*(ELI*DRLDT+ROLNI*DELDT)
      DQLDTV=0.
      DQLDP=SIJ*VTURB*(1.-GFD*ALPI)*(ELI*DRLDP+ROLNI*DELDP)
      RETURN
      END
```

```
FUNCTION THETA(RHOL,RHOV,G,VV,VL,RE,A,D,SIJ,WIJSP,X)
DATA A1,A2,GRAV/0.4,0.6,9.81/
THETA=1.0
IF(X.LE.0..OR.X.GE.1.0) RETURN
XM=(A1*SQRT(RHOL*(RHOL-RHOV)*GRAV*D)/G+A2)/(SQRT(RHOL/RHOV)+A2)
BETA1=0.04*(SIJ/D)**1.5
THETAM=1.+BETA1*A*G*RHOL*(VV-VL)*XM/(WIJSP*D*RHOV*VV)
THETAM= 5.
THETA=1.+(THETAM-1.)*X/XM
IF(X.LE.XM) RETURN
X0=XM*0.57*RE**0.0417
THETA=1.+(THETAM-1.)*(XM-X0)/(X-X0)
RETURN
END
```

```
      SUBROUTINE INNBGS
C
      COMMON A(15000)
      COMMON /POINT/ LNCR,LINDNT,LICC,LIWFZ,LIHTR,  LICR,LIRC,LP,LALP,
     1   LROV,LROL,LEV,LEL,LTV,LTL,LTR, LPN,LALPN,LROVN,LROLN,LEVN,
     2   LELN,LTVN,LTLN,LTRN, LVVX,LVLX,LVVY,LVLY,LVVZ,LVLZ,
     3   LHV,LHL,LHVS,LHLS,LTSAT,LVISV,LVISL, LDX,LDY,LDZ,LARX,LARY,
     4   LARZ,LVOL, LCPVX,LCPVY,LCPVZ,LCPLX,LCPLY,LCPLZ, LFVX,LFVY,
     5   LFVZ,LFLX,LFLY,LFLZ, LAJM1,LAJM2,LCPA,LCPTV,LCPTL,LRHS,
     6   LDP,LQPP,LQV,LQL,LHVFC,LHLNB,LHLFC, LDTRN,LDTW,LTW,LCHFR,
     7   LFRAC,LHDZ,LHDH,LQZ,LQT,LQR,LQPPP,LRN,LCND,LRCP,LRRDR,LVP,LVM,
     8   LRAD,LBOTBC,LTOPBC,LTMPBC,LSIJ,LEND
      COMMON /IC/ NSTEP,NITMAX,NITNO,IITMAX,IITOT,IIC,KRED,NM,NTC,
     1   NC,NRODS,NZ,NR,NCP,NZP,NZP2, IFLASH,ITB,IBB,ICPU,IWFT,IVEC,
     2   NODES,NDM1,NCF,NCC,NG,IHT, ISS,IQSS,ITAM,IRES,IDUMP,NTITLE,
     3   ITWMAX,JTWMAX,ITRMAX,JTRMAX,IMCHFR,JMCHFR,ICHF,IFINTR,IERR,LERR
     4   ,LOUTPU,IMIXM,IMIXE,IAFM,ITFM,IGFM
      LOGICAL LERR,LOUTPU
      COMMON /RC/ DELT,RDELT,ERRN,EPSN,ERRI,EPSI,DTMIN,DTMAX,TEND,
     1   DTSP,DTLP,RTNSP,RTNLP, GRAV,RTIME,HDT,VELX,
     2   Q,Q0,T0,OMG, RADR,THC,THG,TWMAX,TRMAX,AMCHFR
C
C  PERFORM EXPLICIT CALCULATIONS
C
      DIMENSION IA(1),LTABLE(3)
      EQUIVALENCE (A(1),IA(1))
C
      OMEGA = 1.0
      NX = IA(LNCR)
      NY = NR
C
C  PROVIDE SCRATCH STORAGE FOR AUXILIARY ITERATION MATRICES,
C   VIRTUAL RHS AND WORKING AREA.
C
      LAA = LEND
      NBAND = 2*NX+1
      LENAA = NC*NBAND*NZ
      LBB = LAA+LENAA
      LENBB = NC*NZ
      LXL = LBB+LENBB
      LENXLC = NC*(NX+1)
      LENXL = LENXLC*NZ
C
C..SET INITIAL DP = 0.0
C
C     CALL CLEAR(0.0,A(LDP),NZP2*NCP)
C
C..PERFORM PLANE SOR ITERATIONS
C
        CALL INNXYB( A(LDP),A(LAJM1),A(LAJM2),A(LRHS),A(LAA),A(LBB),
     1        A(LXL),IA(LICC),
     2        NZ,NC,NZP2,NCP,NX,NBAND,LENXLC,
     3        EPSI,IITMAX,IIC,ERRI,OMEGA,A(LP) )
C
```

```
RETURN
END
```

```
      SUBROUTINE INNXYB( DP,AJM1,AJM2,RHS,AA,B,XL,ICC,
     1               NZ,NC,NZP2,NCP,NX,NBAND,LENXLC,
     2               EPSI,IITMAX,IIC,ERRI,OMEGA,PREF )
      DIMENSION DP(NZP2,NCP),AJM1(3,NZ,NC),AJM2(4,NZ,NC),RHS(NZ,NC),
     1              AA(NC,NBAND,NZ),B(NC,NZ),XL(LENXLC,NZ),ICC(4,NC)
C  FUNCTION: SOLVES THE SYSTEM [AJM1+AJM2]*[DP] = [RHS]
C   BY SUCCESSIVE XY-BLOCK RELAXATION.
C
      J1 = 1
      J2 = NX
      J0 = NX+1
      J3 = J0+1
      J4 = J0+NX
      JS1 = J1+1
      JF1 = J2-1
      JS2 = J3+1
      JF2 = J4-1
C
      IJOB = 1
C
C..FORM MATRIX[AA] AND PERFORM LU FACTORIZATION
C
      DO 40 IZ=1,NZ
      DO 30 IC=1,NC
      AA(IC,J1,IZ) = AJM2(1,IZ,IC)
       DO 10 J=JS1,JF1
  10   AA(IC,J,IZ) = 0.0
      AA(IC,J2,IZ) = AJM2(2,IZ,IC)
      AA(IC,J0,IZ) = AJM1(1,IZ,IC)
      AA(IC,J3,IZ) = AJM2(3,IZ,IC)
       DO 20 J=JS2,JF2
   20  AA(IC,J,IZ) = 0.0
      AA(IC,J4,IZ) = AJM2(4,IZ,IC)
   30 CONTINUE
C
      CALL LEQT1B(AA(1,1,IZ),NC,NX,NX,NC,B(1,IZ),1,NC,IJOB,XL(1,IZ),IER)
C
   40 CONTINUE
C
      IJOB = 2
      OMEGA1 = 1.0-OMEGA
C
C..ENTER ITERATIVE CYCLE
C
      DO 100 IT=1,IITMAX
      IIC = IT
      ERRI = 0.0
C
C...FORM VIRTUAL RHS AND SOLVE THE X-Y BLOCK
C
      DO 60 IZ=1,NZ
      JZ = IZ+1
      JZM = JZ-1
      JZP = JZ+1
```

```
C
      DO 50 IC=1,NC
      B(IC,IZ) = RHS(IZ,IC) - AJM1(2,IZ,IC)*DP(JZM,IC)
     1                      - AJM1(3,IZ,IC)*DP(JZP,IC)
   50 CONTINUE
C
      CALL LEQT1B(AA(1,1,IZ),NC,NX,NX,NC,B(1,IZ),1,NC,IJOB,XL(1,IZ),IER)
C
      DO 60 IC=1,NC
      DPOLD = DP(JZ,IC)
      DP(JZ,IC) = OMEGA*B(IC,IZ) + OMEGA1*DPOLD
      ERRI = AMAX1(ERRI,ABS(DP(JZ,IC)-DPOLD) )
      ERRI = ERRI/PREF
   60 CONTINUE
C
      IF(ERRI.LE.EPSI) RETURN
C
  100 CONTINUE
      RETURN
      END
```