-WOSUB-
A SUBCHANNEL CODE FOR STEADY-STATE AND TRANSIENT THERMAL-HYDRAULIC ANALYSIS OF BWR FUEL PIN BUNDLES

VOLUME II

USER'S MANUAL

by

L. Guillebaud, A. Levine, W. Boyd,
A. Faya, L. Wolf

Energy Laboratory Report No. MIT-EL 78-024
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This research was initiated about July 1976 when Louis Guillebaud pursued the assessment and extension of the MATTEO-code, which I brought with me to the U.S. already in 1974. Although I had tested the code and its options in the meantime, this was unfortunately only done for a three-subchannel case comprising the symmetry section of the (3 x 3) Rod GE Test Bundle. Louis realized that the code was not capable to run larger cases. He made the code operational and generated a larger version capable to analyze half of (8 x 8) Rod bundles. Furthermore, he presented a first set of consistent comparisons. At that time the code was renamed WOSUB. Some fraction of the material presented in this volume is taken from Louis' thesis [1].

In September 1976, Alan Levine started to extend the computational features of the code by adding the subroutines for evaluating the heat transfer coefficient, the initial heat flux, boiling length, critical quality, and critical power, thus making it possible for the first time to generate design quantities by this code.

He was succeeded by William Boyd in January 1977, who focused his attention toward a parametric sensitivity study of the drift flux parameters and their effects upon the overall results. When he left M.I.T., Arthur Faya began to collect all the pieces of information and to implement them into the code. His first achievement is the addition of a novel fuel pin temperatures numerical technique for the solution which he fully integrated into WOSUB for steady-state and transient calculations. Furthermore, he reduced the solution method and provided additional results and comparisons.

During the course of his Ph.D. thesis over the next two years, Arthur will focus his primary attention on the extension of the physical models in the code and will add a flow logic.

To all these gentlemen I owe a large debt of gratitude for their devotion and tireless efforts in accomplishing all these achievements.

Finally, I would like to acknowledge the financial support by the New England Electric System and Northeast Utilities Service Company as part of the Nuclear Reactor Safety Research Program under the M.I.T. Energy Laboratory's Electric Power Program.

Lothar Wolf
Principal Investigator
Associate Professor of
Nuclear Engineering

ABSTRACT

The WOSUB-codes are spin-offs and extensions of the MATTEO-code [2]. The series of reports describe WOSUB-I and WOSUB-II in their respective status as of July 31, 1977.

This report is the second of a series of three reports describing the WOSUB code. It gives a detailed description of the input data, flow charts, and output, and contains the listings of WOSUB-I and WOSUB-II. For the purpose of future extensions parameters, common blocks and variables used in the code are listed in full detail.

WOSUB-I and WOSUB-II are subchannel computer codes for the steady-state and transient analysis of the thermal-hydraulic characteristics of Boiling Water Reactor (BWR) fuel rod bundles. Both codes are also applicable to analyze PWR bundles, especially when these are ducted--a situation which most often arises in experimental set-ups.

The main difference between WOSUB-I and WOSUB-II is that the former is designed to analyze small bundles, whereas the latter is capable to handle symmetric sections of today's large-sized BWR bundles. In addition, WOSUB-II does not contain all of the additions made in WOSUB-I yet, because it is deemed appropriate to introduce these into the smaller code first, before they are implemented into the bigger one.

Both codes are still in the stage of evolutionary development. Thus, changes are to be expected in the near future. Therefore, it should be noticed that this report reflects the development as of July 1977 only.

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CHAPTER 1

USER'S MANUAL OF THE COMPUTER CODE

WOSUB-I

1.0 Introduction

WOSUB-I is a subchannel computer code for the steady-state and transient thermal-hydraulic analysis of BWR fuel rod bundles. The code is also applicable to PWR bundle analysis as long as they are enclosed by bundle walls. This situation frequently arises in experimental facilities.

The physical models and the numerical solution scheme, which are used in the code are described in full detail in Volume 1 [3] of this series. For convenience, the main features are summarized below.

- The code uses the zuber-Findlay vapor drift flux model.
- A vapor diffusion model is included, which accounts for the vapor's affinity to redistribute into channels with higher velocities as has been observed experimentally.
- The code accounts for thermodynamic nonequilibrium effects.
- It uses a unique methodology introducing the concept of recirculation paths.
- Four heat transfer coefficients each associated with one subchannel are calculated around the pin perimeter.
- The code calculates the boiling length and the critical power.
- A novel collocation method is used for calculating the steady-state and transient fuel pin temperatures.

Based upon these features the computer code WOSUB is therefore supposed to give more insight and a better understanding of the thermal and hydraulic conditions prevailing in the bundle wall near regions of fuel pin bundles. Emphasis has been put specifically to the code's capability to analyze BWR fuel pin bundles where it is expected to give more realistic answers than the conventional codes, such as COBRA or HAMBO, which were specifically designed for analyzing single phase flow and eventually extended to two-phase flow situations by using empirical parameters for the analysis of BWR fuel rod bundles.

Preliminary results for various conditions as well as comparisons with experimental evidence are given in volume 3 [4] of this series.

The purpose of this manual is to introduce the user into the mechanism of running the code by providing information about the input data, flow charts, and options.

If not otherwise mentioned the information given for WOSUB-I holds also for WOSUB-II.

1.1 Input Data Description

All the data of a problem are read in as a single floating point vector; conversion to integer variables is performed by the code where needed. The format is 6E.12--as many data are often zero, only sets of significant data are read in. Each set is preceded by a control card specifying the first and last index in the input vector of the set. These are given as integers adjusted to the right at columns 12 and 24 (Format 2I 12). The last set of data for a problem must be indicated by -1 punched in columns 1 and 2 of the control card.

Every problem must begin with a title card, with any alphanumeric information in column 7 to 80.

Many problems may be treated in the same run, and only the data which are changing from the preceding problem need to be given. A positive integer in columns 1 to 6 of the title card indicates that the problem is the last of the run.

1.1.1 Order of Input Data Cards

Group 0 Control card

Group 1 Title card: Identification

Group 2 General input data

Group 3 Array arrangement input data

Group 4 Recirculation loop specifications

Group 5 Geometrical input data for subchannels

Group 6 Array sizing input data

Group 7 Roughness specification for subchannels

Group 8 Parameters

Group 9 Physical parameters

Group 10 Peaking factors

Group 11 Flux shape

Group 12 Blockage specifications

Group 13 Transient specifications

Group 14 Perturbation timetables

Group 15 Heat transfer coefficient specifications

Group 16 Geometrical and physical characteristics of fuel and cladding

1.1.2 Control Cards

1.1.2.1 Remarks on Control Cards

As mentioned above in Section 1, every set of input data is preceded by a control card, which specifies the width of the field of the set to be read in. The following explains how this method works:

1. If one supposes that the first set of input data contains 10 elements, in this case the value of the index to be placed in column 12 of the control card is 1. In columns 23 and 24 of the control card the value of the index to be placed is 10. One has therefore the deck as shown in Fig. 1.

The control card indicates that a field of 10 E12.6 is reserved for the first set of 10 input data.

Note that each input data card contains 6 zones of 12 columns (because of the fixed read in FORMAT E12.6).

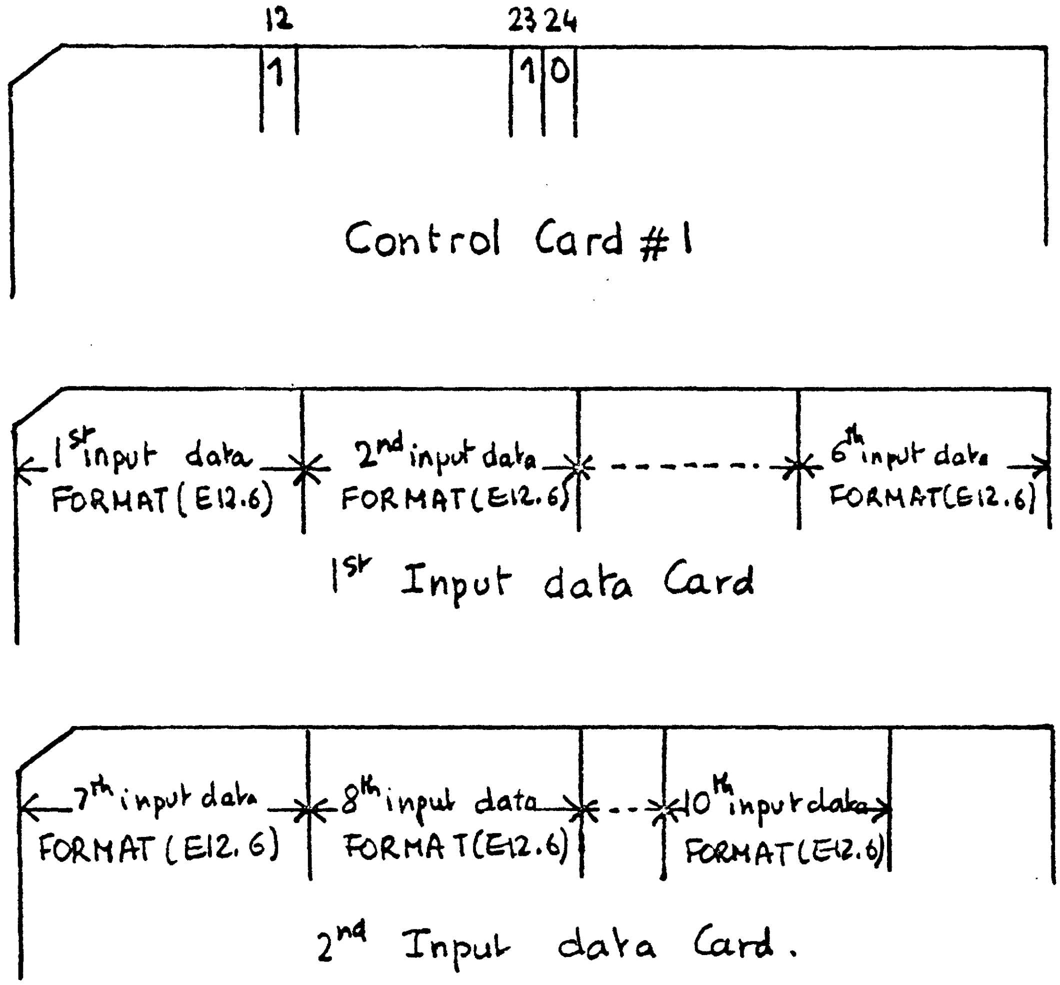

FIG. 1: Input Deck Structure
After 1st Control Card

Therefore, the two remaining zones on the second input data card will be ignored by the code.

2. If a second set of input data contains three elements, the first value of the index (to be placed in columns 11 and 12 of the control card preceding this second set of input data) is 11. The second value of the index (placed in columns 23 and 24 of the control card) is 13. One has therefore the structure shown in Fig. 2. Note that, as before, the three remaining zones (3E12.6) on the input data card are ignored by the code.

3. For any number of elements in a set of input data, the first value of the index, Y, on the control card is equal to the last value of the index on the previous control card, X, plus one, then $Y = X + 1$. The second value of the index, Y, plus the number of input data in the set, n, minus one: $Z = Y - 1 + n$.

The overall advantages of this method can be summarized as follows:

1. After initializing the core memory, which will contain the input data, one is assured to have a bijective correspondence between index value and input data, eliminating therefore the possibility of inputting wrong data into the core at a given index-referenced location.

2. A higher degree of transparency in the input deck structure is a direct result of this technique.

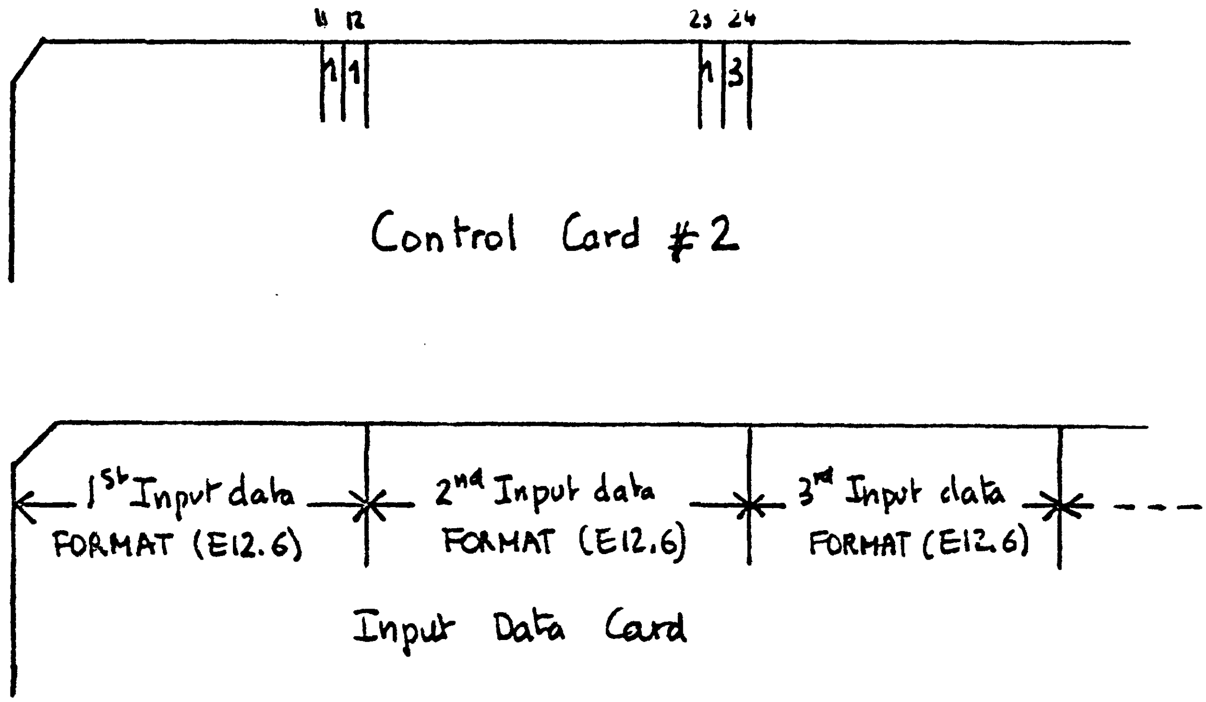

FIG. 2: Input Deck Structure After 2nd Control Card

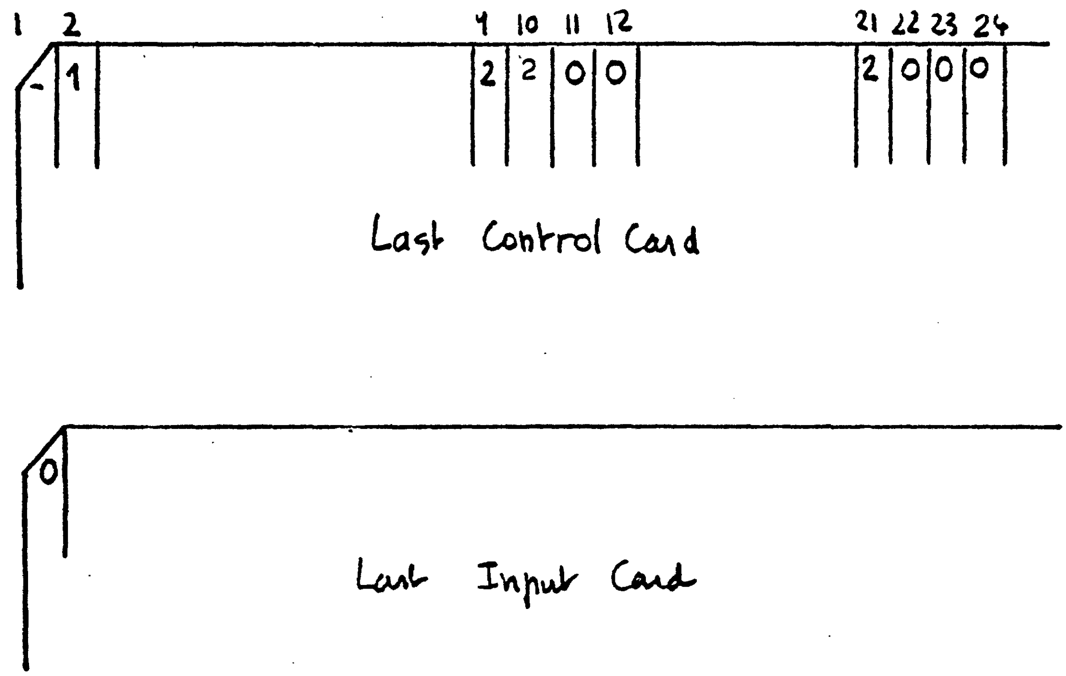

FIG. 3: Input Deck Structure
After Last Control Card

3. Large flexibility of inputting a set of input data of any size since the control card does not operate with a fixed field value.

1.1.2.2 Title Card and Last Card Specifications

The title card is divided into two zones:

Zone - 1: Columns 1 - 6 (included)

Zone - 2: Columns 7 - 80 (included)

If the problem to be treated is the only one in the run, zone-1 of the last problem must contain 1.

The last control card of a problem must be specified as seen in Fig. 3.

Note that the field specified by the last control card is 1. [i.e., in the core memory it corresponds to DATA (2200)]. The value to be affected in this zone is zero. Therefore, the last input card will contain as an input, zero or will be a blank card, since the blanks are read in as zero numbers.

Note that the minus sign in column 1 and the number 1 in column 2 indicate the end of the data set.

1.1.3 Input Data

On the following pages, instructions are given for preparing the input data card deck for the code WOSUB-I. To more easily comprehend the meaning of certain data, additional explanations are given by placing numbers into the column "Remarks," which refers the user to Section 1.1.3.2.

1.1.3.1 List of input data

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS	
1	1		1-6	I6		0=not the last problem in the run 1=last problem in the run		
1	1		7-80	16A4	TITLE	Identification of the run		
2	1	1	1-12	E12.6	NCHAN	Number of subchannel types in the bundle	1	1
2	1	2	13-24	E12.6	NRODS	Number of heating rod	2	
2	1	3	25-36	E12.6	JMAX	Number of axial nodes for calculation		
2	1	4	37-48	E12.6	IHIN	Inlet Enthalpy Indicator 0=subcooled enthalpy (negative) is given 1=enthalpy is given -1=subcooled temp is given (positive if subcooled) -2=inlet temp is given		
2	1	5	49-60	E12.6	ISHAP	0=Flat Power distribution 1=Tabulated distribution -1=Chopped Corinus distribution		
2	1	6	61-72	E12.6	ICON	0=Decimal system input/output 1=BTU input/output	3	1

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
2	2	7	1-12	E12.6	IDOP	0=hyd. dia. renormalized 1=no renormalization turbulent momentum exchange	
2	2	8	13-24	E12.6	IDOWN	0=Upwards flow 1=Downwards flow	
2	2	9	25-36	E12.6	NDRIFT	0=No vapor diffusion subchannel mixing 1=Diffusion vapor mixing model	
2	2	10	37-48	E12.6	IPAR	0=Standard parameters chosen by the code (see DATA 90(+FF) 1=same parameters are input	4
3	1	11	1-12	E12.6	JOIN(1)	Number of subchannels joining to the first	5
3	1	12	13-24	E12.6	NAROD(1)	Number of rods heating first subchannel	6
3	1	13	25-36	E12.6	NJOIN(1,1)	(Order number of subchannel joining to the first) max = 4 subchannel joining to the first	8
3	1	14	37-48	E12.6	NJOIN(1,2)	Subchannel joining to the first	
3	1	15	49-60	E12.6	NJOIN(1,3)	Subchannel joining to the first	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
3	1	16	61-72	E12.6	NJOIN(1,4)	Subchannel joining to the first	
3	2	17	1-12	E12.6	KROD(1,1)	First rod heating first subchannel	
3	2	18	13-24	E12.6	KROD(2,1)	Second rod heating first subchannel	
3	2	19	25-36	E12.6	KROD(3,1)	Third rod heating first subchannel	
3	2	20	37-48	E12.6	KROD(4,1)	Fourth rod heating first subchannel	
3	3	21	1-12	E12.6	JOIN(2)	Number of subchannel joining to the second	
3	3	22	13-24	E12.6	NAROD(2)	Number of rod types heating second subchannel	
3	3	23	25-36	E12.6	NJOIN(2,1)	(Order number of sub-channel joining to the second) max=4 Subchannel joining to the second	
3	3	24	37-48	E12.6	NJOIN(2,2)	Subchannel joining to the second	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
3	3	25	49-60	E12.6	NJOIN(2,3)	Subchannel joining to the second	
3	3	26	61-72	E12.6	NJOIN(2,4)	Subchannel joining to the second	
3	4	27	1-12	E12.6	KROD(1,2)	First rod heating Second subchannel	
3	4	28	13-24	E12.6	KROD(2,2)	Second rod heating Second subchannel	
3	4	29	25-36	E12.6	KROD(3,2)	Third rod heating Second subchannel	
3	4	30	37-48	E12.6	KROD(4,2)	Fourth rod heating Second subchannel	

NOTE: The array arrangement input data is continued the same way for as many as 20 subchannels in the array.

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
4	1	300	1-12	E12.6	NOCIR	Number of independent recirculation paths in bundle	7
4	2	301	1-12	E12.6	MCIRC(1)	Recirculation loop #1 (each subchannel is characterized by two digits:i.e. sub#1=01, either way of circulation is allowed (be consistent))	8
4	2	302	13-24	E12.6	MCIRC(2)	Recirculation loop #2	
4	2	303	25-36	E12.6	MCIR(3)	Recirculation loop #3	

NOTE: On each card a maximum of 6 recirculation loops can be specified (because of the FORMAT i.e.: 6E12.6 = 72 columns) input recirculation loops up to MCIRC (NOCIR).

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
5	1	401	1-12	E12.6	A(1)	Flow area of subchannel 1	
5	1	402	13-24	E12.6	HYD(1)	Hydraulic diameter for same subchannel	
5	1	403	25-36	E12.6	HPER(1,1)	Fraction of first rod perimeter heating sub-channel 1, Same order as KROD must be followed	
5	1	404	37-48	E12.6	HPER(2,1)	Fraction of second rod	
5	1	405	49-60	E12.6	HPER(3,1)	Fraction of third rod	
5	1	406	61-72	E12.6	HPER(4,1)	Fraction of fourth rod	
5	2	407	1-12	E12.6	AL(1)	Gap width corresponding to NJOIN (1,1)	
5	2	408	13-24	E12.6	SL(2,1)	Gap width corresponding to NJOIN (1,2)	
5	2	409	25-36	E12.6	SL(3,1)	Gap width corresponding to NJOIN (1,3)	
5	2	410	37-48	E12.6	SL(4,1)	Gap width corresponding to NJOIN (1,4)	

Same form for second subchannel

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
6	1	601 to 620	1-72	E12.6	CHANN(I)	Number of subchannels of type I in the bundle	9
6		621 to 645	1-72	E12.6	RODN(I)	Number of heating rods of type I in the bundle	10
7	1	651 to 690	1-12	E12.6	RERG(I)	Relative roughness of subchannel type I	

Following parameters are input only when IPAR = 1 (DATA 10)

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
8	1	901	1-12	E12.6	AN	Exponent in boiling heat flux correlation	
8	1	902	13-24	E12.6	ZE	Multiplier of average hydraulic diameter to obtain relaxation length for diabatic vapor concentration profile	
8	1	903	25-36	E12.6	R	Recondensation constant	
8	1	904	37-48	E12.6	ZUBER	Constant for average void drift velocity	
8	1	905	49-60	E12.6	CGRAV	Gravity cosinus (positive) for upward flow	
8	1	906	61-72	E12.6	CPAR	Parameter in subcooled boiling model	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
8	2	907	1-12	E12.6	FL	Multiplier for momentum flow of the liquid	
8	2	908	13-24	E12.6	FV	Same for vapor	
8	2	909	25-36	E12.6	REL1	First attempt relaxation parameter	
8	2	910	37-48	E12.6	REL2	Second attempt relaxation parameter	
8	2	911	49-60	E12.6	RFSTG	Multiplier for second guess choice of diverted flows	
9	1	1001	1-12	E12.6	P	Pressure	
9	1	1002	13-24	E12.6	HINLET	Inlet enthalpy or temp.	
9	1	1003	25-36	E12.6	GTOT	Total mass flow into the bundle (whole bundle)	
9	1	1004	37-48	E12.6	DIAR	Diameter of heating rods	
9	1	1005	49-60	E12.6	POWER	Total bundle power (WATTS)	
9	1	1006	61-72	E12.6	PFDAC	Fraction of power directly added to coolant by neutron moderation and radiation	
9	2	1007	1-12	E12.6	ZTOT	Total height of the bundle	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
10	1	1011 to 1035	1-12	E12.6	PEAK(K)	Relative power of rod type K-Arbitrary normalization performed by the code	
11	1	1050	1-12	E12.6	AXPKF	Axial peaking factor-only for chopped cosinus distribution	
11	2	1051 to 1100	1-72	E12.6	AXSHF(S)	Axial power shape tabulation, arbitrary units give JMAX value, one for each node.	
12	1	1101 to 1106	1-72	E12.6	LOC(IL)	Nodes, where local flow restrictions exist (spaces blockages) up to 10 locations	
	2	1107 to 1110	1-72	E12.6	LOC (IL)	Same	
12	3	1201 to 1223	1-72	E12.6	FFLC(I,J)	Local Restriction Coefficient at Subchannel I at Node LOC (I)	
12		1221 to 1240	1-72	E12.6	FFLL(2,$)	Same for Node LOC(2)	

TRANSIENT SPECIFICATION DATA

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARK
13	1	1500	1-12	E12.6	TFIN	Total time of calculation (sec) if zero only steady state calculation and end of data	
13	1	1501	13-24	E12.6	PRIN	Printing time interval for summary print (sec)	
13	1	1502	25-36	E12.6	MDPR	Detailed printout every MDPR printing steps	
13	1	1503	37-48	E12.6	DT	Time increment for calculation-if omitted it will be chosen by the code	
13	2	1511	1-12	E12.6	IPRESS	Pressure transient Perturbation indicator 0=cte pressure 1=tabulated perturbation 2= sinusoidal perturbation P=PZERO*(1+C1*SIN(C2*TIME) 3=polynomial perturbation P=PZERO*(1.+C(I)*T**I)	
13	2	1512to 1516	13-72	E12.6	CPRESS(I)	Coefficients for mass flow perturbation only where IVINL=2 or3	
13	3	1517	1-12	E12.6	IVINL	Mass flow transient perturbation indicator same code as IPRESS	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARK
13	3	1518 to 1522	13-72	E12.6	CVIN(I)	Coefficients for mass flow perturbation only when IVINL=2 or 3	
13	4	1523	1-12	E12.6	ITIN	Inlet enthalpy (or temperature) perturbation indicator-same code as above	
13	4	1524 to 1528	13-72	E12.6	CTIN(I)	Coefficients for inlet enthalpy or temperature when ITIN = 2 or 3 the definition of these coefficients is different HINLET=HZERO+C1*SIN(C2*TIME) C1 in JOULE/G or Btu/lb. HINLET=HZERO+SUM(C(I)*TIME**I)	
13	5	1529	1-12	E12.6	IPOW	Power transient perturbation indicator (same code)	
13	5	1530 to 1534	13-72	E12.6	CPOW(I)	Coefficient for power where IPOW=2 or 3. The non dimensional definition applies	
13	6	1551	1-12	E12.6	1BLOC	Subchannel where blockage occurs	
13	6	1552	12-24	E12.6	LBLOC	Order number of restriction where blockage occurs (seeLOC(IL) Data 1101 to 1120) LBLOC must correspond to the order number IL of the restriction blocked	
13	6	1553	25-36	E12.6	TIBL	Time for beginning of blockages (sec)	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION REMARKS
13	6	1554	37-48	E12.6	TZBL	Time for completion of blockage (sec)
13	6	1555	49-50	E12.6	FBL1	Local friction factor at completion of blockage
13	6	1556	61-72	E12.6	FBL2	Local friction factor at completion of blockage

PERTURBATION TIME TABLES - Used when the corresponding option is 1. Each table is composed of 50 time values followed by 50 variable values. The first time value must be zero - any number of values may be given. The code will fix the variable at the last value given at times following the last significant time - times are in seconds.

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION REMARKS
14	1 to n	1600 to 1699	1-72	E12.6	PTAB	Pressure timetable pressure values relative to nominal beginning with data 1650.
14	(n+1) to 2n+1	1700 to 1799	1-72	E12.6	QTAB	Mass flow timetable-relative values-same rule
14	2n+2 to 3n+2	1800 to 1899	1-72	E12.6	HTAB	Inlet enthalpy or temperature time table (see data 4) absolute values of perturbation must be given. Units are JOULE/G or C and Btu/lb or F depending on ICON Option (Data 4)

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
14	3n+3 to 4n+3	1900 to 1999	1-72	E12.6	PWTAB	Power time table-relative values-same rules	
15	Following page						
16	Following page						

Last card (see 1.2) 2200: Dummy data may be conveniently employed as the last data set to be kept fixed when modifying a problem at many times.

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION
15	1	2001	1-12	E12-6	MROD	Fuel rod order number where heat transfer coefficient and fuel temperature profile will be calculated.
15	2	2031	1-12	E12-6	JJ1)	First and last axial levels, respectively, for heat transfer coefficient and fuel temperature calculations.
15	2	2032	13-24	E12-6	JJ2)	
15	2	2033	25-36	E12-6	JINC	Increment (code sweeps from JJ1 to JJ2 using increments of JINC axial steps).
15	3	2040	1-12	E12-6	ICISE	Interior subchannel to be used in CISE correlation.
16	1	2051	1-12	E12-6	RC	Clad thickness.
16	1	2052	13-24	E12-6	RG	Fuel-clad gap thickness.
16	1	2053	25-36	E12-6	NF	Number of mesh points in the fuel.
16	1	2054	37-48	E12-6	NC	Number of mesh points in the clad.
16	1	2055	49-60	E12-6	KF	Fuel thermal conductivity.
16	1	2056	61-72	E12-6	KC	Clad thermal conductivity.
16	2	2057	1-12	E12-6	CPF	Fuel specific heat.
16	2	2058	13-24	E12-6	CPC	Clad specific heat.
16	2	2059	25-36	E12-6	RHOF	Fuel density.
16	2	2060	37-48	E12-6	RHOC	Clad density.
16	2	2061	49-60	E12-6	HGAP	Gap conductance.

1.1.3.2 Recommendations for Input Data Selection

1. NCHAN = number of subchannel types in the bundle.

A subchannel is defined by its geometry, and by the types of rods which are associated with it. When inputting NCHAN one has to take advantage of any symmetry in the bundle. For example, a 3 x 3 fuel rod bundle with only one type of heating rod (Fig. 4) will have:

8 side subchannels

4 corner subchannels

4 center subchannels

One can see that this particular bundle has a 45° symmetry, and the analysis can be performed using a configuration of the type shown in Fig. 8. Therefore, for this case NCHAN = 3.

But, for the same example, if the heating rods have different peaking factors (see Fig. 5), the number of subchannel types to be entered is 16.

2. NRODS = number of heating rods

Once one chooses a configuration for the analysis of the fuel rod bundle, one must number all the fuel rods starting from 1 through NRODS.

Consider, for example, the fuel rod bundle shown in Fig. 6. For this case:

NCHAN = 8

NRODS = 6

One has:

16 cards of GROUP 3 or from DATA 11 to DATA 90

16 cards of GROUP 5 or from DATA 401 to DATA 480

3 cards of GROUP 6 or from DATA 601 to DATA 608

621 to DATA 626

The second example illustrates a symmetric (3 x 3) fuel rod bundle, where symmetry of the bundle is to be understood for the peaking factors fo the rods with respect to the following diagonal. (See Fig. 7)

For this case one has:

NCHAN = 10

NRODS = 6

and therefore the following groupings result:

20 cards of GROUP 3 or from DATA 11 to DATA 110

20 cards of GROUP 5 or from DATA 401 to DATA 500

3 cards of GROUP 6 or from DATA 601 to DATA 610

621 to DATA 626

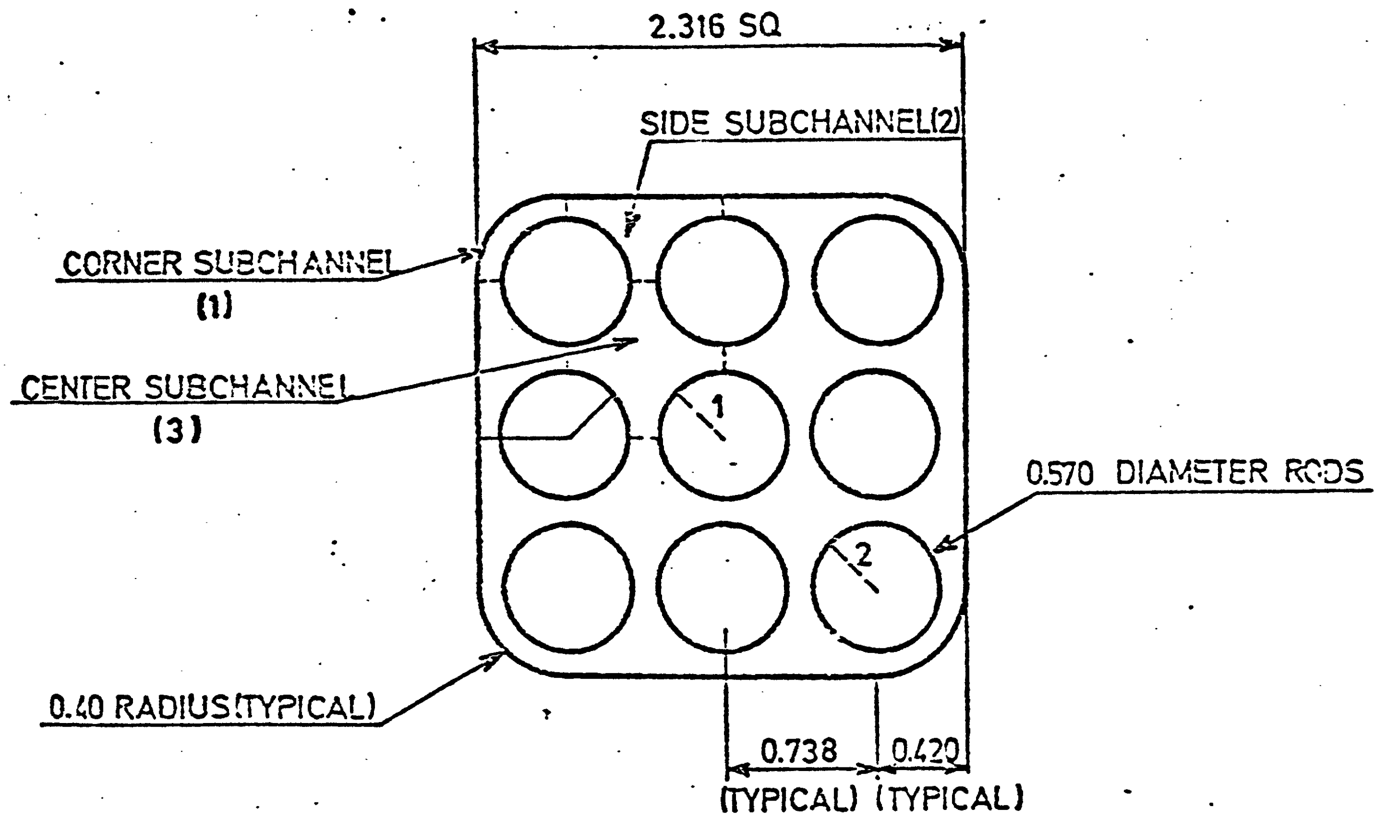

Fig. 4 Nine-Rod Bundle with Uniform Power Distribution

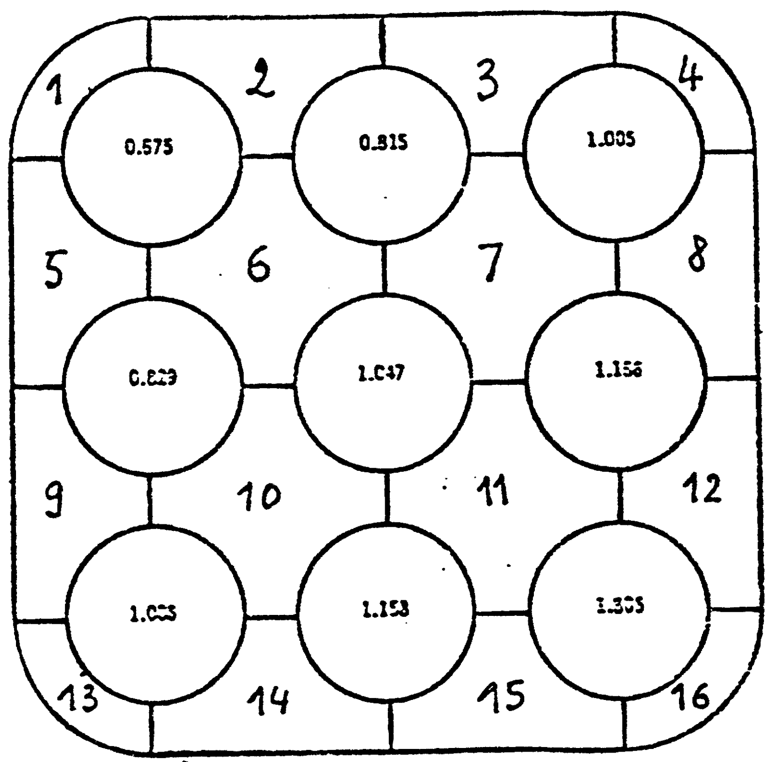

FIG. 5: 9-Rod Bundle with Non-Uniform Power Distribution
(from GE-13049)

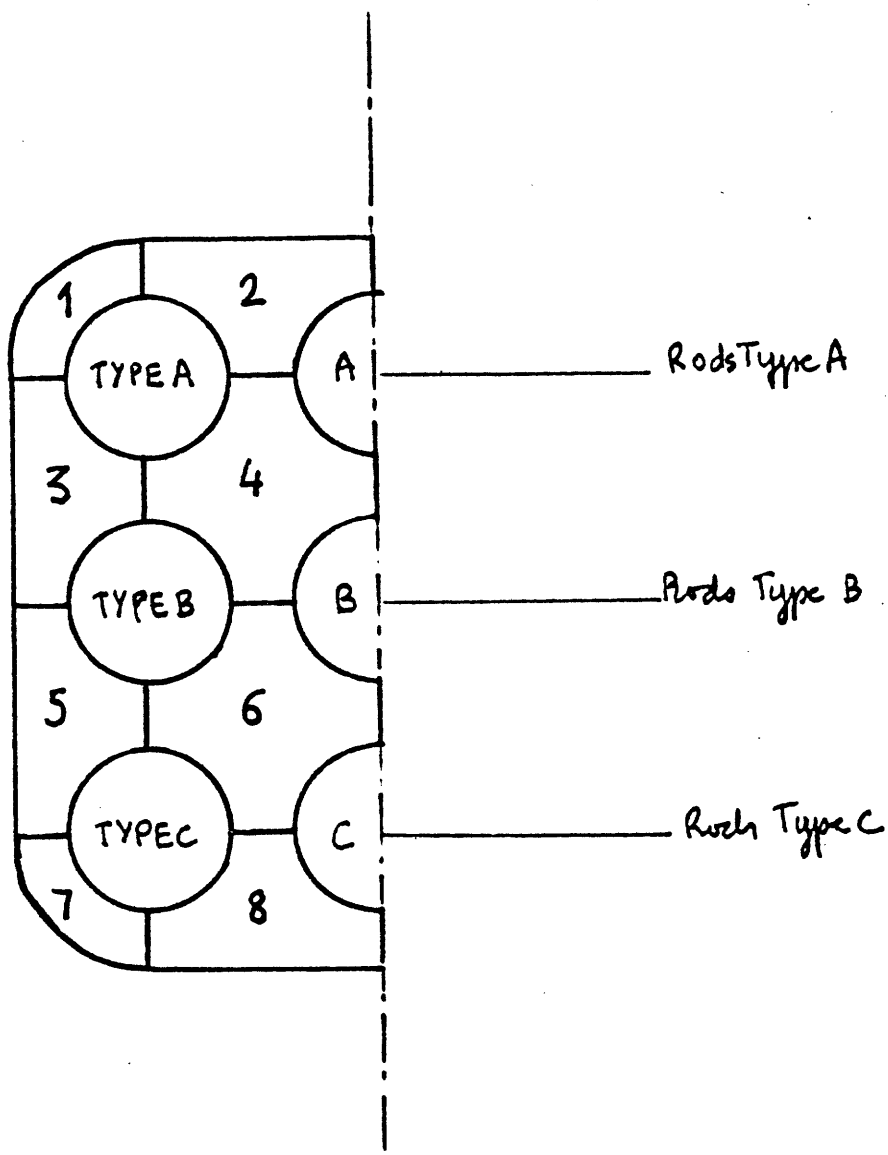

FIG. 6: 8 Subchannel Bundle Case (Symmetric with Respect to the Second Column of Rods)

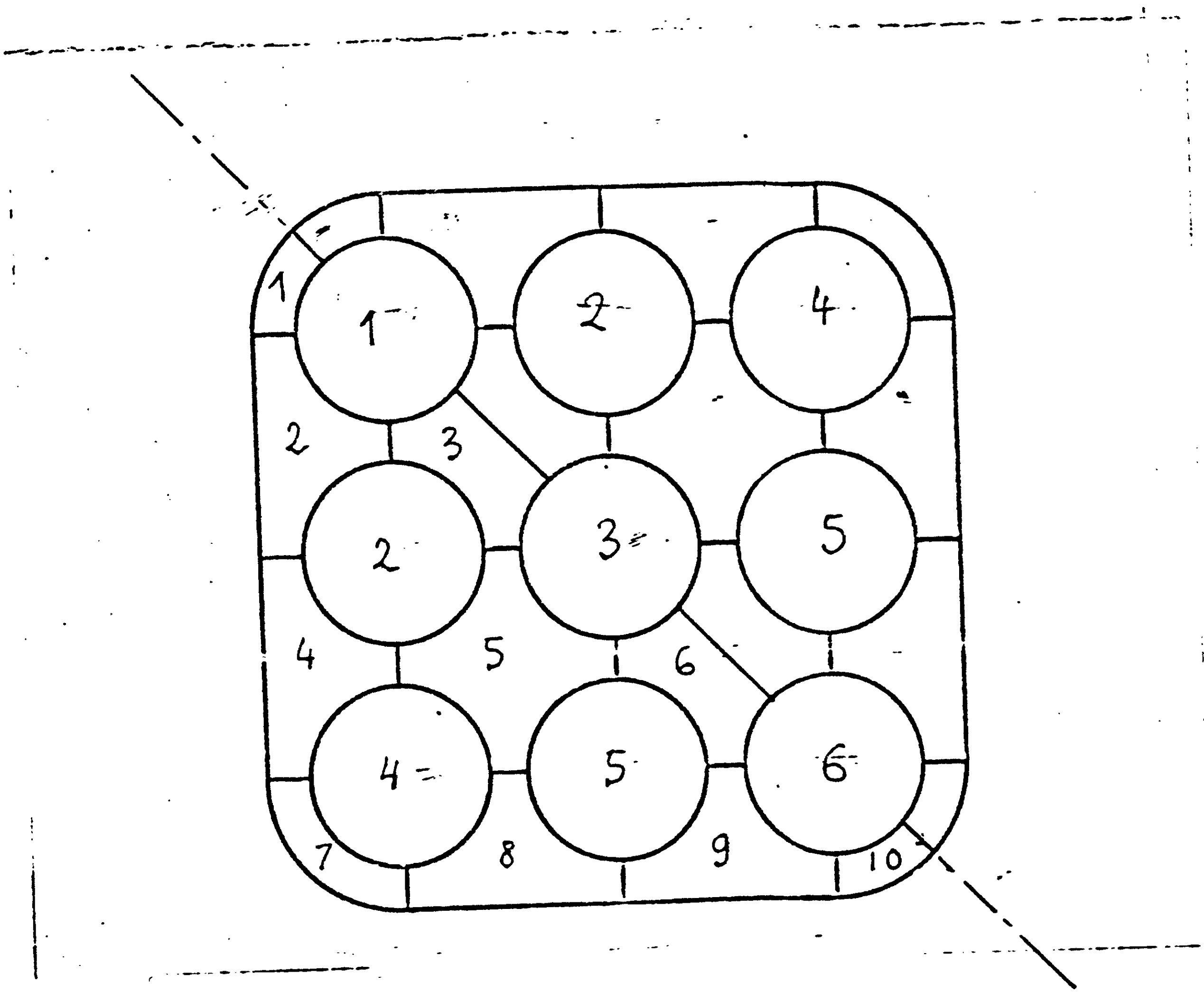

FIG. 7: 10 Subchannel Bundle Case (Symmetric with Respect to the Principal Diagonal)

3. ICON = Key for selecting input system of units. See Section 1.2 for a complete discussion of the procedures used by the code in both cases of unit systems.

4. IPAR = Key for selecting sets of parameters Refer to Section 1.3.2.

5,6. Figure 8 will be used to describe the input data #11 to #20.

Subchannel 1 = (Corner subchannel) is

1) heated by rod 1

2) has subchannel 2 as neighbor

3) heated by (1/8) (fraction) of rod 1

4) shares a gap of width A with sub. 2.

Therefore, the input for subchannel 1 are:

JOIN(1) = 1

NAROD(1) = 1

NJOIN (1,1) = 2   NJOIN (1,2) = 0   NJOIN (1,3) = 0

NJOIN (1,4) = 0

KROD (1,1) = 1   KROD (2,1) = 0   KROD (3,1) = 0

KROD (4,1) = 0

Subchannel 2 = side subchannel is

1) heated by rods 1 and 2

2) has subchannels 1 and 3 as neighbors

3) heated by (¼) of rod 1 and (¼) of rod 2

4) shares a gap of width A with sub 1 and a gap of width B with sub 3.

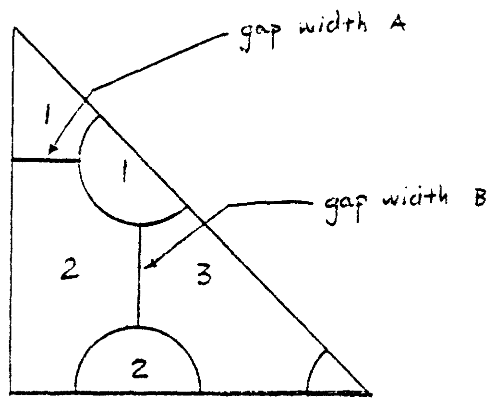

Fig. 8: Simple subchannel layout to describe input data #11 through #20

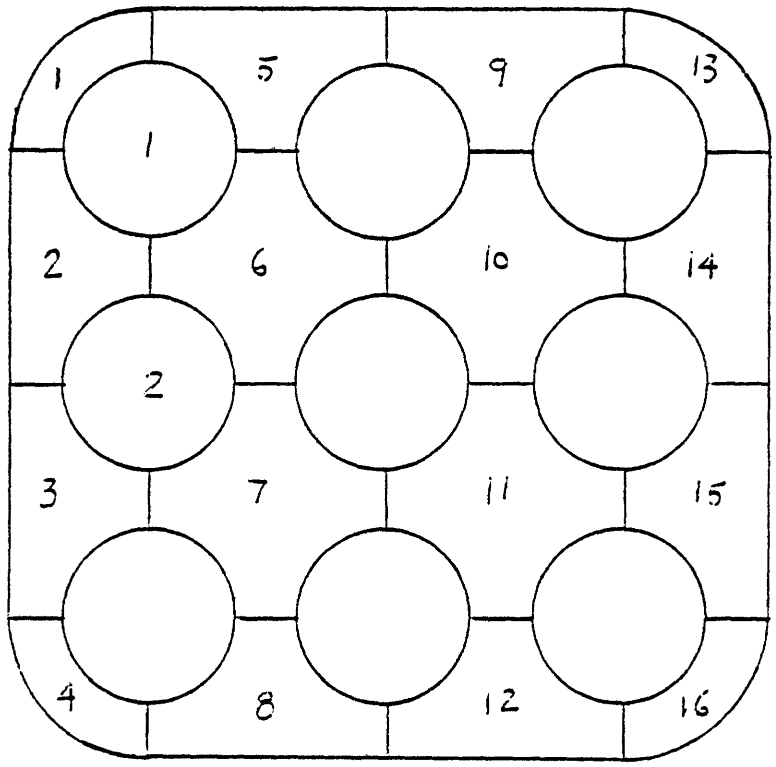

Fig. 9: Sample subchannel numbering scheme used for the explanation of the concept of recirculation loop

Loop 1 around rod 1: 01050602

Loop 2 around rod 2: 02060703

Therefore, the input data for subchannel 2 are:

JOIN (2) = 2

NAROD (2) = 2

NJOIN (2,1) = 1   NJOIN (2,2) = 3   NJOIN (2,3) = 0   NJOIN (2,4) = 0

KROD (1,2) = 1   KROD (2,2) = 2   KROD (3,2) = 0   KROD (4,2) = 0

Subchannel 3 = ½ center subchannel is:

1) heated by rods 1,2 and 3

2) has subchannels 2 as neighbor

3) heated by (1/8) of rod 1, (¼) of rod 2, and (1/8) of rod 3

4) shares a gap of width B with sub 2.

Therefore, the input data for subchannel 3 are:

JOIN (3) = 1

NAROD (3) = 3

NJOIN (3,1) = 2   NJOIN (3,2) = 0   NJOIN (3,3) = 0   NJOIN (3,4) = 0

KROD (1,3) = 1   KROD (2,3) = 2   KROD (3,3) = 3   KROD (4,3) = 0

Now for the data 401 to 410 and similar for GROUP 5.

HPER (1,1) = .125   HPER (2,1) = 0   IHER (3,1) = 0

HPER (4,1) = 0

SL (1,1) = A   SL (2,1) = 0   SL(3,1) = 0   SL (4,1) = 0

HPER (1,2) = .25   HPER (2,2) = .25   HPER (3,2) = 0

HPER (4,2) = 0

SL (1,2) = A   SL (2,2) = B   SL (3,2) = 0   SL (4,L) = 0

HPER (1,3) = .125   HPER (2,3) = .25   HPER (3,3) = .125

HPER (4,3) = 0

SL (1,3) = B   SL (2,3) = 0   SL (3,3) = 0   SL (4,3) = 0

7, 8 NOCIR and MCIRC(K) Recirculation loop specifications

WOSUB-I used the concept of the recirculation loop in fuel rod bundles. This concept requires that the net recirculation volume flow around each rod is zero. The way of entering such input data is explained for the case of a (3 x 3) fuel rod bundle shown in Fig. 9.

9 rods imply 9 recirculation loops: therefore, for this example NOCIR = 9.

Choosing the clockwise rotation as ordering scheme around each rod, the recirculation loops are specified as follows:

First loop:	01050602
2nd loop:	02060703
3rd loop:	03070804
4th loop	05091006
5th loop	06101107
6th loop:	07111208
7th loop:	09131410
8th loop:	10141511
9th loop:	11151612

Note that each subchannel is specified by two digits: i.e., subchannel 1 is 01.

9, 10 CHANN (I) and RODN (L)

For the case of 8 subchannels as shown in Fig. 6, these input data read if entered by the first option:

CHANN (1) = DATA (601) = 2

CHANN (8) = DATA (608) = 2

RODN (1) = DATA (626) = 3

RODN (3) = DATA (623) = 3

On the other hand if the problem is entered the second way one gets:

CHANN (1) = DATA (601) = 2

CHANN (8) = DATA (608) = 2

RODN 91) = 2 = DATA (621)

RODN (2) = 1 = DATA (622)

RODN (3) = 2 = DATA (623)

RODN (4) = 1 = DATA (624)

RODN (5) = 2 = DATA (625)

RODN (6) = 1 = DATA (626)

1.1.3.3 <u>Error Messages</u>

If for any reason the input data are incorrect, the code will automatically print out one or two error messages generated in subroutine GEOMRY. Parts of this subroutine are solely devoted to assess the validity of the inputted date, especially of the types contained in GROUPS 3, 5, and 6. Obvious input errors will be detected by the checks built into GEOMRY.

1.1.3.4 Sample Input

Fig. 10 shows the sample case layout. The dimensions are given in inches. Other data of importance are:

Pressure

Total bundle power

Power distribution

Rod 1

Rod 2

Rod 3

Rod 4

Inlet enthalpy

Inlet mass flow

Total height of the bundle

Table 1 is a card image of WOSUB-I input for the sample case.

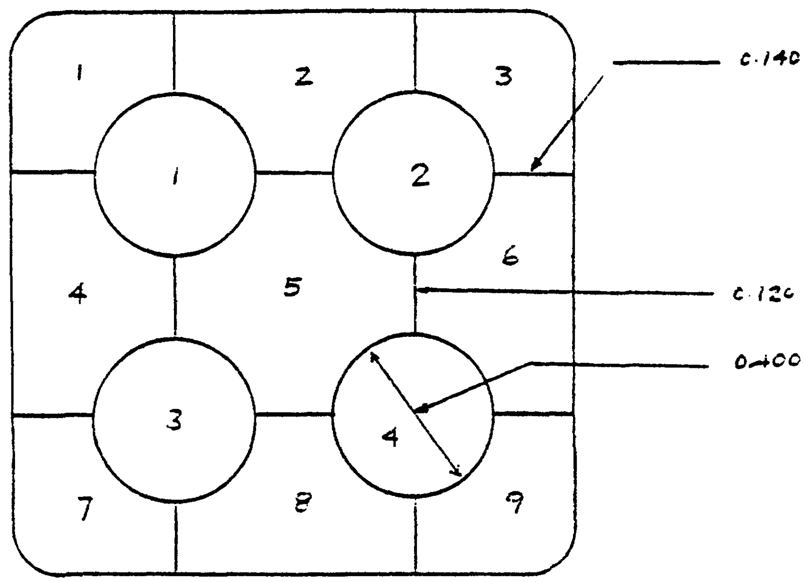

Fig. 10: Sample Case Layout

```
       1 ***** SAMPLE PROBLEM *****
                1                10
3.             4.              25.          1.                          1.
                                1.
               11                20
2.             1.              2.           4.
1.
               21                30
3.             2.              1.           3.           5.
1.             2.
               31                40
2.             1.              2.           6.
2.
               41                50
3.             2.              1.           5.           7.
1.             3.
               51                60
4.             4.              2.           4.           6.           8.
1.             2.              3.           4.
               61                70
3.             2.              3.           5.           9.
2.             4.
               71                80
2.             1.              4.           8.
3.
               81                90
3.             2.              5.           7.           9.
3.             4.
               91               100
2.             1.              6.           8.
4.
              300               304
4.             01020504.       02030605.    04050807.    05060908.
              401               410
.0642          .3397           .25
.140           .140
              411               420
.1140          .397            .25          .25
.140           .140            .120
              421               430
.0642          .3387           .25
.140           .140
              431               440
.1140          .397            .25          .25
.140           .120            .140
              441               450
.1446          .4507           .25          .25          .25          .25
.120           .120            .120         .120
              451               460
.1140          .397            .25          .25
.140           .120            .140
              461               470
.0642          .3397           .25
.140           .140
              471               480
.1140          .397            .25          .25
.120           .140            .140
              481               490
.0642          .3387           .25
.140           .140
              601               609
```

Table 1 Card Image of WOSUB-I Input for Sample Problem

1.		1.		1.	1.	1.	1.
1.		1.		1.			
	621		624				
1.		1.		1.	1.		
	1001		1007				
1000.		500.		.01	.4	120000.	
5.							
	1011		1014				
1.2		1.4		0.6	0.8		
	1500		1503				
	2001		2001				
2.							
	2031		2033				
25.		25.		1.			
	2040		2040				
5.							
	2051		2061				
.024		.002		2.	2.	1.5	9.5
.03		.071		684.	409.	1000.	
-1	2200		2200				

Table 1 (Continued)

1.2 Output Description

The printout of the input data and the results are organized by a hierarchy of three levels.

1. After having read the input data as shown in Section 1.1.3.4, the routine MAIN prints out a map of these data as shown in Table 2.

2. The subroutine DISPLAY prints out the number of subchannel types, the number of rod types, the subchannel layout, the number and recirculation loops, the rod peak factors, the subchannel geometry, the options chosen for the calculation,the transient specifications, the physical parameters for steady state, the coolant properties, the heating rod diameter, and the node height. (See print out for the same example as above depicted by Table 3.

   Note that an explanation for the unit system used for the printed out by the code, is given in Section 1.3.2.1.

3. During and after the calculation, the results are printed by the subroutines EDIT and EDIT2. Samples of such printouts are given again for the same example as above in Table 4.

The next section explains the notations and abbreviations used in the output.

1.2.1 List of Some Important Notations Used in the Output of the Code

GTOT	Total mass flow into the bundle
FMOUT	Total mass flow out of the bundle
TBAL	Total energy output of the bundle (enthalpy out--enthalpy in)
AVX	Average exit quality
DPTOT	Total pressure drop
TOAVVF	Average void fraction of the whole bundle
AVDEN	Average density
HINLET	Inlet enthalpy
XOUT	Subchannel exit quality
GOUT	Exit mass flow
GOUTV	Exit vapor mass flux
GOUTL	Exit liquid mass flux
GINLET	Inlet mass flux
BAL	Energy balance for each subchannel (enthalpy out--enthalpy in) (Watts)
ENI	Energy input (Watts)
VFAV	Average void fraction
HL	Liquid enthalpy
TQ	True quality
G	Mass flux
QTR	Volumetric crossflow into the subchannel per node
ALPHA	Local void fraction
FIMAX	Maximum heat flux
X	Thermodynamic equilibrium quality

PDROP	Pressure drop across one node
ITER	Number of iterations to achieve convergence
AVG HTC	Average heat transfer coefficient
AVG TW	Average clad surface temperature
AVG TF	Average coolant temperature
R	Radical position in the fuel
T	Fuel temperature
DT/DR	Fuel temperature gradient
HF	Heat flux in the fuel

1.2.2 Sample Output

WOSUB PROGRAM FOR SUBCHANNEL ANALYSIS OF BWR

SWEDISH EXP;870 KW,50 STEPS,NO VAPOR DIFFUSION************

1	0.800000E+01	2	0.600000E+01	3	0.500000E+02	4	-0.100000E+01	5	0.0	6	0.0
7	0.0	8	0.0	9	0.0	10	0.0				
11	0.200000E+01	12	0.100000E+01	13	0.200000E+01	14	0.300000E+01	15	0.0	16	0.0
17	0.100000E+01	18	0.0	19	0.0	20	0.0				
21	0.200000E+01	22	0.200000E+01	23	0.100000E+01	24	0.400000E+01	25	0.0	26	0.0
27	0.100000E+01	28	0.200000E+01	29	0.0	30	0.0				
31	0.300000E+01	32	0.200000E+01	33	0.100000E+01	34	0.400000E+01	35	0.500000E+01	36	0.0
37	0.100000E+01	38	0.300000E+01	39	0.0	40	0.0				
41	0.300000E+01	42	0.400000E+01	43	0.200000E+01	44	0.300000E+01	45	0.600000E+01	46	0.0
47	0.100000E+01	48	0.200000E+01	49	0.300000E+01	50	0.400000E+01				
51	0.300000E+01	52	0.200000E+01	53	0.300000E+01	54	0.600000E+01	55	0.700000E+01	56	0.0
57	0.300000E+01	58	0.500000E+01	59	0.0	60	0.0				
61	0.300000E+01	62	0.400000E+01	63	0.400000E+01	64	0.500000E+01	65	0.800000E+01	66	0.0
67	0.300000E+01	68	0.400000E+01	69	0.500000E+01	70	0.600000E+01				
71	0.200000E+01	72	0.100000E+01	73	0.500000E+01	74	0.800000E+01	75	0.0	76	0.0
77	0.500000E+01	78	0.0	79	0.0	80	0.0				
81	0.200000E+01	82	0.200000E+01	83	0.600000E+01	84	0.700000E+01	85	0.0	86	0.0
87	0.500000E+01	88	0.600000E+01	89	0.0	90	0.0				
300	0.300000E+01										
301	0.102040E+07	302	0.304061E+07	303	0.506081E+07						
401	0.617310E+00	402	0.823200E+00	403	0.250000E+00	404	0.0	405	0.0	406	0.0
407	0.352500E+00	408	0.352500E+00	409	0.0	410	0.0				
411	0.983600E+00	412	0.110725E+01	413	0.250000E+00	414	0.250000E+00	415	0.0	416	0.0
417	0.352500E+00	418	0.405000E+00	419	0.0	420	0.0				
421	0.993600E+00	422	0.110703E+01	423	0.250000E+00	424	0.250000E+00	425	0.0	426	0.0
427	0.352500E+00	428	0.405000E+00	429	0.352500E+00	430	0.0				
431	0.147831E+01	432	0.153650E+01	433	0.250000E+00	434	0.250000E+00	435	0.250000E+00	436	0.250000E+00
437	0.405000E+00	438	0.405000E+00	439	0.405000E+00	440	0.0				
441	0.983600E+00	442	0.110703E+01	443	0.250000E+00	444	0.250000E+00	445	0.0	446	0.0
447	0.352500E+00	448	0.405000E+00	449	0.352500E+00	450	0.0				
451	0.147831E+01	452	0.153650E+01	453	0.250000E+00	454	0.250000E+00	455	0.250000E+00	456	0.250000E+00
457	0.405000E+00	458	0.405000E+00	459	0.405000E+00	460	0.0				
461	0.617310E+00	462	0.823000E+00	463	0.250000E+00	464	0.0	465	0.0	466	0.0
467	0.352500E+00	468	0.352500E+00	469	0.0	470	0.0				
471	0.983600E+00	472	0.110703E+01	473	0.250000E+00	474	0.250000E+00	475	0.0	476	0.0
477	0.405000E+00	478	0.352500E+00	479	0.0	480	0.0				
601	0.200000E+01	602	0.200000E+01	603	0.200000E+01	604	0.200000E+01	605	0.200000E+01	606	0.200000E+01
607	0.200000E+01	608	0.200000E+01								
621	0.200000E+01	622	0.100000E+01	623	0.200000E+01	624	0.100000E+01	625	0.200000E+01	626	0.100000E+01
1001	0.700000E+02	1002	0.100000E+02	1003	0.162500E+01	1004	0.122500E+01	1005	0.870000E+06	1006	0.0
1007	0.150000E+03										
1011	0.0	1012	0.0	1013	0.900000E+00	1014	0.900000E+00	1015	0.210000E+01	1016	0.210000E+01
2000	0.0										

** DEBUG #1 IN MATSET***********

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

TABLE 2 Map of Input Data

INPUT DISPLAY

NCHAN-NUMBER OF SUBCHANNELS TYPES 8
NRODS-NUMBER OF HEATING RODS TYPES 6

SUBCHANNELS LAYOUT

CHAN	CHANN	JOIN.CHANN.				JOIN.RODS			
1	2.00	2	3	0	0	1	0	0	0
2	2.00	1	4	0	0	1	2	0	0
3	2.00	1	4	5	0	1	3	0	0
4	2.00	2	3	6	0	1	2	3	4
5	2.00	3	6	7	0	3	5	0	0
6	2.00	4	5	8	0	3	4	5	6
7	2.00	5	8	0	0	5	0	0	0
8	2.00	6	7	0	0	5	6	0	0

NOCIR-NUMBER OF RECIRCULATION PATHS 3
RECIRCULATIONS 1020403 3040605 5060807

ROD PEAK FACTORS

ROD 1 PEAKF 0.0 ROD 2 PEAKF 0.0 ROD 3 PEAKF 0.9000 ROD 4 PEAKF 0.9000
ROD 5 PEAKF 2.1000 ROD 6 PEAKF 2.1000 ROD

SUBCHANNELS GEOMETRY

CHAN	HD	A	GAP WIDTHS			
1	0.87723E+00	0.61731E+00	0.35250E+00	0.35250E+00	0.0	0.0
2	0.11244E+01	0.98360E+00	0.35250E+00	0.40500E+00	0.0	0.0
3	0.11229E+01	0.98360E+00	0.35250E+00	0.40500E+00	0.35250E+00	0.0
4	0.14679E+01	0.14783E+01	0.40500E+00	0.40500E+00	0.40500E+00	0.0
5	0.11229E+01	0.98360E+00	0.35250E+00	0.40500E+00	0.35250E+00	0.0
6	0.14678E+01	0.14783E+01	0.40500E+00	0.40500E+00	0.40500E+00	0.0
7	0.87704E+00	0.61731E+00	0.35250E+00	0.35250E+00	0.0	0.0
8	0.11241E+01	0.98360E+00	0.40500E+00	0.35250E+00	0.0	0.0

OPTIONS

FLAT AXIAL POWER DISTRIBUTION

DECIMAL SYSTEM FOR INPUT OUTPUT

HYDRAULIC DIAMETERS RENORMALIZED

NO VAPOUR MIXING EFFECT

UPWARDS FLOW

TRANSIENT SPECIFICATIONS
0=CONSTANT 1=TABULATED 2=SINUSOIDAL 3=POLYNOMIAL
PRESSURE -1 MASS FLOW -1 INLET ENTHALPY -1 POWER -1

TABLE 3 Input Display

```
LIQUID DENSITY   0.73970  TSAT   285.800  HSAT   1262.55  LAT.HEAT  1509.554
VAPOUR DENS. 0.36640E-01  GAMMA 0.0495338  VISC0.9323E-03  TH.COND.0.5652E-02  SURF.TENS.0.1868E+02

 HEATING RODS DIAMETER  1.225CCM
NCDE HEIGTH DZ      3.000CM  TIME STEP DT**********SEC

                  LOCAL RESTRICTIONS
NCDE        LOCAL LOSS COEFF.IN SUBCHANNELS
NCNF
```

TABLE 3 (Continued)

STEADY STATE RESULTS ; SW-870 (NO VAPOR)

TIME= 0.0 SEC PRESSURE 70.000 TSAT 285.80 GAV 0.9999E+02

POWER WATT	GTOT KG/SEC	FMOUT KG/SEC	TBAL WATT	AVX	DPTOT BAR	TOAVVP	AVDEN G/CU-CM	HINLET JOULE/G
0.87000E+06	0.16250E+01	0.16250E+01	0.86999E+06	0.31979E+00	0.14670E+00	0.45953E+00	0.41662E+00	-0.52640E+02

CHAN	XOUT	GOUT	GOUTV	GOUTL	GINLET	BAL	ENI	VPAV
1	-0.70936E-02	0.15054E+03	0.23452E+00	0.15030E+03	0.11928E+03	0.28810E+04	0.0	0.11179E-01
2	-0.12646E-01	0.17207E+03	0.16081E+00	0.17191E+03	0.14135E+03	0.40877E+04	0.0	0.73767E-02
3	0.11521E+00	0.11567E+03	0.13331E+02	0.10233E+03	0.11321E+03	0.25647E+05	0.0	0.32002E+00
4	0.15035E+00	0.12235E+03	0.18396E+02	0.10396E+03	0.12048E+03	0.50426E+05	0.43500E+05	0.37414E+00
5	0.62653E+00	0.72519E+02	0.45434E+02	0.27084E+02	0.81071E+02	0.71659E+05	0.0	0.65893E+00
6	0.95104E+00	0.58715E+02	0.55840E+02	0.28746E+01	0.77850E+02	0.13067E+06	0.43500E+05	0.71281E+00
7	0.90282E+00	0.66962E+02	0.53758E+02	0.13204E+02	0.72654E+02	0.52456E+05	0.0	0.69632E+00
8	0.11014E+01	0.57142E+02	0.62937E+02	-0.57948E+01	0.71882E+02	0.97171E+05	0.0	0.73221E+00

TABLE 4

Printout of Results

SUBCH 2 TIME 0.0

NODE	HL JOULE/GR	TQ	G GP/SQ-CM S	CTR CU-CM/SEC	ALPHA	FIMAX WATT/SQ-CM	X	PDROP BAR	ITER
1	-0.52640E+02	0.0	0.14135E+03	0.0	0.0	0.0	-0.34871E-01	0.27307E-02	4
2	-0.52608E+02	0.0	0.14103E+03	-0.41749E+00	0.0	0.0	-0.34850E-01	0.26668E-02	6
3	-0.52529E+02	0.0	0.14119E+03	0.20577E+00	0.0	0.0	-0.34798E-01	0.27625E-02	7
4	-0.52352E+02	0.97603E-06	0.14205E+03	0.11475E+01	0.15085E-04	0.0	-0.34679E-01	0.29200E-02	8
5	-0.52097E+02	0.23190E-05	0.14304E+03	0.13288E+01	0.35870E-04	0.0	-0.34509E-01	0.29539E-02	6
6	-0.51823E+02	0.30130E-05	0.14372E+03	0.91677E+00	0.46631E-04	0.0	-0.34327E-01	0.28943E-02	9
7	-0.51535E+02	0.31150E-05	0.14414E+03	0.56632E+00	0.48228E-04	0.0	-0.34136E-01	0.28408E-02	5
8	-0.51231E+02	0.27334E-05	0.14437E+03	0.30489E+00	0.42328E-04	0.0	-0.33935E-01	0.28012E-02	4
9	-0.50907E+02	0.22056E-05	0.14449E+03	0.17113E+00	0.34159E-04	0.0	-0.33721E-01	0.27801E-02	5
10	-0.50552E+02	0.20037E-05	0.14459E+03	0.12724E+00	0.31034E-04	0.0	-0.33486E-01	0.27725E-02	10
11	-0.50159E+02	0.26729E-05	0.14469E+03	0.14601E+00	0.41403E-04	0.0	-0.33225E-01	0.27751E-02	7
12	-0.49722E+02	0.50685E-05	0.14484E+03	0.22141E+00	0.78516E-04	0.0	-0.32933E-01	0.27847E-02	5
13	-0.49237E+02	0.99484E-05	0.14506E+03	0.32584E+00	0.15413E-03	0.0	-0.32607E-01	0.28002E-02	4
14	-0.48702E+02	0.18613E-04	0.14536E+03	0.46943E+00	0.28839E-03	0.0	-0.32243E-01	0.28189E-02	4
15	-0.48118E+02	0.32399E-04	0.14575E+03	0.63662E+00	0.50204E-03	0.0	-0.31842E-01	0.28397E-02	6
16	-0.47484E+02	0.53257E-04	0.14624E+03	0.83345E+00	0.82529E-03	0.0	-0.31401E-01	0.28608E-02	9
17	-0.46810E+02	0.76688E-04	0.14680E+03	0.99052E+00	0.11885E-02	0.0	-0.30930E-01	0.28812E-02	8
18	-0.46092E+02	0.10316E-03	0.14745E+03	0.11632E+01	0.15988E-02	0.0	-0.30432E-01	0.29007E-02	5
19	-0.45355E+02	0.13287E-03	0.14818E+03	0.13290E+01	0.20595E-02	0.0	-0.29909E-01	0.29182E-02	5
20	-0.44583E+02	0.16568E-03	0.14897E+03	0.14872E+01	0.25683E-02	0.0	-0.29364E-01	0.29341E-02	5
21	-0.43792E+02	0.20000E-03	0.14980E+03	0.16119E+01	0.31004E-02	0.0	-0.28904E-01	0.29481E-02	13
22	-0.42982E+02	0.23600E-03	0.15067E+03	0.17297E+01	0.36588E-02	0.0	-0.28231E-01	0.29605E-02	9
23	-0.42156E+02	0.27510E-03	0.15158E+03	0.18541E+01	0.42652E-02	0.0	-0.27643E-01	0.29716E-02	6
24	-0.41316E+02	0.31542E-03	0.15251E+03	0.19467E+01	0.48903E-02	0.0	-0.27045E-01	0.29815E-02	8
25	-0.40462E+02	0.35893E-03	0.15346E+03	0.20599E+01	0.55649E-02	0.0	-0.26435E-01	0.29904E-02	14
26	-0.39597E+02	0.40352E-03	0.15443E+03	0.21481E+01	0.62560E-02	0.0	-0.25817E-01	0.29982E-02	16
27	-0.38719E+02	0.45174E-03	0.15542E+03	0.22522E+01	0.70030E-02	0.0	-0.25186E-01	0.30050E-02	19
28	-0.37837E+02	0.49866E-03	0.15640E+03	0.23024E+01	0.77294E-02	0.0	-0.24554E-01	0.30110E-02	11
29	-0.36946E+02	0.54715E-03	0.15739E+03	0.23887E+01	0.85112E-02	0.0	-0.23912E-01	0.30163E-02	14
30	-0.36051E+02	0.60003E-03	0.15838E+03	0.24436E+01	0.92982E-02	0.0	-0.23267E-01	0.30205E-02	13
31	-0.35151E+02	0.65196E-03	0.15936E+03	0.25025E+01	0.10101E-01	0.0	-0.22619E-01	0.30246E-02	13
32	-0.34252E+02	0.70285E-03	0.16033E+03	0.25298E+01	0.10897E-01	0.0	-0.21972E-01	0.30273E-02	13
33	-0.33356E+02	0.75215E-03	0.16128E+03	0.25527E+01	0.11649E-01	0.0	-0.21328E-01	0.30296E-02	14
34	-0.32465E+02	0.80074E-03	0.16221E+03	0.25606E+01	0.12399E-01	0.0	-0.20688E-01	0.30308E-02	16
35	-0.31578E+02	0.84982E-03	0.16313E+03	0.25832E+01	0.13156E-01	0.0	-0.20051E-01	0.30316E-02	15
36	-0.30701E+02	0.89484E-03	0.16402E+03	0.25484E+01	0.13851E-01	0.0	-0.19424E-01	0.30314E-02	20
37	-0.29834E+02	0.93842E-03	0.16488E+03	0.25336E+01	0.14523E-01	0.0	-0.18806E-01	0.30306E-02	12
38	-0.28973E+02	0.99508E-03	0.16554E+03	0.23613E+01	0.15391E-01	0.0	-0.18179E-01	0.30266E-02	20
39	-0.28128E+02	0.10281E-02	0.16634E+03	0.24543E+01	0.15901E-01	0.0	-0.17596E-01	0.30261E-02	16
40	-0.27302E+02	0.10559E-02	0.16711E+03	0.23062E+01	0.16332E-01	0.0	-0.17011E-01	0.30235E-02	11
41	-0.26500E+02	0.10773E-02	0.16782E+03	0.22695E+01	0.16663E-01	0.0	-0.16458E-01	0.30195E-02	15
42	-0.25719E+02	0.10943E-02	0.16851E+03	0.21942E+01	0.16929E-01	0.0	-0.15925E-01	0.30154E-02	16
43	-0.24965E+02	0.11044E-02	0.16913E+03	0.20656E+01	0.17089E-01	0.0	-0.15415E-01	0.30103E-02	19
44	-0.24237E+02	0.11079E-02	0.16972E+03	0.19538E+01	0.17146E-01	0.0	-0.14930E-01	0.30048E-02	20
45	-0.23536E+02	0.11077E-02	0.17026E+03	0.18398E+01	0.17152E-01	0.0	-0.14466E-01	0.29987E-02	12
46	-0.22862E+02	0.11000E-02	0.17075E+03	0.16996E+01	0.17039E-01	0.0	-0.14028E-01	0.29913E-02	16
47	-0.22222E+02	0.10762E-02	0.17119E+03	0.14931E+01	0.16681E-01	0.0	-0.13629E-01	0.29796E-02	15
48	-0.21618E+02	0.10394E-02	0.17154E+03	0.12679E+01	0.16124E-01	0.0	-0.13267E-01	0.29675E-02	9
49	-0.21050E+02	0.99521E-03	0.17183E+03	0.10860E+01	0.15453E-01	0.0	-0.12935E-01	0.29526E-02	13
50	-0.20519E+02	0.93457E-03	0.17207E+03	0.87583E+00	0.14529E-01	0.0	-0.12646E-01	0.29386E-02	20

TABLE 4. (Contd.)

STEADY STATE RESULTS

TIME= 0.0 SEC PRESSURE 1000.000 TSAT 544.54 GAV 0.1536E+01

POWER	GTOT	FMOUT	TBAL	AVX	DPTOT	TOAVVF	AVDEN	HINLET
WATT	MLB/HR	MLB/HR	WATT		PSI		LB/CU-FT	BTU/LB
0.12000E+06	0.10000E-01	0.99998E-02	0.12000E+06	0.50684E-03	0.26953E+01	0.30169E-01	0.44933E+02	-0.40662E+02

CHAN	XOUT	GOUT	GOUTV	GOUTL	GINLET	BAL	ENI	VFAV
1	0.83411E-03	0.14801E+01	0.89697E-02	0.14712E+01	0.14377E+01	0.10145E+05	0.90000E+04	0.24940E-01
2	0.14015E-01	0.14390E+01	0.21843E-01	0.14172E+01	0.15123E+01	0.17306E+05	0.19500E+05	0.56786E-01
3	0.72496E-02	0.14239E+01	0.13754E-01	0.14102E+01	0.14229E+01	0.11059E+05	0.90000E+04	0.37283E-01
4	-0.32157E-02	0.16044E+01	0.73110E-02	0.15971E+01	0.15611E+01	0.13931E+05	0.19500E+05	0.19105E-01
5	0.14838E-01	0.15295E+01	0.24981E-01	0.15045E+01	0.16682E+01	0.24299E+05	0.30000E+05	0.59072E-01
6	0.50401E-02	0.15320E+01	0.13362E-01	0.15187E+01	0.15477E+01	0.15755E+05	0.19500E+05	0.34687E-01
7	-0.18418E-01	0.15764E+01	0.11560E-02	0.15753E+01	0.14863E+01	0.70997E+04	0.90000E+04	0.29614E-02
8	-0.11026E-01	0.16555E+01	0.35855E-02	0.16520E+01	0.15981E+01	0.12298E+05	0.19500E+05	0.82494E-02
9	-0.12136E-01	0.15566E+01	0.27275E-02	0.15539E+01	0.14684E+01	0.31095E+04	0.90000E+04	0.83555E-02

Table 5: Sample Output

SUBCH 1 TIME 0.0

NODE	HL BTU/LB	TQ	G MLB/SQ-FT H	QTR CU-FT/HR	ALPHA	FIMAX BTU/SQ-FT HR	X	PDROP PSI	ITER
1	-0.39336E+02	0.19729E-03	0.14377E+01	0.0	0.32014E-02	0.23482E+00	-0.60024E-01	0.10502E+00	3
2	-0.37894E+02	0.28598E-03	0.14383E+01	0.75466E-02	0.46333E-02	0.23482E+00	-0.57723E-01	0.10409E+00	2
3	-0.36392E+02	0.33766E-03	0.14391E+01	0.93987E-02	0.54659E-02	0.23482E+00	-0.55369E-01	0.10378E+00	2
4	-0.34854E+02	0.37818E-03	0.14400E+01	0.11334E-01	0.61179E-02	0.23482E+00	-0.52971E-01	0.10380E+00	2
5	-0.33290E+02	0.41729E-03	0.14408E+01	0.99997E-02	0.67462E-02	0.23482E+00	-0.50536E-01	0.10379E+00	2
6	-0.31708E+02	0.45890E-03	0.14419E+01	0.13566E-01	0.74140E-02	0.23482E+00	-0.48071E-01	0.10403E+00	2
7	-0.30111E+02	0.50509E-03	0.14427E+01	0.11384E-01	0.81541E-02	0.23482E+00	-0.45579E-01	0.10406E+00	2
8	-0.28505E+02	0.55722E-03	0.14436E+01	0.10575E-01	0.89880E-02	0.23482E+00	-0.43067E-01	0.10416E+00	2
9	-0.26892E+02	0.61647E-03	0.14443E+01	0.10774E-01	0.99337E-02	0.23482E+00	-0.40536E-01	0.10430E+00	2
10	-0.25274E+02	0.68419E-03	0.14452E+01	0.11402E-01	0.11013E-01	0.23482E+00	-0.37991E-01	0.10447E+00	2
11	-0.23655E+02	0.76191E-03	0.14462E+01	0.15174E-01	0.12248E-01	0.23482E+00	-0.35433E-01	0.10481E+00	2
12	-0.22040E+02	0.85145E-03	0.14477E+01	0.20368E-01	0.13667E-01	0.23482E+00	-0.32868E-01	0.10523E+00	2
13	-0.20430E+02	0.95590E-03	0.14491E+01	0.20960E-01	0.15317E-01	0.23482E+00	-0.30298E-01	0.10550E+00	2
14	-0.18829E+02	0.10777E-02	0.14507E+01	0.25691E-01	0.17233E-01	0.23482E+00	-0.27723E-01	0.10597E+00	2
15	-0.17240E+02	0.12206E-02	0.14525E+01	0.29078E-01	0.19472E-01	0.23482E+00	-0.25146E-01	0.10642E+00	2
16	-0.15666E+02	0.13893E-02	0.14546E+01	0.34215E-01	0.22102E-01	0.23482E+00	-0.22566E-01	0.10700E+00	2
17	-0.14112E+02	0.15901E-02	0.14569E+01	0.41024E-01	0.25211E-01	0.23482E+00	-0.19985E-01	0.10772E+00	2
18	-0.12585E+02	0.18309E-02	0.14596E+01	0.48965E-01	0.28914E-01	0.23482E+00	-0.17404E-01	0.10861E+00	3
19	-0.11090E+02	0.21223E-02	0.14626E+01	0.59230E-01	0.33354E-01	0.23482E+00	-0.14823E-01	0.10968E+00	3
20	-0.96366E+01	0.24780E-02	0.14660E+01	0.71724E-01	0.38717E-01	0.23482E+00	-0.12241E-01	0.11096E+00	4
21	-0.82347E+01	0.29164E-02	0.14697E+01	0.85624E-01	0.45238E-01	0.23482E+00	-0.96562E-02	0.11247E+00	4
22	-0.68974E+01	0.34609E-02	0.14734E+01	0.10030E+00	0.53206E-01	0.23482E+00	-0.70641E-02	0.11422E+00	3
23	-0.56398E+01	0.41417E-02	0.14767E+01	0.11504E+00	0.62965E-01	0.23482E+00	-0.44585E-02	0.11619E+00	3
24	-0.44792E+01	0.49948E-02	0.14791E+01	0.12782E+00	0.74886E-01	0.23482E+00	-0.18297E-02	0.11836E+00	3
25	-0.34337E+01	0.60601E-02	0.14801E+01	0.13937E+00	0.89308E-01	0.23482E+00	0.83411E-03	0.12069E+00	4

Table 5: Sample Output (Continued)

1.3 Organization of the Code

1.3.1 Flow Chart

The flow chart of the overall program organization is given in Fig. 11. MAIN calls either subroutine STEADY or TRANS. The flow of information in these subroutines is shown in Figs. 12 and 13 respectively. Fig. 14 gives some details about the subroutine SWEEP, which is the most important one accounting for all the physical models and the solution scheme. The iterative loop used in SWEEP is shown in some detail in Fig. 15.

1.3.1.1 Description of Subroutines

MAIN Reads the input and checks the options; some preliminary calculations are performed

DISPL Input display

ROFUN(P) Liquid density as function of pressure

GEOMRY Geometrical and physical calculations and checks of topology; renormalization of hydraulic diameter.

MATSET Set up of the matrix containing the sub-channel eonnections and flow recirculations

INVERT Inversion of the matrix

STEADY Master subroutine for steady-state calculations

TRANS Master subroutine for transient calculation; sets inlet conditions for each time step and controls printout.

TIMEF Linear fitting of input timetables of the forcing functions

SWEEP Solution scheme for subchannel flows in steady-state in transient calculations

VMIX	Calculation of vapor mixing in subchannels
MIXIN	Vapor mixing model
entry SLIPF	Transverse slip model
entry REYSF	Turbulent shear stress calculation
SPLITD	Splitting the diversion flow into vapor and liquid flow; evaluates turbulent diffusion enthalpy and momentum transfer
SOLMAT	Solution of the matrix equation for crossflows
WATER	Evaluation of water properties
CONTI	Solution of the continuity equations in each of the subchannels
HYDP	Evaluation of the hydraulic parameters
FFACT	Evaluation of the friction factor
TPEM	Two-phase flow multiplies
TFLM	Local two-phase flow multiplies
EDIT	Printout
CHF	Calculation of critical heat flux, critical power, and boiling length
CHEN	Calculation of subchannel heat transfer coefficient
FUEL	Calculation of fuel temperature profile
TRANSI	Calculation of model coefficient
FVS12	Hermite cubic polynomials

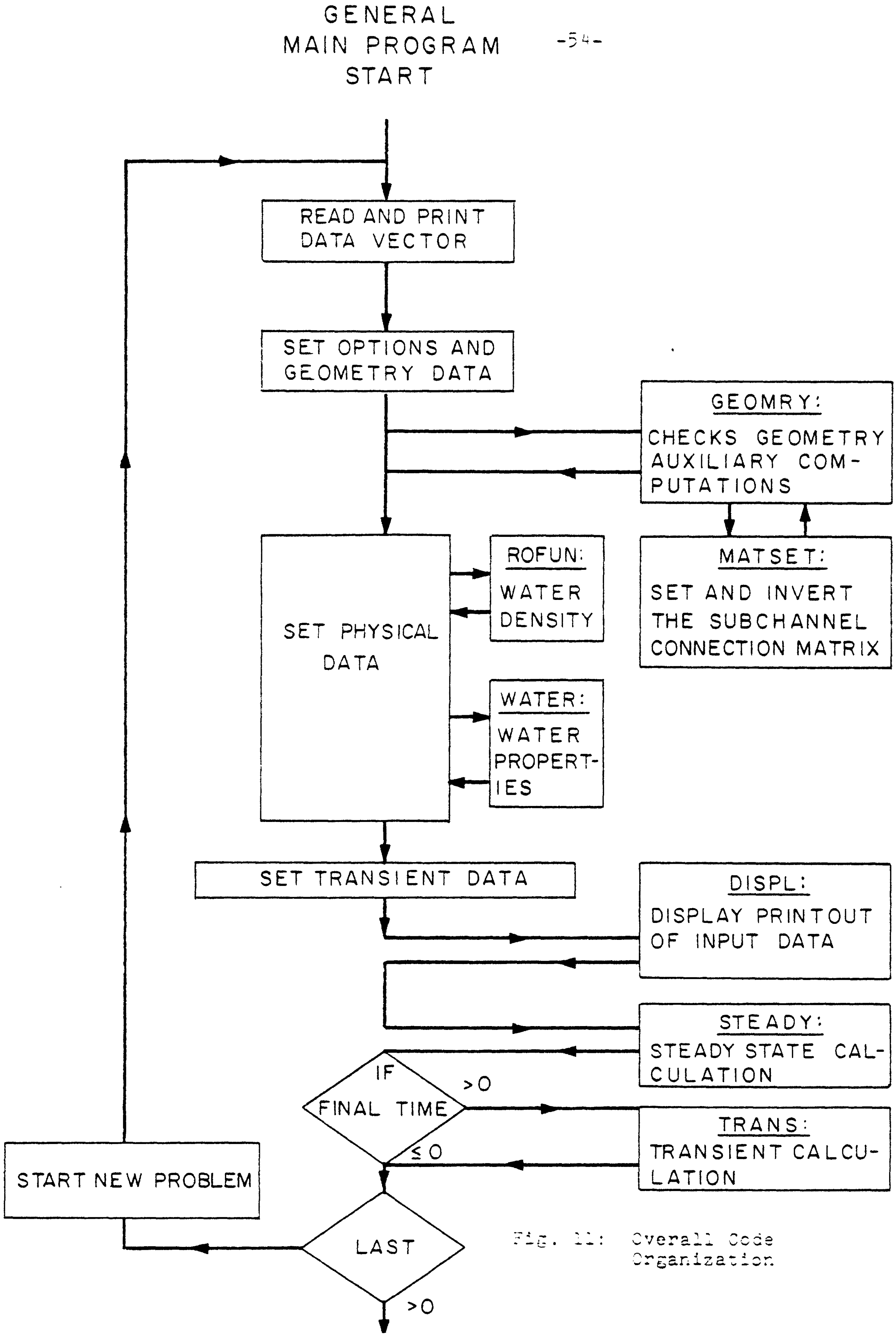

Fig. 11: Overall Code Organization

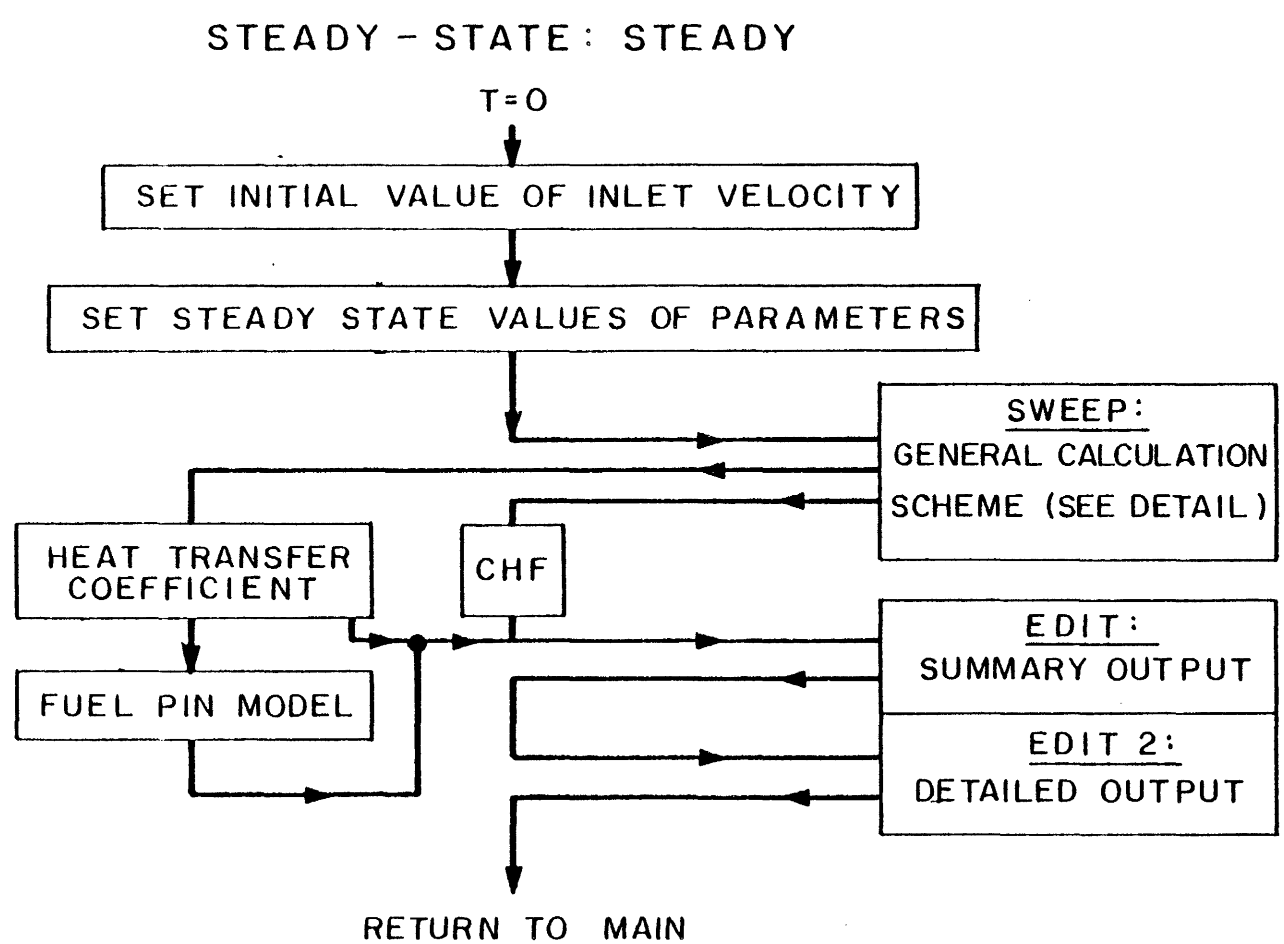

Fig. 12: Subroutine STEADY

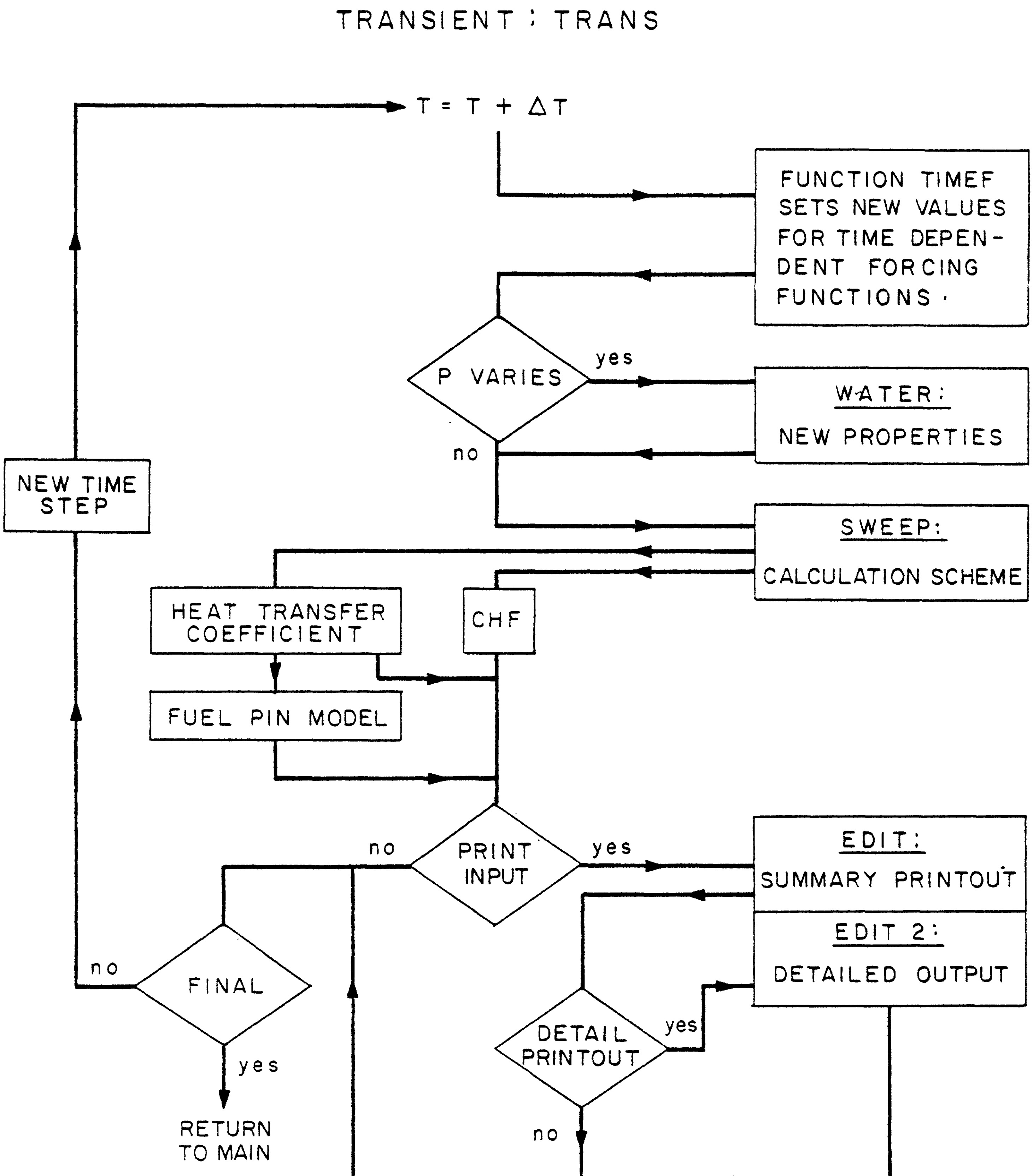

Fig. 13: Subroutine TRANS

CALCULATION SCHEME
SUBROUTINE SWEEP

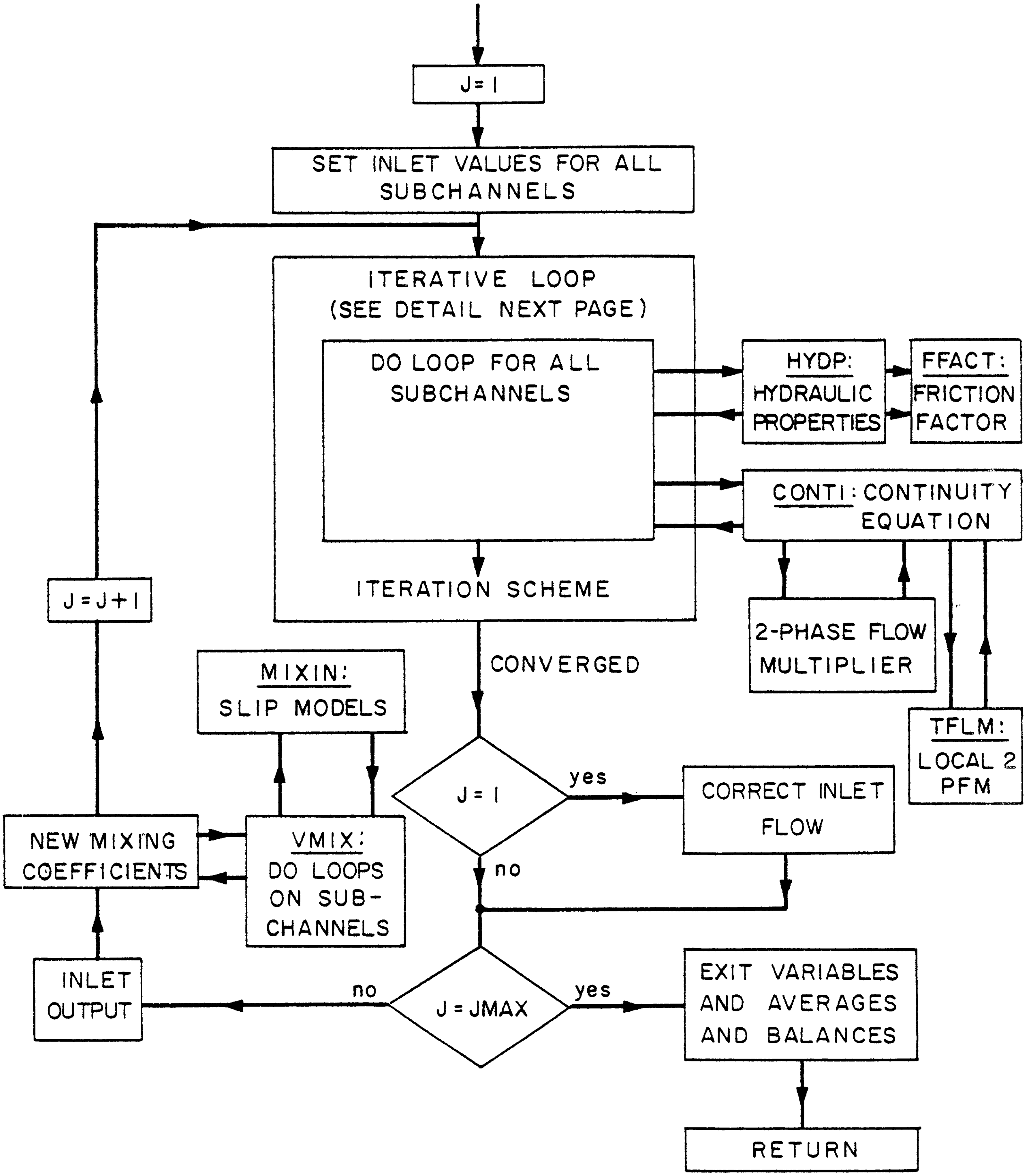

Fig. 14: Subroutine SWEEP

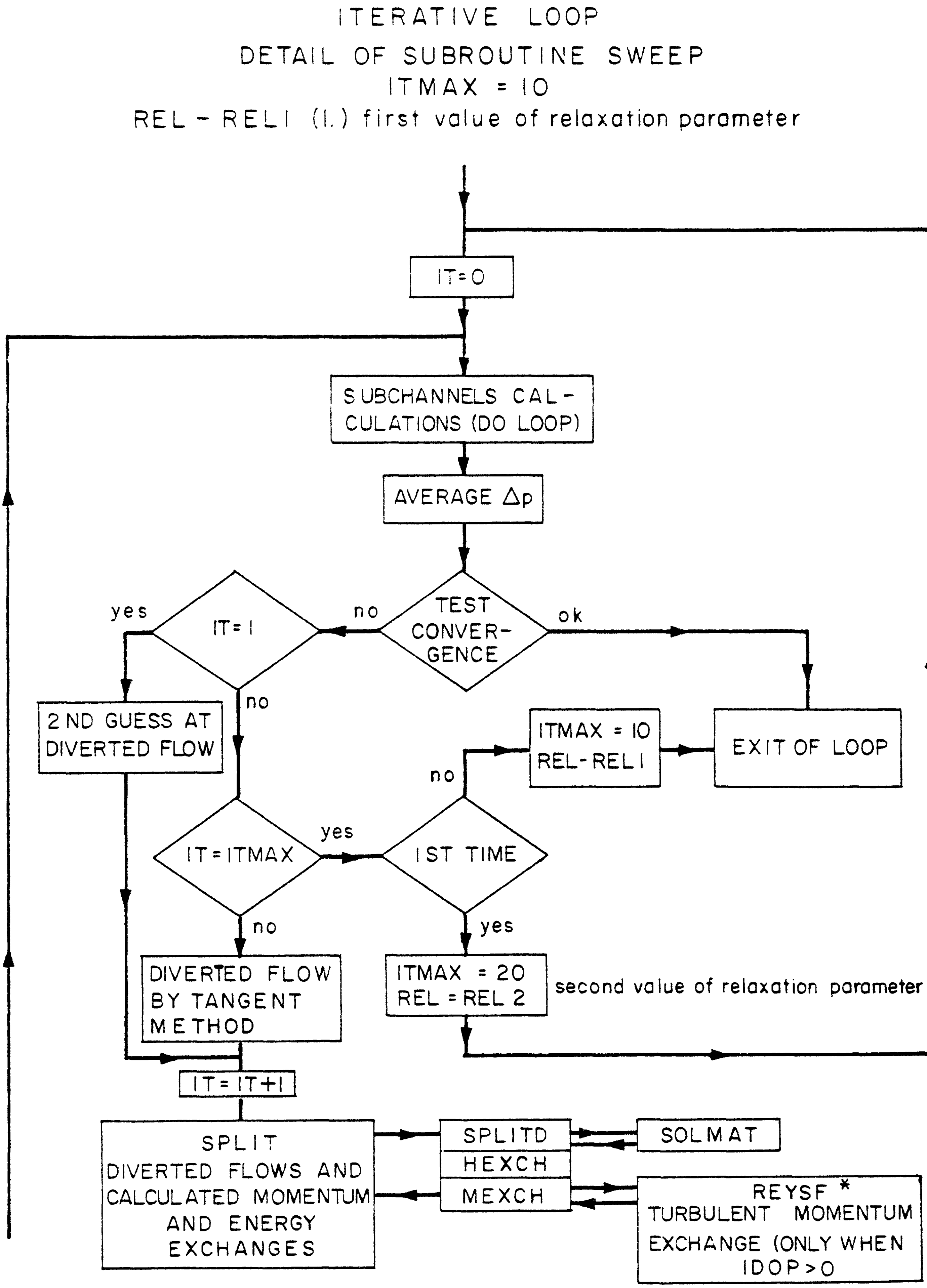

Fig. 15: Iterative Solution Procedure in SWEEP

1.3.1.2 List of common blocks

The common blocks of the WOSUB-II code are listed in Table 6 where it is shown what subroutine needs what common blocks.

	UNI	PROP	GEN	GEOM	TABL	PRINT	DISP	RELAX	WETP	MIX	CONT	SCVEC	MIKE	MAT	LOG	RESVE	RES	ARR	CHI	FUEL1	FUEL2	FUEL3
MAIN	X	X	X	X	X	X	X	X												X	X	
DISPLAY	X	X	X	X	X	X	X		X											X		
GEOMRY		X	X	X					X	X												
MATSET			X	X										X								
INVERT																						
STEADY	X	X	X	X		X				X	X										X	
TRANS	X	X	X	X	X	X				X	X										X	X
VMIX			X	X			X					X	X									
MIXIN	X	X	X	X			X		X	X		X	X	X								
SPLITD	X	X	X	X						X		X		X	X							
WATER	X	X																				
HYDP	X	X									X											
SOLMAT			X	X										X								
CONTI	X	X									X											
SWEEP	X	X	X					X			X	X			X	X	X	X				
EDIT	X	X	X	X		X																
CHF	X	X	X	X	X		X											X				
CHEN	X	X	X															X	X		X	
FUEL	X		X		X	X	X												X	X	X	X
TRANSI	X					X													X	X		X
FVS12																						

Table 6: Common blocks of WOSUB-I code

1.3.2 Parameters Specified in the Code

This section deals with two different kinds of parameters set internally by the code.

1.3.2.1 Parameters Used for Conversion Purposes

WOSUB-1 features as an option the possibility of entering the input data either in BTU system or in MKSA system.

The code will not convert from one system of unit to another, but will only print out in the same system of unit in which the input have been entered.

The only reason for the conversion parameters put into the code is that the power of the bundle has to be entered in WATTs for both unit systems. Therefore, when input data are entered in BTU units the code will automatically convert everything in MKSA unit; this conversion is done in MAIN. In the code, all the calculations will be carried out in MKSA up to the subroutine EDIT and EDIT 2 where the physical data are converted back into the system.

Note that DISPLAY is a subroutine for print out of input data only, and that the version of WOSUB-1 does not print out the correct system of unit if data are entered in BTU unit. The subroutine DISPLAY prints out converted input data (BTU input data converted already in MAIN) with the MKSA unit.

In other words, the subroutine DISPLAY prints out only in MKSA units, thus far.

The built-in conversion factors in MAIN and EDIT/EDIT 2 are:

HCONF = .4304	(For enthalpy)
GCONF = .007373	(For mass flow rates)
FICONF = .003173	(For heat fluxes)
FCONF = .007937	(For mass fluxes)
PCONF = 14.503	(For pressure)
DCONF = 62.383	(For product of density void fraction)

1.3.2.2 Parameters used for the Physical Models:

For the void diffusion model, a built-in option allows to either select parameters or to use those already built into the code as standard option. (Group 2, card 2, data #9).

In the case where the calculation uses the parameters already set in the code, the values are:

AN = 4.

ZE = 0.

R = 5.

FL = 1.

FV = 1.

CPAR = 1

ZUBER = 2.5

RFSTG = .5

Note that the values of the overrelaxation parameters for the first loop, REL 1, and for the second loop REL 2 are set as follows:

REL 1 = 1.

REL 2 = .7

Moreover the code uses with this option:

GRAD = 980. *ABS (CGRAV)

ANI = 1. /AN

ANM = 1. /(AN 1.)

1.4 Listing of WOSUB-I

1.4.1 Listing of MAIN

```
C *** MAIN PROGRAM
C *** READS THE INPUT AND PROCESS THE OPTIONS
C *** PRELIMINARY CALCULATIONS ARE MADE
      LOGICAL ICON
      LOGICAL NDRIFT
      LOGICAL IPAR
      REAL KF,KC
      COMMON /PROP/PO,ROVAP,HVAP,HSAT,ALAM,ULAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRANDL,HB,PROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IOOP
      COMMON/TABL/PEAKF(25),AXSHF(50),IPRESS,CPRESS(5),IVINL,CVIN(5),
     1ITIN,CTIN(5),IPOW,CPOW(5),PTAB(100),QTAB(100),HTAB(100),PWTAB(100)
      COMMON /UNIT/DZ,DT,VZERO,AN,AN1,ZE,P,FL,FV,CPAR,ZUBER,P
      COMMON/GEN/NAROD(20),NROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),EFLC(10,20),
     2NRODS,GTFAC,GTUP,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX
      COMMON/PRINT/T,ICON,PDPW(25) ,THIN,PERI
      COMMON /DISP/ ISHAP,AXPKF,ZTOT,DIAR,NDRIFT
      COMMON/RELAX/REL1,REL2,RESTG
      COMMON /FUEL1/ NF,NC,KF,KC,CPF,CPC,RHOF,RHOC,HGAP,RC,RG,RCS,RFS,
     1 RCI,G1
      COMMON /FUEL2/ JJ1,JJ2,JINC,MROD,KCHAN(4,25)
      COMMON DATA(2200)
      DIMENSION AVHF(25)
      DIMENSION TITLE(16)
      DATA HCONF,GCONF,FICONF,FCONF,PCONF,DCONF
     1/.4304,.007373,.003173,.007937,14.503,62.383/
      CALL INIT
      DO 5000 K=1,2200
 5000 DATA(K)=0.
 1000 READ(5,1)LAST,TITLE
    1 FORMAT(I5,16A4)
      WRITE(6,2)TITLE
    2 FORMAT(1H1,/10X,45HWOSUB  PROGRAM FOR SUBCHANNEL ANALYSIS OF BWR/
     120X,16A4)
  100 READ(5,3)KZ,K1,K2,(DATA(K),K=K1,K2)
    3 FORMAT(2I6,I12,/(6F12.6))
      WRITE(6,4)(K,DATA(K),K=K1,K2)
    4 FORMAT(6(I5,E14.6))
      IF(KZ.GE.0)GO TO 100
C     SET DATA-GEOMETRY
      NCHAN=  INT(DATA(1)*1.001)
      NRODS=  INT(DATA(2)*1.001)
      JMAX=   INT(DATA(3)*1.001)
      IHIN=INT(DATA(4)*1.001)
      ISHAP=INT(DATA(5)*1.001)
      ICON=.FALSE.
      IF(DATA(6).GT.0.)ICON=.TRUE.
      IOOP=INT(DATA(7)*1.001)+1
      IDOWN=INT(DATA(8)*1.001)
      NDRIFT=.TRUE.
      IF(DATA(9).GT.0.)NDRIFT=.FALSE.
      IPAR=.TRUE.
      IF(DATA(10).GT.0.)IPAR=.FALSE.
      CPAR=1.
      AN=4.
      ZE=0.
```

```
 49 CHAN(I)=DATA(LI)
    L=620
    DO 50 K=1,NRODS
    LK=L+K
 50 RODN(K)=DATA(LK)
    DO 550 I=1,NCHAN
550 BERGH(I)=DATA(I+650)
    CALL GEOMRY
C      PHYSICAL DATA
    P=DATA(1001)
    IF(ICON)
   1P=P/PCONF
    RO=POFUN(P)
    ROGRAV=RO*CGRAV*980.
    CALL WATER(P)
    SAVE=DATA(1002)
    IF(IHIN)57,55,56
 55 IF(ICON)SAVE=SAVE/HCONF
    HINLET=SAVE
    HZERO=SAVE+HSAT
    GO TO 59
 56 IF(ICON)SAVE=SAVE/HCONF
    HZERO=SAVE
    HINLET=SAVE-HSAT
    GO TO 59
 57 IF(IHIN.LT.(-1))GO TO 58
    IF(ICON)SAVE=.55556*SAVE
    HINLET=-CP*SAVE
    HZERO=HINLET+HSAT
    GO TO 59
 58 IF(ICON)SAVE=.55556*(SAVE-32.)
    HINLET=CP*(SAVE-TSAT)
    HZERO=HINLET+HSAT
 59 CONTINUE
    GTOT=DATA(1003)
    IF(ICON)
   1GTOT=GTOT/FCONF
    GTOT=1000.*GTOT
    DIAR=DATA(1004)
    IF(ICON)
   1DIAR=2.54*DIAR
    PERI=3.1416*DIAR
    DO 110 I=1,NCHAN
    KM=NARON(I)
    DO 110 K=1,KM
110 HPER(K,I)=PERI*HPER(K,I)
    POWER=DATA(1005)
    PEDAC=DATA(1006)
    FNOR=0.
    TOTINP=0.
    DO 120 K=1,NRODS
    PEAKF(K)=DATA(K+1010)
    TOTINP=TOTINP+RODN(K)
120 FNOR=PEAKF(K)*RODN(K)+FNOR
    FNOR=POWER/FNOR
    DO 121 K=1,NRODS
121 PRODS(K)=FNOR*PEAKF(K)
    ZTOT=DATA(1007)
    IF(ICON)
   1ZTOT=30.48*ZTOT
    DZ=ZTOT/FLOAT(JMAX)
```

```
      P=5.
      FL=1.
      FV=1.
      CPAR=1.
      ZUBER=2.5
      PFL1=1.
      PFL2=.7
      PFSTG=.5
      GRAD=980.*ABS(CGRAV)
      AN1=1./AN
      ANM=1./(AN-1.)
      L=10
      DO 10 I=1,NCHAN
      JOIN(I)=  INT(DATA(L+1)*1.001)
      NROD(I)=  INT(DATA(L+2)*1.001)
      L=L+2
      DO 11 K=1,4
      LK=L+K
   11 NJOIN(I,K)=  INT(DATA(LK)*1.001)
      L=L+4
      DO 12 K=1,4
      LK=L+K
   12 KROD(K,I)=  INT(DATA(LK)*1.001)
   10 L=L+4
      DO 16 I=1,NRODS
      M=1
      DO 16 N=1,NCHAN
      DO 16 K=1,4
      IF(KROD(K,N).EQ.I)KCHAN(M,I)=N
      IF(KROD(K,N).EQ.I)M=M+1
   16 CONTINUF
      NOCIR=  INT(DATA(300)*1.001)
      IF(NOCIR) 2001,2001,3000
 3000 DO 20 I=1,NOCIR
   20 MCIRC(I)=INT(DATA(I+300)+.8)
      GO TO 5001
 2001 DO 4000 I=1,4
 4000 MCIRC(I)=0.
 5001 CONTINUF
      L=400
      DO 30 I=1,NCHAN
      A(I)=DATA(L+1)
      IF(ICON)A(I)=6.4516*A(I)
      HYD(I)=DATA(L+2)
      IF(ICON)
     1HYD(I)=2.54*HYD(I)
      L=L+2
      DO 31 K=1,4
      LK=L+K
   31 HPER(K,I)=DATA(LK)
      L=L+4
      DO 32 K=1,4
      LK=L+K
      SL(K,I)=DATA(LK)
      IF(ICON)
     1SL(K,I)=2.54*SL(K,I)
   32 CONTINUE
    3 L=L+4
      L=600
      DO 40 I=1,NCHAN
      LI=L+I
```

```
      AFAC=ZTOT*PERI
      AFAC=1./AFAC*(1.-PEDAC)
      DO 122 K=1.NRODS
  122 AVHF(K)=AFAC*PORW(K)
C *** AXIAL POWER SHAPE SPECIFICATION
      IF(ISHAP)125.123.124
  123 DO 1230 J=1.JMAX
 1230 AXSHF(J)=1.
      GO TO 130
  124 L=1050
      FNOR=0.
      DO 1240 J=1.JMAX
      LJ=L+J
      SAVE=DATA(LJ)
      FNOR=FNOR+SAVE
 1240 AXSHF(J)=SAVE
      FNOR=FLOAT(JMAX)/FNOR
      DO 1241 J=1.JMAX
 1241 AXSHF(J)=FNOR*AXSHF(J)
      GO TO 130
  125 AXPKF=DATA(1050)
      ARG=1.5
      DO 1250 M=1.10
      SARG=SIN(ARG)
      SPF=ARG/SARG
      DELT=AXPKF-SPF
      IF(ABS(DELT).LT.0.001)GO TO 1251
      SAVE=(SARG-ARG*COS(ARG))/SARG**2
      ARG=ARG+DELT/SAVE
      IF(ARG.GT.1.57)ARG=1.57
      IF(ARG.LT.0.01)ARG=0.01
 1250 CONTINUE
 1251 J1=JMAX/2
      DARG=2.*ARG/FLOAT(JMAX)
      SAVE=ARG-.5*DARG
      SUM=0.
      DO 1252 J=1.J1
      SAV1=COS(SAVE)
      AXSHF(J)=SAV1
      JMJ=JMAX+1-J
      AXSHF(JMJ)=SAV1
      SUM=SUM+SAV1
 1252 SAVE=SAVE-DARG
      IF(2*J1.EQ.JMAX)GO TO 1253
      AXSHF(J1+1)=1.
      SUM=SUM+1.
 1253 FNOR =FLOAT(JMAX)/SUM
      DO 1254 J=1.JMAX
 1254 AXSHF(J)=FNOR*AXSHF(J)
  130 DO 140 J=1.JMAX
      DO 140 K=1.NRODS
  140 HF(J,K)=AXSHF(J)*AVHF(K)
C *** SPACER GRIDS AND BLOCKAGE SPECIFICATION
      L=1100
      DO 150 IL=1.10
      LIL=L+IL
  150 LOC(IL)=INT(DATA(LIL)+0.1)
      L=1200
      DO 160 IL=1.10
      DO 170 I=1.NCHAN
      LI=L+I
```

```
  170 FFLC(IL,I)=DATA(LI)
  160 L=L+20
      IF(IPAR)GO TO 2000
      IF(DATA(901).GT.0.)AN=DATA(901)
      ZE=DATA(902)
      R=DATA(903)
      ZUBER=DATA(904)
      CGRAV=DATA(905)
      IF(DATA(906).GT.0.)CPAR=DATA(906)
      IF(DATA(907).GT.0.)FL=DATA(907)
      IF(DATA(908).GT.0.)FV=DATA(908)
      IF(DATA(909).GT.0.)REL1=DATA(909)
      IF(DATA(910).GT.0.)REL2=DATA(910)
      IF(DATA(911).GT.0.)RESTG=DATA(911)
      AN1=1./AN
      ANM=1./(AN-1.)
 2000 ZE=ZE*AVHYD
C *** TRANSIENT SPECIFICATION
      TFIN=DATA(1500)
      IF(TFIN.EQ.0.)GO TO 240
      PRIN=DATA(1501)
      MDPR=INT(DATA(1502)+.1)
      DT=DATA(1503)
C *** PRESSURE TRANSIENT SPECIFICATION
      IPRESS=INT(DATA(1511)*1.001)
      DO 180 M=1,5
  180 CPRESS(M)=DATA(M+1511)
C *** FLOW TRANSIENT SPECIFICATION
      IVINL=INT(DATA(1517)*1.001)
      DO 190 M=1,5
  190 CVIN(M)=DATA(M+1517)
C *** INLET ENTHALPY SPECIFICATION
      ITIN=INT(DATA(1523)*1.001)
      DO 200 M=1,5
  200 CTIN(M)=DATA(M+1523)
C *** POWER TRANSIENT SPECIFICATION
      IPOW=INT(DATA(1529)*1.001)
      DO 210 M=1,5
  210 CPOW(M)=DATA(M+1529)
C ***  TIME TABLES FOR TRANSIENT
      DO 230 M=1,100
      PTAB(M)=DATA(M+1599)
      GTAB(M)=DATA(M+1699)
      HTAB(M)=DATA(M+1799)
  230 PWTAB(M)=DATA(M+1899)
C *** CHANNEL BLOCKAGE SPECIFICATION
      HC=DATA(2951)
      IBLOC=INT(DATA(1551)*1.001)
      LBLOC=INT(DATA(1552)*1.001)
      T1BL=DATA(1553)
      T2BL=DATA(1554)
      FBL1=DATA(1555)
      FBL2=DATA(1556)
      SAVE=DT/DZ
C *** FIX DT IF NOT GIVEN IN INPUT
      IF(SAVE.LE.0.)SAVE=.05 *AREA *RO/GTOT
      VZERO=1./SAVE
      DT=DZ/VZERO
      PRIN=PRIN-.1*DT
C *** HEAT TRANSFER COEFFICIENT SPECIFICATIONS
  240 CONTINUE
```

```
      MROD=INT(DATA(2001)*1.001)
      JJ1=INT(DATA(2031)*1.001)
      JJ2=INT(DATA(2032)*1.001)
      JINC=INT(DATA(2033)*1.001)
C *** GEOMETRICAL AND PHYSICAL PROPERTIES OF FUEL AND CLADDING
      RC=DATA(2051)
      RG=DATA(2052)
      NF=INT(DATA(2053)*1.001)
      NC=INT(DATA(2054)*1.001)
      KF=DATA(2055)
      KC=DATA(2056)
      CPF=DATA(2057)
      CPC=DATA(2058)
      RHOF=DATA(2059)
      RHOC=DATA(2060)
      HGAP=DATA(2061)
      RCS=DATA(1004)/2.
      RCI=RCS-RC
      RFS=RCI-RG
      IF(.NOT.ICON)GO TO 300
      RFS=2.54*RFS
      RCI=2.54*RCI
      RCS=2.54*RCS
      RG=2.54*RG
      RC=2.54*RC
      RHOF=.01602*RHOF
      RHOC=.01602*RHOC
      KF=.01731*KF
      KC=.01731*KC
      CPF=4.187*CPF
      CPC=4.187*CPC
      HGAP=.0005679*HGAP
  300 CONTINUE
      CALL DISPL
      PFDAC=1./(1.-PFDAC)
      CALL STEADY
      IF (IFIN.LE.0.)GO TO 250
      CALL TRANS
  250 CONTINUE
      IF(LAST.GT.0)STOP
      GO TO 1000
      END
```

1.4.2 Listing of Subroutine DISPL

```
      SUBROUTINE DISPL
C ***  INPUT DISPLAY
      REAL KF,KC
      LOGICAL ICON, NDRIFT
      COMMON/TABL/PEAKF(25),AXSHF(50),IPRESS,CPRESS(5),IVINL,CVIN(5),
     1ITIN,CTIN(5),IPOW,CPOW(5),PTAB(100),QTAB(100),HTAB(100),PWTAB(100)
      COMMON /WETP/ WP(20)
      COMMON/PRINT/T,ICON,POPW(25) ,THIN,PERI
      COMMON /UNI/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,P
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MOPR,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,PROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      COMMON /DISP/ ISHAP,AXPKF,ZTOT,DIAR,NDRIFT
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IDOP
      COMMON /FUEL1/ NF,NC,KF,KC,CPF,CPC,RHOF,RHOC,HGAP,RC,RG,RCS,RFS,
     1 RCI,G1
      WRITE(6,1)
    1 FORMAT(1H1,20X, ' INPUT DISPLAY'//)
      WRITE(6,2)NCHAN,NRODS
    2 FORMAT(1H,5X,  'NCHAN-NUMBER OF SUBCHANNELS TYPES',I6/6X,
     1    'NRODS-NUMBER OF HEATING RODS TYPES',I6//)
      WRITE(6,3)
    3 FORMAT(20X,'SUBCHHANELS LAYOUT'//'  CHAN',5X,' CHANN',9X,
     1 'JOIN,CHANN,',11X,'JOIN,RODS')
      DO 10 I=1,NCHAN
      WRITE(6,4)I,CHANN(I),(NJOIN(I,N),N=1,4),(KROD(M,I),M=1,4)
    4 FORMAT(I6,F12.2,4I5,1X,4I5)
   10 CONTINUE
      WRITE(6,5)NOCIR,(MCIRC(I),I=1,NOCIR)
    5 FORMAT(1H0/3X,'NOCIR-NUMBER OF RECIRCULATIONS PATHS',I6/
     1 '    RECIRCULATIONS',4I15,/(17X,4I15/))
      WRITE(6,6)
    6 FORMAT(1H0,20X,'ROD PEAK FACTORS'/)
      WRITE(6,7)(K,PEAKF(K),K=1,NRODS)
    7 FORMAT(4('    ROD',I4,' PEAKF',F8.4))
      WRITE(6,8)
    8 FORMAT(1H0/20X,'SUBCHANNELS GEOMETRY'/'  CHAN',6X,'HD',11X,
     1 'A',20X,'GAP WIDTHS'/)
      DO 20 I=1,NCHAN
      WRITE(6,9)I,HYD(I),A(I),(SL(K,I),K=1,4)
    9 FORMAT(I6,2F12.5,2X,4F12.5)
   20 CONTINUE
      WRITE(6,11)
   11 FORMAT(1H0/20X,' OPTIONS')
      IF(ISHAP)31,30,40
   31 WRITE(6,12)AXPKF
   12 FORMAT(' CHOPPED COSINUS AXIAL POWER DISTRIBUTION - PEAK FACTOR',
     1 F8.5)
      GO TO 50
   30 WRITE(6,13)
   13 FORMAT('  FLAT AXIAL POWER DISTRIBUTION')
      GO TO 50
   40 WRITE(6,14)(AXSHF(J),J=1,JMAX)
   14 FORMAT('  AXIAL POWER SHAPE'/(8F12.4))
   50 CONTINUE
```

```
      IF(ICON)GO TO 60
      WRITE(6,15)
   15 FORMAT(32H DECIMAL SYSTEM FOR INPUT OUTPUT)
      GO TO 70
   60 WRITE(6,16)
   16 FORMAT(1X,'BRITISH SYSTEM FOR INPUT, MKSA SYSTEM FOR OUTPUT')
   70 CONTINUE
      GO TO(80,90),IDOP
   80 WRITE(6,17)
   17 FORMAT('  HYDRAULIC DIAMETERS RENORMALIZED')
   90 CONTINUE
      IF(NODRIFT)WRITE(6,22)
   22 FORMAT('  NO VAPOR MIXING EFFECT')
      IF(.NOT.NODRIFT)WRITE(6,221)
  221 FORMAT('  VAPOR MIXING MODEL INCLUDED')
      IF(IDOWN)100,100,110
  100 WRITE(6,18)
   18 FORMAT(' UPWARDS FLOW')
      GO TO 120
  110 WRITE(6,19)
   19 FORMAT(' DOWNWARDS FLOW')
  120 WRITE(6,21)IPRESS,IVINL,ITIN,IPOW
   21 FORMAT('         TRANSIENT SPECIFICATIONS'/'  0=CONSTANT  1=TABULATED
     1  2=SINUSOIDAL  3=POLYNOMIAL'/'  PRESSURE',I5,3X,' MASS FLOW',I5,
     2 3X,'INLET ENTHALPY',I5,3X,'POWER',I5)
      WRITE(6,23)P,GTOT,POWER,PFDAC,ZTOT,HINLET
   23 FORMAT('              PHYSICAL PARAMETERS FOR STEADY STATE'/
     1 '    PRESSURE',E12.5,'BAR  TOTAL MASS FLOW',E12.5,'G/SEC  TOTAL BU
     2NDLE POWER',E12.5,'WATT'/3X,'POWER FRACTION TO COOLANT',F10.5/
     3'    TOTAL HEIGHT',F10.2,' CM  INLET ENTHALPY SUBC.',E12.5)
      WRITE(6,24)RO,TSAT,HSAT,ALAM,ROVAP,GAMMA,AMU,WCON,SIGMA
   24 FORMAT('             COOLANT PROPERTIES(CGS UNITS,JOULE/G FOR ENGY)',
     1 '    LIQUID DENSITY',F10.5,'  TSAT',F10.3,'  HSAT',F14.5,/' LAT.HE
     2AT',F10.3/ '  VAPOR.DENS.',E12.5,'  GAMMA',F10.7,'  VISC',E10.4,
     3 '  TH.COND.',E10.4,'  SURF.TENS.',E10.4)
      WRITE(6,25)DIAR,DZ,DT
   25 FORMAT('     HEATING RODS DIAMETER',F8.4,'CM'/'   NODE HEIGHT DZ',
     1 F10.3,'CM   TIME STEP DT',F10.4,'SEC')
      WRITE(6,26)
   26 FORMAT(1H0,20X,'LOCAL RESTRICTIONS'/'  NODE',8X,
     1 'LOCAL LOSS COEFF. IN SUBCHANNELS')
      DO 200 L=1,10
      IF(LOC(L).LE.0 )GO TO 201
      WRITE(6,27)LOC(L),(FFLC(L,I),I=1,NCHAN)
   27 FORMAT(I5,10F10.3/6X,10F10.3)
  200 CONTINUE
      GO TO 202
  201 IF(L.EQ.1)WRITE(6,28)
   28 FORMAT('  NONE')
      GO TO 130
  202 IF(IBLOC.EQ.0)GO TO 130
      WRITE(6,29)IBLOC,LBLOC,T1BL,FBL1,T2BL,FBL2
   29 FORMAT(1H0/'     TRANSIENT BLOCKAGE IN SUBCHANNEL',I5,'  AT NODE',
     1 I5,'   INITIAL TIME FOR BLOCK',F8.2,'RESTR.COEFF.',F10.3,/
     2 '    FINAL TIME FOR BLOCK',F8.2,'RESTR.COEFF.',F10.3)
  130 WRITE(6,37)RC,RG,KF,KC,CPF,CPC,RHOF,RHOC,HGAP
   37 FORMAT(//,5X,'PHYSICAL PROPERTIES OF FUEL AND CLADDING'/
     1 '  CLAD THICKNESS ',F10.4,'  FUEL/CLAD GAP ',F10.4,
     2 '  FUEL TH. CONDUCTIVITY ',F10.4,/'  CLAD TH. CONDUCTIVITY ',
     3 F10.4,'  FUEL SPECIFIC HEAT ',F10.4,'  CLAD SPECIFIC HEAT ',F10.4
     4  ,/'  FUEL DENSITY ',F10.4,'  CLAD DENSITY ',F10.4,
```

```
5 '   GAP CONDUCTANCE',F10.4)
  RETURN
  END
```

1.4.3 Listing of Subroutine GEOMRY

```
      FUNCTION ROFUN(P)
C *** LIQUID DENSITY FITTING AS A FUNCTION OF THE PRESSURE
      PP=1.01972*P
      Q=1.1025*(1.+3.464E- 3*PP-4.13E-6*PP*PP)
      ROFUN=1./Q
      RETURN
      END
      SUBROUTINE GEOMRY
C *** GEOMETRICAL AND PHYSICAL CALCULATIONS AND CHECKS
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IOOP
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),EFLC(10,20),
     2NRODS,GTFAC,GTUP,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,TIBL,T2BL,FBL1,FBL2,PRIN,MOPR,
     4HYD(20),LOC(10),HPER(4,20),PEDAC,DERP,NCHAN,JMAX
      COMMON /WETP/ WP(20)
      COMMON/MIX/ALFOO,RMIX,SLIP(20),TURMT,VEX,VR7(20,4)
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,PROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      DIMENSION CHYD(20)
C ***  CHECK GEOMETRY
      SAVE=0.
      DO 60 I=1,NCHAN
      K=NAROD(I)
      DO 60 M=1,K
   60 SAVE=SAVE+CHANN(I)*HPER(M,I)
      TOTROD=0.
      DO 70 K=1,NRODS
   70 TOTROD=TOTROD+RODN(K)
      CHECK=ABS(TOTROD-SAVE)
      IF(CHECK/SAVE.GT.0.001)WRITE(6,5)
    5 FORMAT(1H0,2X,'WARNING-PERIMETER BALANCE IS NOT CORRECT')
      DO 90 I=1,NCHAN
      KM=JOIN(I)
      DO 90 K=1,KM
      L=NJOIN(I,K)
      IF(L.LE.0.OR.L.GT.NCHAN)GO TO 93
      IF(L.LT.I)GO TO 90
      MM=JOIN(L)
      DO 91 M=1,MM
      IF(NJOIN(L,M).EQ.I)GO TO 90
   91 CONTINUE
      DO 92 M=1,MM
      IF(NJOIN(L,M).NE.0)GO TO 92
      NJOIN(L,M)=I
      SL(M,L)=SL(K,I)
      GO TO 90
   92 CONTINUE
   93 CONTINUE
      WRITE(6,6)I
    6 FORMAT(1H0,2X,'ADJOINING CHANNELS SPECIFICATION WRONG FOR SUBCHANN
     1EL',I5)
      STOP
   90 CONTINUE
   80 CONTINUE
      DO 15 I=1,NCHAN
      K=JOIN(I)
      DO 15 K=1,K
   15 VR7(I,K)=(SL(K,I)/HYD(I))**(1./7.)
```

```
   15 CONTINUE
C *** HYDRAULIC DIAMETER RENORMALIZATION OPTION
      GO TO (1,2),IOOP
    1 DO 11 I=1,NCHAN
      WP(I)=4.*A(I)/HYD(I)
      SAVE=0.
      TOTP=WP(I)
      L=IDIN(I)
      DO 12 K=1,L
   12 TOTP=TOTP+SL(K,I)
      DO 13 K=1,L
      M=NJOIN(I,K)
   13 SAVE=SAVE+SL(K,I)/TOTP*HYD(M)
   11 CHYD(I)=SAVE+WP(I)/TOTP*HYD(I)
      DO 14 I=1,NCHAN
   14 HYD(I)=CHYD(I)
    2 GTFAC=0.25*SQRT(0.005/2.)/72.
      AREA=0.
      TOTWP=0.
      DO 21 I=1,NCHAN
      AREA=AREA+CHANN(I)*A(I)
   21 TOTWP=TOTWP+CHANN(I)*WP(I)
      AVHYD=4.*AREA/TOTWP
      GTFAC=GTFAC/(0.0392*AVHYD)
      CALL MATSET
      RETURN
      END
```

1.4.4 Listing of Subroutine MATSET

```
      SUBROUTINE MATSET
C *** SETS UP THE MATRIX OF SUBCHANNELS CONNECTIONS AND FLOW
C *** RECIRCULATIONS
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IDOP
      COMMON/MAT/ MATDIM,NEQ,NTW(20,4),TMATI(40,40),TMAT(40,40),
     1 XLU(40,40)
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FF_C(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWD,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MOPP,
     4HYD(20),LOC(10),HPER(4,20),PEDAC,DERP,NCHAN,JMAX
      EQUIVALENCE(NSUB,NCHAN)
      DIMENSION IJ(5)
      DO 1 I=1,40
      DO 1 J=1,40
      XLU(I,J)=0.
      TMATI(I,J)=0.
    1 TMAT(I,J)=0.
      MATDIM=NSUB+NOCIR-1
      IPNTR=1
      DO 6000 I=1,NSUB
      JJ = JOIN(I)
      DO 6000 J=1,JJ
 6000 NTW(I,J)=0
      DO 6005 I=1,NSUB
      JJ=JOIN(I)
      DO 6005 J=1,JJ
      M=NJOIN(I,J)
      IF(-.LT.I) GO TO 6004
      IF(NTW(I,J).NE.0)GO TO 6003
      NTW(I,J)=IPNTR
      KK=JOIN(M)
      DO 6001 K=1,KK
      IF(NJOIN(M,K).EQ.I)GO TO 6002
 6001 CONTINUE
 6002 NTW(M,K)=IPNTR
      TMAT(I,IPNTR)=1.
      IPNTR=IPNTR+1
      GO TO 6005
 6003 M=NTW(I,J)
      TMAT(I,M)=1.
      GO TO 6005
 6004 M=NTW(I,J)
      TMAT(I,M)=-1.
 6005 CONTINUE
      DO 8000 I=1,NSUB
      JJ=JOIN(I)
      DO 8000 J=1,JJ
 8000 CONTINUE
      IF(NOCIR.LE.0)GO TO 6021
      DO 500 NN=1,4
  500 IJ(NN)=MOD(MCIRC(1),10**(2*NN))/10.**(2*NN-2)
      IF(IJ(4).EQ.0)GO TO 6006
      IJ(5)=IJ(1)
      II=5
      KK=4
      GO TO 6007
 6006 IJ(4)=IJ(1)
      II=4
      KK=3
```

```
 6007 WRITE(6,650)(IJ(J),J=1,KK)
  650 FORMAT(4I16)
      NEQ=IJ(1)
      DO 6050 I=1,MATDIM
      TMAT(NEQ,I)=0.
 6050 CONTINUE
      DO 6012 I=1,KK
      M=IJ(I)
      JJ=JOIN(M)
      DO 6009 J=1,JJ
      IF(NJOIN(M,J).EQ.IJ(I+1))GO TO 6010
 6009 CONTINUE
 6010 JJ=NTW(M,J)
      IF(IJ(I).GT.IJ(I+1))GO TO 6011
      TMAT(NEQ,JJ)=1.
      GO TO 6012
 6011 TMAT(NEQ,JJ)=-1.
 6012 CONTINUE
      IF(NOCIR.EQ.1)GO TO 6021
      II=NSUB+1
      IPNTR=2
      DO 6020 I=II,MATDIM
      DO 600 NN=1,4
  600 IJ(NN)=MOD(MCIRC(IPNTR),10**(2*NN))/10**(2*NN-2)
      IF(IJ(4).EQ.0)GO TO 6013
      JJ=5
      KK=4
      IJ(5)=IJ(1)
      GO TO 6014
 6013 IJ(4)=IJ(1)
      JJ=4
      KK=3
 6014 WRITE(6,650)(IJ(J),J=1,KK)
      DO 6019 K=1,KK
      M=IJ(K)
      JJ=JOIN(M)
      DO 6016 J=1,JJ
      IF(NJOIN(M,J).EQ.IJ(K+1))GO TO 6017
 6016 CONTINUE
 6017 JJ=NTW(M,J)
      IF(IJ(K).GT.IJ(K+1))GO TO 6018
      TMAT(I,JJ)=1.
      GO TO 6019
 6018 TMAT(I,JJ)=-1.
 6019 CONTINUE
 6020 IPNTR=IPNTR+1
      WRITE(6,6025)
 6025 FORMAT(//20X,'CONNECTION MATRIX'/)
      DO 6030 I=1,MATDIM
 6030 WRITE(6,6035)(TMAT(I,J),J=1,MATDIM)
 6035 FORMAT(1H ,30F4.1,/)
 6021 IF (NSUB.EQ.2)GO TO 1701
      CALL INVERT(MATDIM,TMAT,TMATI,XLU,40,NERR)
      WRITE(6,6031)
 6031 FORMAT(//20X,'INVERSE OF CONNECTION MATRIX'/)
      GO TO 300
 1701 TMATI(1,1)=1.
  300 DO 6022 I=1,40
      DO 6022 J=1,40
      XLU(I,J)=0.
 6022 TMAT(I,J)=0.
```

```
6023 RETURN
     END
```

1.4.5 Listing of Subroutine STEADY

```
      SUBROUTINE STEADY
C *** STEADY STATE ROUTINE. SETS INITIAL CONDITIONS
      LOGICAL IBR,IREV,IFREV,ITRA,ILOC
      COMMON /UNIT/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAP,ZUPER,P
      COMMON/CONT/FI(4),IBR,IREV,IFREV,ITRA,ILOC,TETA,APAR,TIN,H,HP,TW,
     1PSI,HOLD,VFOLD,VFIN,HRAP,TD,AA,AJIN,AJVIN,HLINJ,HIN,GFLIN,GOLD,Q,
     2QV,QL,FFAC,FFLOC,AJ,AJV,AJL,VF,HL,G,DPF,DP,DPEXC,SAVEN,QP,PH(4),
     3XT,KR,GFLUX
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2RODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PEDAC,DERP,NCHAN,JMAX
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1ROM(25),AREA,IDOP
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1RCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      COMMON/PRINT/T,ICON,RORW(25) ,THIN,PERI
      COMMON/MIX/ALFOD,RMIX,SLIP(20),TURMT,VEX,VR7(20,4)
      COMMON /FUEL2/JJ1,JJ2,JINC,MROD,KCHAN(4,25)
      ITRA=.FALSE.
      DERP=0.
      DLAM=0.
      DHSAT=0.
      ROVRA=1.
      DZUMG=DZ*(1.-GAMMA)
      POWO=POWER
      PZERO=P
      GZERO=GTOT
      VIZERO=GTOT/RO/AREA
      VEX=EXP(-SQRT(VIZERO/100.))
      T=0.
      DO 1 I=1,NCHAN
    1 VINLET(I)=VIZERO
      AVREY=RO*AVHYD*VIZERO/AMU
      GTUR=GTFAC*AVREY*AMU
      CALL SWEEP
      WRITE(6,100)
  100 FORMAT(1H1//20X,'STEADY STATE RESULTS')
      CALL EDIT
      CALL EDIT2
      CALL CHF
      CALL CHFU
      CALL FUEL
      WRITE(6,101)
  101 FORMAT('  END OF STEADY STATE CALCULATION')
      RETURN
      END
```

1.4.6 Listing of Subroutine TRANS

```
      SUBROUTINE TRANS
C *** TRANSIENT ROUTINE. SETS INLET CONDITIONS FOR EACH TIME STEP
C *** AND CONTROLS PRINTOUT
      LOGICAL ICON
      LOGICAL IBR,IREV,IFREV,ITRA,ILOC
      COMMON/TABL/PEAKF(25),AXSHF(50),IPRESS,CPRESS(5),IVINL,CVIN(5),    00000
     1ITIN,CTIN(5),IPOW,CPOW(5),PTAB(100),VTAB(100),HTAB(100),PWTAB(100)00000
      COMMON /UNI/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,P
      COMMON/CONT/FI(4),IBR,IREV,IFREV,ITRA,ILOC,TETA,APAR,TIN,H,HP,TW,
     1PSI,HOLD,VFOLD,VFIN,HBAR,TD,AA,AJIN,AJVIN,HLINJ,HIN,GFLIN,GOLD,Q,
     2QV,QL,FFAC,FFLOC,AJ,AJV,AJL,VF,HL,G,DPF,DP,DPEXC,SAVEN,QP,PH(4),
     3XT,KR,GFLUX
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MOPR,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IDOP
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMMA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      COMMON/PRINT/T,ICON,RDPW(25)  ,IHIN,PERI
      COMMON/MIX/ALFDD,RMIX,SLIP(20),TURMT,VEX,VRZ(20,4)
      COMMON /FUEL2/ JJ1,JJ2,JINC,MROD,KCHAN(4,25)
      COMMON /FUEL3/ TPRI,PPN
      DATA HCONF/.4304/
      WRITE(6,500)
  500 FORMAT(1H1,20X,9HTRANSIENT)
      ITRA=.TRUE.
      TPRI=0.
      MP=0
      VIN=VIZERO
      AVREY=RO*AVHYD*VIZERO/AMU
      DPTAC=0.
      ROVAP1=ROVAP
  100 T=T+DT
      IF(T.GT.TFIN)RETURN
      PRESS1=P
      IF(IPRESS.LE.0)GO TO 1
      P=TIMEF(T,IPRESS,CPRESS,PZERO,PTAB)
      DERP=0.1*(P-PRESS1)/DT
      ROVAP1=ROVAP
      HVAP1=HVAP
      ALAM1=ALAM
      HSAT1=HSAT
      CALL WATER(P)
      DLAM=ALAM-ALAM1
      DHSAT=HSAT-HSAT1
      ROVRA=ROVAP1/ROVAP
      DZUMG=0.7*(1.-GAMMA)
    1 CONTINUE
      IF(ITIN.LE.0)GO TO 2
      SAVE=TIMEF(T,ITIN,CTIN,1.,HTAB)
      IF(ITIN.GT.1)SAVE=SAVE-1.
      IF(IHIN)22,21,21
   21 IF(ICON)SAVE=SAVE/HCONF
      GO TO 23
   22 IF(ICON)SAVE=.55556*SAVE
      SAVE=SAVE*CP
   23 HINLET=HZERO+SAVE
```

```
2 CONTINUE
  IF(IVINL.LE.0)GO TO 3
  VIN1=VIN
  VIN=TIMEF(T,IVINL,CVIN,VIZERO,OTAB)
  VEX=EXP(-SQRT(VIN/100.))
  VFAC=VIN/VIN1
  DO 4 I=1,NCHAN
4 VINLET(I)=VFAC*VINLET(I)
  AVREY=VFAC*AVREY
  GTUR=GTFAC*AVREY*AMU
  GTOT=RO*VIN*AREA
3 IF(IPOW.LE.0.)GO TO 5
  POW1=POWER
  POWER=TIMEF(T,IPOW,CPOW,POWO,PWTAB)
  PWFAC=POWER/POW1
  DO 6 J=1,JMAX
  DO 6 K=1,NRODS
6 HF(J,K)=PWFAC*HF(J,K)
5 CONTINUE
  IF(IBLOC.EQ.0)GO TO 7
  IF(T.LT.T1BL)GO TO 7
  FFLC(LBLOC,IBLOC)=FBL2
  IF(T.LT.T2BL)FFLC(LBLOC,IBLOC)=FBL1+(FBL2-FBL1)*(T-T1BL)/(T2BL
 1 -T1BL)
7 CONTINUE
  CALL SWEEP
  TPRI=TPRI+DT
  IF(TPRI.LT.PRIN)GO TO 100
  CALL EDIT
  CALL CHF
  CALL CHEN
  CALL FUEL
  MP=MP+1
  IF(MP.LT.MPPR)GO TO 100
  CALL EDIT2
  MP=0
  GO TO 100
  END
```

1.4.7 Listing of Subroutine SWEEP

```
      SUBROUTINE SWEEP
C *** SCHEME FOR SUBCHANNELS CALCULATION IN STEADY STATE AND TRANSIENT
      LOGICAL IBB,IREV,IFREV,ILOC,IR(20),IRE(20),IFRE(20),IRN(20),IREN(20000
     10),ITRA,ICONV                                                     000
      LOGICAL IBCH                                                      000
      LOGICAL ITIND                                                     000
      COMMON /UNI/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,P            000
      COMMON /LOGI/IB,IBCH
      COMMON/CONT/FI(4),IBB,IREV,IFREV,ITRA,ILOC,TETA,APAR,TIN,H,HP,TW, 000
     1PSI,HOLD,VFOLD,VFIN ,HBAR,TD,AA,AJIN,AJVIN,HLINJ,HIN,GFLIN,GOLD,Q,000
     2QV,QL,FFAC,FFLOC,AJ,AJV,AJL,VF,HL,G,DPF,DP,DPEXC,SAVEN,QP,PH(4),XT000
     3,KP,GFLUX                                                         000
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMMA,ROVRA,000
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,              000
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)                000
      COMMON/SCVEC/AJT(20),AJVAP(20),FIHLIN(20),QT(20),QVT(20),QLT(20), 000
     1EXCHM(20),HLIN(20),HDIV(20),TDH(20),GFL(20),VFI(20),AJN(20),AJVN(20000
     20),AJLN(20),DPFR(20),VFN(20),HLN(20),GN(20),GFN(20),GT(20), SAVN(20000
     30),ENSAVE(20),FAC(20),DPS(20),EDP(20),EDPO(20),QTO(20),AJLI(20),  000
     4XTR(20)                                                           000
      COMMON/RESVE/VFAV(20),GOUT(20),GOUTV(20),GOUTL(20),XOUT(20),EOUT(20000
     10),BAL(20)                                                        000
      COMMON/RES/ITER(50),PDROP(50),TEOUT,FMOUT,PACC,TBAL,AVX,DPTOT     000
      COMMON/ARR/QTP(50,20),ALF(50,20),HEL(50,20),GR(50,20),            000
     1TQUAL(50,20),XQUAL(50,20)                                         000
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),  000
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),                    000
     2NRODS,GTFAC,GTHR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,        000
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX                  000
      COMMON/RELAX/REL1,REL2,RFSTG                                      000
      TEST=.001                                                         000
      ITMAX=10                                                          000
      REL=REL1                                                          000
      J=1                                                               000
      ITIND=.FALSE.                                                     000
 2233 CONTINUE                                                          000
      IBCH=.FALSE.                                                      000
      IL=1                                                              000
      IT=0                                                              000
C     SET BOUNDARY CONDITIONS FOR FIRST NODE                            000
      DO 50 I=1,NCHAN                                                   000
      AJT(I)=VINLET(I)                                                  000
      AJLT(I)=AJT(I)                                                    000
      AJVAP(I)=0.                                                       000
      FIHLIN(I)=HINLET*VINLET(I)                                        000
      QT(I)=0.                                                          000
      QVT(I)=0.                                                         000
      QLT(I)=0.                                                         000
      EXCHM(I)=0.                                                       000
      HLIN(I)=HINLET                                                    000
      HDIV(I)=0.                                                        000
      TDH(I)=0.                                                         000
      GFL(I)=RO*VINLET(I)**2*FL                                         000
      VFI(I)=0.                                                         000
      GT(I)=RO*VINLET(I)                                                000
      IR(I)=.FALSE.                                                     000
      IRE(I)=.FALSE.                                                    000
      IFRE(I)=.TRUE.                                                    000
      ENSAVE(I)=FIHLIN(I)                                               000
   50 CONTINUE                                                          000
```

```
      CALL VMIX                                             00001
  100 ILOC=LOC(IL).EQ.J                                     00001
    1 DPAV=0.                                               00001
      SAVG=0.                                               00001
      ICONV=.TRUE.                                          00001
      DO 10 I=1,NCHAN                                       00001
      AA=A(I)                                               00001
      AJIN=AJT(I)                                           00001
      AJVIN=AJVAP(I)                                        00001
      HLINJ=FIHLIN(I)                                       00001
      Q=QT(I)                                               00001
      QV=QVT(I)                                             00001
      QL=QLT(I)                                             00001
      DPEXC=EXCHM(I)                                        00001
      HIN=HLIN(I)                                           00001
      HBAR=HDIV(I)                                          00001
      TO=TOH(I)                                             00001
      IBB=IB(I)                                             00001
      IREV=IRE(I)                                           00001
      IFREV=IFRE(I)                                         00001
      GFLIN=GFL(I)                                          00001
      IF(J.GT.1)GO TO 9                                     00001
      GFLIN=RO*FL*(AJIN+Q/AA)**2                            00001
      DPEXC=0.                                              00001
    9 CONTINUE                                              00001
      GIN=GT(I)                                             00001
      VFIN=VFI(I)                                           00001
      TIN=HIN/CP                                            00001
      HOLD=HEL(J,I)                                         00001
      VFOLD=ALF(J,I)                                        00001
      GOLD=GP(J,I)                                          00001
      SAVEN=ENSAVE(I)                                       00001
      IF(ILOC)FFLOC=0.5*FFLC(IL,I)                          00001
C     HEAT FLUXES AND ENERGY ADDITION                       00001
      KR=NAROD(I)                                           00001
      QP=0.                                                 00001
      DO 11 K=1,KR                                          00001
      KRO=KROD(K,I)                                         00001
      FI(K)=HF(J,KRO)                                       00001
      PH(K)=HPER(K,I)                                       00001
   11 QP=QP+PH(K)*FI(K)*PFDAC                               00001
      QP=QP/AA                                              00001
      IF(ITRA)QP=QP+DERP                                    00001
      GLO=GIN+RO*(QL+GAMMA*QV)/A(I)                         00001
      DIAH=HYD(I)                                           00001
      REY=ABS(GLO)*DIAH/AMU                                 00001
      RROUGH=RERGH(I)                                       00001
      CALL HYDP(REY,DIAH,GLO)                               00001
      CALL CONTT                                            00001
      QPS(I)=QP                                             00001
      SAVE=A(I)*ABS(GIN)                                    00001
      QPAV=QPAV+SAVE*QP                                     00001
      SAVG=SAVG+SAVE                                        00001
      AJN(I)=AJ                                             00001
      AJVN(I)=AJV                                           00001
      AJLN(I)=AJL                                           00001
      DPFR(I)=DPF                                           00001
      VFN(I)=VF                                             00001
      HLN(I)=HL                                             00001
      GN(I)=G                                               00001
      GFN(I)=GFLUX                                          00001
```

```
      SAVN(I)=SAVEN                                                     00001
      XTP(I)=XT                                                         00001
      IBN(I)=IHB                                                        00001
      IPEN(I)=IPEV                                                      00001
   10 CONTINUE                                                          00001
      DPAV =DPAV/SAVG                                                   00001
C     ITERATION SCHEME                                                  00001
      DO 12I=1,NCHAN                                                    00001
      EDP(I)=DPS(I)-DPAV                                                00001
      IF(ABS(EDP(I)).GT.TEST*ABS(DPAV))ICONV=.FALSE.                    00001
   12 CONTINUE                                                          00001
      IF(IT.EQ.ITMAX)GO TO 200                                          00001
      IF(ICONV)GO TO 201                                                00001
      IF(IT.GT.0)GO TO 101                                              00001
C     SECOND GUESS FOR DIVERTED FLOWS                                   00001
      QTOT=0.                                                           00001
      FACS=0.                                                           00001
      DO 2 I=1,NCHAN                                                    00001
      SAVE=AJT(I)/DPS(I)                                                00001
      QTT=QT(I)-.5*A(I)*SAVE*EDP(I)*RESTG                               00001
      QTO(I)=QT(I)                                                      00001
      QT(I)=QTT                                                         00001
      QTOT=QTOT+QTT*CHANN(I)
      FAC(I)=A(I)                                                       00001
    2 FACS=FACS+FAC(I)*CHANN(I)                                         00001
      RENO=QTOT/FACS                                                    00001
      DO 3 I=1,NCHAN                                                    00001
      QT(I)=QT(I)-FAC(I)*RENO                                           00001
    3 EDPO(I)=EDP(I)                                                    00001
      GO TO 5                                                           00001
C     ITERATION                                                         00001
  101 QTOT=0.                                                           00001
      DO 6 I=1,NCHAN                                                    00001
      QTT=QT(I)                                                         00001
      SAVE=EDP(I)-EDPO(I)                                               00001
      IF(ABS(SAVE).LT.0.1)GO TO 4                                       00001
      QTT=QTT-REL*EDP(I)*(QTT-QTO(I))/SAVE                              00001
    4 CONTINUE                                                          00001
      QTO(I)=QT(I)                                                      00001
      QT(I)=QTT                                                         00001
    6 QTOT=QTOT+QTT*CHANN(I)                                            00001
      RENO=QTOT/FACS                                                    00001
      DO 7 I=1,NCHAN                                                    00001
      QT(I)=QT(I)-FAC(I)*RENO                                           00001
    7 EDPO(I)=EDP(I)                                                    00001
    5 CALL SPLITD(J)                                                    00001
      CALL HEXC(J)                                                      00001
      CALL MEXC (J)                                                     00001
      IT=IT+1                                                           00001
      GO TO 1                                                           00001
C     SAVING RESULTS AND SETTING INITIAL CONDITIONS FOR NEXT NODE       00001
 1000 ITER(J)=IT                                                        00001
      PDROP(J)=DPAV                                                     00001
      DO 20 I=1,NCHAN                                                   00001
      QTR(J,I)=QT(I)                                                    00001
      ALF(J,I)=VEN(I)                                                   00001
      HEL(J,I)=HLN(I)                                                   00001
      TQUAL(J,I)=XTP(I)                                                 00001
      XQUAL(J,I)=RO*(HLN(I)*AJLN(I)+GAMLA*AJVN(I))/GN(I)/ALAM           00001
      HLIN(I)=HLN(I)                                                    00001
      GR(J,I)=GN(I)                                                     00001
```

```
      VFI(I)=VFN(I)
      AJT(I)=AJN(I)
      AJVAP(I)=AJVN(I)
      AJLI(I)=AJLN(I)
      FIHLIN(I)=HLIN(I)*AJLN(I)
      GFL(I)=GFN(I)
      GT(I)=GN(I)
      IB(I)=IBN(I)
      IRE(I)=IREN(I)
      IFRE(I)=.TRUE.
      ENSAVE(I)=FIHLIN(I)
      IF(.NOT.IRE(I))GO TO 20
      IFRE(I)=.FALSE.
      ENSAVE(I)=SAVN(I)
   20 CONTINUE
      IF(J.EQ.JMAX)GO TO 2000
      IT=0
    8 J=J+1
      CALL VMIX
  202 CONTINUE
      DO 22 I=1.NCHAN
      QT(I)=0.
      IF(ITRA)QT(I)=QTR(J.I)
   22 CONTINUE
      CALL SPLITD(J)
      CALL HEXC(J)
      CALL MEXC(J)
      IF(ILOC)IL=IL+1
      IF(J.EQ.1) GO TO 2233
      GO TO 100
 2000 CONTINUE
C     CORRECT INLET VELOCITY OF FIRST NODE
      DO 1001 I=1.NCHAN
      VINLET(I)=VINLET(I)+QTR(1.I)/A(I)
      GINLET(I)=RO*VINLET(I)
 1001 QTR(1.I)=0.
C     CALCULATE EXIT VARIABLES AND BALANCES
      DO 1002 I=1.NCHAN
      VFAV(I)=0.
      DO 1003 J=1.JMAX
 1003 VFAV(I)=VFAV(I)+ALF(J.I)
      VFAV(I)=VFAV(I)/FLOAT(JMAX)
      GOUT(I)=GN(I)
      GOUTV(I)=ROVAP*AJVN(I)
      GOUTL(I)=GOUT(I)-GOUTV(I)
      EOUT(I)=HLN(I)*GOUTL(I)+ALAM*GOUTV(I)
      XOUT(I)=EOUT(I)/(GOUT(I)*ALAM)
 1002 BAL(I)=A(I)*(EOUT(I)--HINLET*GINLET(I))
      TEOUT=0.
      DO 1004 I=1.NCHAN
      TEOUT=TEOUT+EOUT(I)*A(I)*CHANN(I)
      WRITE(6.2025) TEOUT.EOUT(I)
 2025 FORMAT(1X.'TEOUT='.E14.5.'EOUT(I)='.E14.5)
 100  CONTINUE
      TBAL=TEOUT-GTOT*HINLET
      BACC=POWER-TBAL
      FLOUT=0.
      DO 1005 I=1.NCHAN
 1005 FLOUT=FLOUT+A(I)*GOUT(I)*CHANN(I)
      XAV=TEOUT/FLOUT/ALAM
      SPTH1=0.
```

```
      DO 1006 J=1,JMAX                                              000
 1006 DPTOT=DPTOT+PDROP(J)                                          000
      RETURN                                                        000
  200 IF(ITIND)GO TO 201                                            000
      ITIND=.TRUE.                                                  000
      REL=REL2                                                      000
      ITMAX=20                                                      000
      IT=0                                                          000
      GO TO 202                                                     000
  201 IF(.NOT.ITIND)GO TO 1000                                      000
      ITIND=.FALSE.                                                 00
      REL=REL1                                                      000
      ITMAX=10                                                      000
      GO TO 1000                                                    000
      END                                                           000
```

1.4.8 Listing of Subroutines VMIX and MIXIN

```
      SUBROUTINE VMIX
C *** GENERAL SCHEME FOR VAPOR MIXING IN SUBCHANNELS
      LOGICAL NODRIFT
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX
      COMMON/SCVEC/AJT(20),AJVAP(20),FIHLIN(20),QT(20),QVT(20),QLT(20),
     1 EXCHM(20),HLIN(20),HDIV(20),TDH(20),GFL(20),VFI(20),AJN(20),
     2 AJVN(20),AJLN(20),DPER(20),VFN(20),HLN(20),GN(20),GFN(20),GT(20),
     3 SAVN(20),FNSAVE(20),FAC(20),DPS(20),EDP(20),EDPO(20),QTO(20),
     4 AJLI(20),XTR(20)
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IDOP
      COMMON /DISP/ ISHAP,AXPKF,ZTOT,DIAR,NDRIFT
      COMMON /MIKE/ KI
      DO 1 I=1,NCHAN
    1 CALL SLIPF(I,JJ)
      DO 10 I=1,NCHAN
      KS=JOIN(I)
      DO 20 K=1,KS
      JJ=NJOIN(I,K)
      KI=K
      CALL MIXIN(I,JJ)
   20 CONTINUE
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MIXIN(I,JJ)
C *** VAPOR MIXING MODEL
      LOGICAL ICON,NDRIFT
      COMMON /UNI/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUPER,P
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2NRODS,GTFAC,GTUP,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPP,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IDOP
      COMMON /DISP/ ISHAP,AXPKF,ZTOT,DIAR,NDRIFT
      COMMON/SCVEC/AJT(20),AJVAP(20),FIHLIN(20),QT(20),QVT(20),QLT(20),
     1 EXCHM(20),HLIN(20),HDIV(20),TDH(20),GFL(20),VFI(20),AJN(20),
     2 AJVN(20),AJLN(20),DPFR(20),VFN(20),HLN(20),GN(20),GFN(20),GT(20),
     3 SAVN(20),ENSAVE(20),FAC(20),DPS(20),EDP(20),EDPO(20),QTO(20),
     4 AJLI(20),XTR(20)
      COMMON /WETP/ WP(20)
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,REPGH(20)
      COMMON/MIX/ALFDD,PMIX,SLIP(20),TURMT,VEX,VRZ(20,4)
      COMMON /MAT/ MATDIM,NEQ,NTW(20,4),TMATI(40,40),SRMIX(40,40),
     1 SALDD(40,40)
      COMMON /MIKE/ KI
      DATA EFFAC,AKPAR, GCRIT,GCR1/0.005,2.,3.8,1./
      DATA GCONF/.007373/
      DATA PARK/100./
      AKTP =0.0264*SQRT(.5*EFFAC)
C ***  VOID DRIFT CALCULATION
      IF(NDRIFT)GO TO 100
      AVALF=VFI(I)
      IF(AVALF.LE.0.)GO TO 100
      CMIXM=SQRT(1./GAMMA)
      DAV=HYD(I)
      GAV=ABS(GT(I))
      GBU=GCONF*GAV
      U=ABS(AJT(I))
      ALCZ=0.
      ALFC1=0.37
      ALFC2=.775-.0504*GBU-.0171*GBU*GBU
C ***  VOID DRIFT
      ALC2=ALFC2
      IF(GBU.GT.GCRIT)ALC2=ALFC1
      XI=1.
      IF(ALVALF.LE.ALCZ)GO TO 2
      IF(AVALF-ALFC1)3,4,4
    3 XI=1.+(CMIXM-1.)*(AVALF-ALCZ)/(ALFC1-ALCZ)
      GO TO 5
    4 IF(AVALF-ALC2)6,6,7
    6 XI=CMIXM
      GO TO 5
    7 XI=1.+(CMIXM-1.)*.5*(1.+COS(3.1416*(AVALF-ALC2)/(1.-ALC2)))
    5 XI=1.
      SS=AKPAR*(GAV/GCRIT-1.)
      IF(GBU.GT.GCRIT.AND.SS.LT.100.)XI=1.+(XI-1.)*EXP(-SS)
    2 CONTINUE
      PMIX=AKTP*XI*U*DAV*DZ
      PMIX=PMIX*EXP(-PARK*VEX*(1.-VRZ(I,KI)))*15.
  100 CONTINUE
      SRMIX(I,JJ)=PMIX
```

```
      RETURN
  100 ALFDD=0.
      RMIX=0.
      GO TO 101
C ***  DIVERTED FLOW SLIP FACTOR
      ENTRY SLIPF(I,JJ)
C *** TRANSVERSAL SLIP MODEL
      ALFI=VFI(I)
      ALCZ=.2
   11 SLIP(I)=1./AK
      IF(ALFI.LE.ALCZ)SLIP(I)=SLIP(I)*ALFI/ALCZ
      RETURN
C *** TURBULENT SHEAR STRESS CALCULATION
       ENTRY REYSF(I,JJ)
      TURMT=0.
      KS=JOIN(I)
      DO 20 K=1,KS
      JJ=NJOIN(I,K)
      GST=GT(JJ)-GT(I)
      AAV=A(I)+A(JJ)
      DAV=4.*AAV/(WP(I)+WP(JJ))
      U=(AJT(I)*A(I)+AJT(JJ)*A(JJ))/AAV
      SAVE=DZ*AKPT*U*DAV*GST
   20 TURMT=TURMT+SAVE
      RETURN
      END
```

1.4.9 Listing of Subroutines SPLITD and SOLMAT

```
      SUBROUTINE SPLITD(J)
C *** SPLITS THE DIVERTED FLOW INTO VAPOR AND LIQUID FLOW. EVALUATES
C *** TURBULENT DIFFUSION ENTHALPY AND MOMENTUM TRANSFER
      LOGICAL IBCH,IB(20)
      COMMON /UNT/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,P
      COMMON /LOGI/IB,IBCH
      COMMON/SCVEC/AJT(20),AJVAP(20),FIHLIN(20),QT(20),QVT(20),QLT(20),
     1 EXCHM(20),HLIN(20),HDIV(20),TDH(20),GFL(20),VFI(20),AJN(20),
     2 AJVN(20),AJLN(20),DPFR(20),VFN(20),HLN(20),GN(20),GFN(20),GT(20),
     3 SAVN(20),ENSAVE(20),FAC(20),DPS(20),EDP(20),EDPO(20),QTO(20),
     4 AJLI(20),XTR(20)
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,ULAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,PROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IDOP
      COMMON /MAT/ MATDIM,NEQ,NTW(20,4),TMATI(40,40),SRMIX(40,40),
     1 SALDO(40,40)
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX
      COMMON/MIX/ALFOD,RMIX,SLIP(20),TURMT,VEX,VR7(20,4)
      DIMENSION QTK(20,4),QVK(20,4),QLK(20,4)
      J1=J
      JM1=J-1
C ***  FIND CROSS FLOWS
      CALL SOLMAT(QTK,QT)
C *** FIND QVT(I) VAPOR INLET CROSS FLOWS
      DO 1 I=1,NCHAN
      QVMIX=0.
      QVDIV=0.
      KS=JOIN(I)
      DO 2 K=1,KS
      JJ=NJOIN(I,K)
      SAVE=SRMIX(JJ,I)*VFI(JJ)-SRMIX(I,JJ)*VFI(I)
      QVMIX=QVMIX+SAVE
      QVK(I,K)=SAVE
      IF(QTK(I,K))4,2,3
    3 SAVE=SLIP(JJ)*VFI(JJ)*QTK(I,K)
      GO TO 100
 4    SAVE=SLIP(I)*VFI(I)*QTK(I,K)
  100 QVDIV=QVDIV+SAVE
      QVK(I,K)=QVK(I,K)+SAVE
    2 QLK(I,K)=QTK(I,K)-QVK(I,K)
      QVT(I)=QVMIX+QVDIV
    1 QLT(I)=QT(I)-QVT(I)
      RETURN
      ENTRY HEXC(J)
C *** CALCULATES ENTHALPY EXCHANGE
      IF(IBCH)RETURN
      DO 5 I=1,NCHAN
      IF(IB(I)) GO TO 5
      GO TO 7
    5 CONTINUE
      IBCH=.TRUE.
      DO 6 I=1,NCHAN
    6 HDIV(I)=0.
      RETURN
    7 CONTINUE
```

```
C *** DIVERTED FLOW ENTHALPY
      DO 10 I=1,NCHAN
      SAVE=0.
      KS=JOIN(I)
      DO 11 K=1,KS
      JJ=NJOIN(I,K)
      IF(QLK(I,K))13,11,12
   12 SAVE= SAVE+HLIN(JJ)*QLK(I,K)
      GO TO 11
   13 SAVE=SAVE+HLIN(I)*QLK(I,K)
   11 CONTINUE
   10 HDIV(I)=SAVE
C *** TURBULENT DIFFUSION ENTHALPY
      IF(IBCH)GO TO 200
      DO 20 I=1,NCHAN
      SAVE=0.
      KS=JOIN(I)
      DO 21 K=1,KS
      JJ=NJOIN(I,K)
      SAVE=SAVE+HLIN(JJ)-HLIN(I)
   21 CONTINUE
   20 TDH(I)=GTUR*DZ*SAVE
      RETURN
  200 DO 201 I=1,NCHAN
  201 TDH(I)=0.
      RETURN
      ENTRY MEXC(J)
C *** CALCULATES MOMENTUM TRANSFER
C *** DIVERTED FLOW MOMENTUM
      DO 30 I=1,NCHAN
      SAVE=0.
      KS=JOIN(I)
      DO 31 K=1,KS
      JJ=NJOIN(I,K)
      IF(QLK(I,K))33,34,32
   32 SAVE=SAVE+QLK(I,K)*AJLI(JJ)/(1.-VFI(JJ))
      GO TO 34
   33 SAVE=SAVE+QLK(I,K)*AJLI(I)/(1.-VFI(I))
   34 IF(QVK(I,K))36,31,35
   35 IF(VFI(JJ).LE.0.)GO TO 31
      SAVE=SAVE+GAMMA*QVK(I,K)*AJVAP(JJ)/VFI(JJ)
      GO TO 31
   36 IF(VFI(I).LE.0.) GO TO 31
      SAVE=SAVE+GAMMA*QVK(I,K)*AJVAP(I)/VFI(I)
   31 CONTINUE
   30 EXCHM(I)=RO/A(I)*SAVE
      IF(IJOP.EQ.1)RETURN
      DO 40 I=1,NCHAN
      CALL REYSF(I,J)
   40 EXCHM(I)=EXCHM(I)+DZ*TURMT/A(I)
      RETURN
```

```
      END
      SUBROUTINE SOLMAT(TW3,W)
C *** SOLVES THE MATRIX EQUATION FOR CROSS FLOWS
      DIMENSION TW3(20,4),W(20),RHS(20),VEC(40)                        0000
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,       0000
     1RODN(25),AREA,IDOP                                                0000
      COMMON/MAT/MATDIM,NEQ,NTW(20,4),TMATI(40,40),TMAT(40,40),XLU(40,400000
     1)                                                                 0000
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FF_C(10,20),                    0000
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,       0000
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,                              0000
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX                  0000
      EQUIVALENCE(NSUB,NCHAN)                                           0000
      DO 823 I=1,MATDIM
  823 RHS(I)=0.
      DO 8 I=1,NSUB
      RHS(I)=W(I)
    8 CONTINUE
      IF(NOCIR .LE.0)   GO TO 9                                         0000
      RHS(NEQ) = 0.                                                     0000
    9 DO 10 I = 1,MATDIM                                                0000
      VEC(I) =  TMATI(I,1)*RHS(1)                                       0000
      DO 10 J = 2,MATDIM                                                0000
      VEC(I)=VEC(I)+TMATI(I,J)*RHS(J)
   10 CONTINUE
      DO 12 I = 1,NSUB                                                  0000
      JJ = JOIN(I)                                                      0000
      DO 12 J = 1,JJ                                                    0000
      K = NTW(I,J)                                                      0000
      NNN = NJOIN(I,J)                                                  0000
      IF(NNN .LT. I)    GO TO 11                                        0000
      TW3(I,J) = VEC(K)                                                 0000
      GO TO 12                                                          0000
   11 TW3(I,J) = -VEC(K)                                                0000
   12 CONTINUE                                                          0000
      RETURN
      END                                                               0000
```

1.4.10 Listing of Subroutine CONTI

```
      SUBROUTINE CONTI
C *** SOLVES CONTINUITY EQUATIONS IN EACH OF THE SUBCHANNELS
      LOGICAL IBB,IREV,IFREV,ITRA,ILOC
      COMMON /UNI/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,P
      COMMON/CONT/FI(4),IBB,IREV,IFREV,ITRA,ILOC,TETA,APAR,TIN,H,HP,TW,
     1PSI,HOLD,VFOLD,VFIN,HBAR,TD,AA,AJIN,AJVIN,HLINJ,HIN,GFLIN,GOLD,Q,
     2QV,QL,FFAC,FFLOC,AJ,AJV,AJL,VF,HL,G,DPF,DP,DPEXC,SAVEN,QP,PH(4),
     3XT,KR,GFLUX
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
C *** VAPOR SOURCE EQUATION
C *** HEAT FLUX SPLIT AND WALL TEMPERATURE
      PSIS=0.
      TC=TETA*(1.-TIN/TETA)**AN1
      TC=TETA*((TC-TIN)/TETA)**AN1
      DO 1 K=1,KR
      TW=TIN+FI(K)/H
      IF(TW-TC)1,1,2
    2 FIC=H*(TC-TIN)-HP*TC**AN
      FIB=FI(K)-FIC
      TW=(FIB/HP)**AN1
      PSIS=PSIS+PH(K)/AA*FIB/RO/(GAMLA-CPAR*HIN)
    1 CONTINUE
C *** TOTAL VAPOR SOURCE
      IF(IBB)GO TO 3
      PSIB=0.
      IF(R.LE.0.)GO TO 40
      C1=AK*(AJVIN+QV/AA+DZ*PSIS)+ZE*PSIS
      IF(ITRA)C1=C1+VZERO*ROVRA*VFOLD*AK
      IF(C1.LE.0.)GO TO 40
      C1=-R*TIN*C1
      B1=AJIN+Q/AA+DZUMG*PSIS+AK*VDRIFT-R*TIN*AK*DZ
      IF(ITRA)B1=B1+AK* VZERO-VZERO*VFOLD*(1.-ROVRA)
      SAVE=B1*B1-4.*C1*DZUMG
      IF(SAVE)41,42,42
   41 PSIB=-PSIS
      GO TO 40
   42 PSIB=0.5*(SQRT(SAVE)-B1)/DZUMG
   40 PSI=PSIS+PSIB
      GO TO 4
    3 SAVE=DZ/RO*QP+HLINJ+HBAR/AA+TD/(RO*AA)
      IF(ITRA)SAVE=SAVE-VZERO*(DLAM*ROVRA*VFOLD+DHSAT*(1.-VFOLD*
     1 (1.-ROVRA))-HOLD*(1.-VFOLD))
   31 PSI=SAVE/GAMLA/DZ
      SAVEN=0.
C *** TOTAL CONTINUITY EQUATION
    4 AJ=AJIN+DZUMG*PSI+Q/AA
      IF(ITRA)AJ=AJ-VZERO*(1.-ROVRA)*VFOLD
C ***  VAPOR CONTINUITY
      SAVE=AJVIN+DZ*PSI+QV/AA
      SAVJ=AJ+AK*VDRIFT
      IF(.NOT.ITRA)GO TO 5
      SAVE=SAVE+VZERO*ROVRA*VFOLD
      SAVE=SAVJ*SAVE-VZERO*ZE*PSIS
      SAVE=SAVE/(SAVJ+AK*VZERO)
    5 AJV=SAVE
C ***  VOID FRACTION CALCULATION
      VF= (AK*AJV+ZE*PSIS)/SAVJ
      IF(VF-0.00001)43,43,44
   43 VF=0.
```

```
      AJV=0.
      Q=AJVIN+QV/AA
      IF(ITRA)Q=Q+VZERO*ROVRA*VFOLD
      PSI=Q/DZ
      AJ=AJIN+DZUMG*PSI+Q/AA
      IF(ITRA)AJ=AJ-VZERO*(1.-ROVRA)*VFOLD
   44 CONTINUE
C ***  LIQUID CONTINUITY
      AJL=AJ-AJV
C ***  TEST FLOW REVERSAL
      IF(AJL.LE.0.)IREV=.TRUE.
C ***  ENERGY CONTINUITY
      HL=0.
      IF(IBB)GO TO 6
      SAVE=HLINJ+DZ/RO*QP+HBAR/AA+TD/(RO*AA)-DZ*GAMLA*PSI
      IF(ITRA)SAVE=SAVE-VZERO*(DLAM*ROVRA*VFOLD+DHSAT*(1.-VFOLD*
     1 (1.-ROVRA))-HOLD*(1.-VFOLD))
      IF(IREV)GO TO 7
      DEN=AJL
      IF(ITRA)DEN=DEN+VZERO*(1.-VFOLD)
      HL=SAVE/DEN
      IF(HL)6,7,7
    7 HL=0.
      IBB=.TRUE.
      SAVE=SAVE+DZ*GAMLA*PSI
      GO TO 31
    6 CONTINUE
C ***  PRESSURE DROP CALCULATION
      DPG=ROGRAV*(1.-VF+GAMMA*VF)*DZ
      GSAVE=AJL+GAMMA*AJV
      G=RO*GSAVE
      G2=G*ABS(GSAVE)
      XT=ROVAP*AJV/G
      FFM=TPFM(XT,AFRIC,BFRIC)
      DPF=DZ*FFAC*G2*FFM
      IF(.NOT.ILOC)GO TO 8
      FFML=TFLM(XT,VF,GAMMA)
      DPF=DPF+FFML*FFLOC*G2
    8 GFLUX=RO*FL*AJL*ABS(AJL)/(1.-VF)
      IF(VF.GT.0.)GFLUX=GFLUX+ROVAP*FV*AJV*ABS(AJV)/VF
      DPACC=GFLUX-GFLIN
      DP=DPG+DPF+DPACC-DPEXC
      IF(ITRA)DP=DP+VZERO*(G-GOLD)
      RETURN
      END
```

1.4.11 Listing of Subroutine CHF

```
      SUBROUTINE CHF
C     THIS ROUTINE CALCULATES THE CRITICAL HEAT FLUX AND CRITICAL
C    POWER FOR THE BUNDLE ACCORDING TO FOUR SEPARATE CORRELATIONS.
C     THE CISE CORRELATION IS USED ONLY FOR THE INTERIOR SUBCHANNELS
C     OF THE BUNDLE.  AN INTERIOR CHANNEL ORDER NUMBER
C      MUST BE INPUT AS  DATA  POINT  2040.  THE
C    THREE CORRELATIONS ARE OF THE ROD BUNDLE VARIETY, AND ARE
C    CALCULATED WITHOUT REGARD TO SUBCHANNELS.  IN ADDITION, THE
C    BARNETT CORRELATION HAS A CORRECTION FACTOR BASED ON EQUIVALENT
C    THERMODYNAMIC QUALITY FOR NON UNIFORM AXIAL HEAT FLUX.  ALL
C    CALCULATIONS ARE DONE IN THE ENGLISH SYSTEM OF UNITS, AND THE
C    OUTPUT IS IN THE UNITS SPECIFIED BY DATA POINT 6.
      COMMON /UNIT/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUPER,P
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,REPGH(20)
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PEDAC,DERP,NCHAN,JMAX
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1RODN(25),AREA,IDOP
      COMMON/TABL/PEAKF(25),AXSHF(50),IPRESS,CPRESS(5),IVINL,CVIN(5),
     1ITIN,CTIN(5),IPOW,CPOW(5),PTAB(100),QTAB(100),HTAB(100),PWTAB(100)
      COMMON /DISP/ ISHAP,AXPKF,ZTOT,DIAR,NDRIFT
      COMMON /ARP/QTR(50,20),ALF(50,20),HEL(50,20),GR(50,20),
     1TQUAL(50,20),XQUAL(50,20)
      COMMON DATA(2200)
      DIMENSION PFAVG(20),RC(20),CHFC(20),PHITOT(50),PHIBAR(50),
     1 XINT(50),F(50),COR(50),XMCRIT(50),CHFB(50),DEQ(50),BL(20)
      DIMENSION CPC(20),ANEW(20),HFNEW(50,25)
      DATA HCONF,GCONF,FICONF,FCONF,PCONF,DCONF
     1 /.4304,.007373,.003173,.007937,14.505,62.383/
      WRITE(6,1000)
 1000 FORMAT(//10X,'CHF CORRELATIONS - HEAT FLUXES IN BTU/HR-SQ FT  OR
     1 W/SQ CM : POWERS IN KW'/)
      WRITE(6,450)
  450 FORMAT(//10X,'BOILING  LENGTHS',5X,'CHANNELS')
      IFLAG=0
      TOTROD=0.
      DO 120 I=1,NRODS
  120 TOTROD=TOTROD+RODN(I)
      XZTOT=ZTOT/30.48
      XDZ=DZ/2.54
      XP=P*PCONF
      XGTOT=GTOT*FCONF/1000.
      XAREA=AREA/6.4516
      XHIN=HINLET*HCONF
      DELTAH=-XHIN
      XALAM=ALAM*HCONF
      XDIAR=DIAR/2.54
      DO 2 J=1,JMAX
      DO 2 I=1,NRODS
    2 HFNEW(J,I)=HF(J,I)*FICONF*1000000.
      DO 3 I=1,NCHAN
    3 ANEW(I)=A(I)/6.4516
      AVX=0.0
      DO 4 I=1,NCHAN
    4 AVX=AVX+TQUAL(JMAX,I)
      AVX=AVX/NCHAN
```

```
      GBAR=XGTOT*1000000./(XAREA/144.)
      GMBAR=GBAR/1000000.
C     CISE CORRELATION
      PCRIT=3204.
      PRED=XP/PCRIT
      AC=(1-PRED)/((1.356*GMBAR)**0.3333)
      JTOP=JMAX-1
      I=INT(DATA(2040)*1.001)
      PFAVG(I)=0.
      LK=10*(I-1)+2
      DEQ(I)=DATA(400+LK)
      IF(DATA(6).LE.0.) DEQ(I)=DEQ(I)/2.54
      IFLAG = IFLAG+1
      DO 20 J=1,JTOP
      XJ=J
      JX=J+1
      TEST=XQUAL(J,I)*XQUAL(JX,I)
      IF(TEST)30,31,32
   30 BL(I)=XZTOT-XZTOT*(XJ+0.5)/JMAX
      GO TO 21
   31 BL(I)=XZTOT-XZTOT*(XJ+1.)/JMAX
      GO TO 21
   32 IF(J.EQ.JTOP) BL(I)=0.
   20 CONTINUE
   21 CONTINUE
      WRITE(6,460)BL(I),I
  460 FORMAT(' ',11X,E12.6,10X,I2)
      N=NAROD(I)
      DO 40 L=1,N
      LL=KROD(L,I)
      PFAVG(I)=1./PEAKF(LL)+PFAVG(I)
   40 CONTINUE
      PFAVG(I)=PFAVG(I)/N
      BC(I)=167.59*(((1./PRED)-1.)**0.4)*GMBAR*((DEQ(I)/12.)**1.4)
      CHFC(I)=XALAM*GBAR*(ANEW(I)/144.)*AC*PFAVG(I)/(3.14159*(XDIAR/
     112.)*(BL(I)+BC(I)))
      CPC(I)=3.14159*XDIAR/12.*BL(I)*TOTROD*CHFC(I)
      IF(IFLAG.EQ.1) GO TO 9
      IF(CHFC(I).LT.CRITC) CRITC=CHFC(I)
      IF(CPC(I).LT.CRITP1) CRITP1=CPC(I)
      GO TO 10
    9 CRITC=CHFC(I)
      CRITP1=CPC(I)
   10 CONTINUE
      CRITP1=CRITP1/3413.
      CRITP2=CRITP1+(GBAR*XAREA/144.*DELTAH)/3413.
      IF(DATA(6).LE.0.) CRITC=CRITC/3169.781
      WRITE(6,50) CRITC,CRITP1,CRITP2
   50 FORMAT(//10X,'CISE CORRELATION:  CHF',E12.6,5X,'CRIT POWER-BL',
     1E12.6,5X,'BUNDLE CRIT. POWER',E12.6)
C     ISRAEL ROD BUNDLE CORRELATION
    5 CRITIS=1000000.*((0.688+0.144*(GMBAR**1.4))-((0.831+0.221*
     1(GMBAR**2.72))*AVX))
      IF(DATA(6).LE.0.) CRITIS=CRITIS/3169.781
      WRITE(6,60) CRITIS
   60 FORMAT(//10X,'ISRAEL ROD BUNDLE CHF PREDICTION:',E12.6)
C     JANSSEN-LEVY CORRELATION
      X1=0.197-0.108*GMBAR
      X2=0.254-0.026*GMBAR
      IF(AVX.GE.X1) GO TO 70
      CRITJL=1000000.*(0.705+0.237*GMBAR)
```

```
      GO TO 90
   70 IF(AVX.GT.X2) GO TO 80
      CRITJL=1000000.*(1.63-(0.270*GMBAR)-(4.71*AVX))
      GO TO 90
   80 CRITJL=1000000.*(0.605-(0.164*GMBAR)-0.653*AVX)
   90 IF(XP.NE.1000.) CRITJL=CRITJL+440.*(1000.-XP)
      IF(DATA(6).LE.0.) CRITJL=CRITJL/3169.781
      WRITE(6,100) CRITJL
  100 FORMAT(//10X,'JANSSEN-LEVY CHF PREDICTION:',E12.6)
C     BARNETT CHF CORRELATION
      DO 110 I=1,NRODS
      IF(I.EQ.1) GO TO 109
      IF(PEAKF(I).GT.PFMAX) PFMAX=PEAKF(I)
      GO TO 110
  109 PFMAX=PEAKF(I)
  110 CONTINUE
      S=TOTROD/PFMAX
      DHE=4.*XAREA/(3.14159*XDIAR*S)
      DO=(XDIAR*(XDIAR+DHE))**0.5
      EQUIV=DO-XDIAR
      AB=67.47*(DHE**0.68)*(GMBAR**0.192)*(1.-0.744*EXP(-6.512*
     1EQUIV*GMBAR))
      IF(XP.NE.1000.) AB=AB*XALAM/649.
      BB=0.2587*(DHE**1.261)*(GMBAR**0.817)
      CB=185.*(EQUIV**1.415)*(GMBAR**0.212)
      DO 130 J=1,JMAX
      XJ=J
      CHFB(J)=(AB+BB*DELTAH)/(CB+(XJ*XDZ))*1000000.
  130 CONTINUE
      IF(DATA(5).EQ.0.) GO TO 210
      DO 140 J=1,JMAX
  140 PHITOT(J)=0.
      DO 150 J=1,JMAX
      DO 150 I=1,NRODS
  150 PHITOT(J)=RODN(I)*HFNEW(J,I)+PHITOT(J)
      DO 160 J=1,JMAX
  160 PHIBAR(J)=PHITOT(J)/TOTROD
      DO 170 J=1,JMAX
      IF(J.EQ.1) GO TO 169
      IF(PHIBAR(J).GT.PHIMAX) PHIMAX=PHIBAR(J)
      GO TO 170
  169 PHIMAX=PHIBAR(J)
  170 CONTINUE
      DO 180 J=1,JMAX
      F(J)=PHIBAR(J)/PHIMAX
  180 XINT(J)=0.
      DO 200 J=1,JMAX
      XJ=J
      JJ=J-1
      IF(J.EQ.1) GO TO 189
      XINT(J)=XINT(JJ)+(F(J)*XDZ)
      GO TO 190
  189 XINT(J)=XINT(J)+(F(J)*XDZ)
  190 COR(J)=(CB+(XJ*XDZ))/(CB*F(J)+XINT(J))
      XMCRIT(J)=CHFB(J)*COR(J)
      CHFB(J)=XMCRIT(J)/PHIMAX*PHIBAR(J)
  200 CONTINUE
  210 CONTINUE
      DO 220 J=1,JMAX
      IF(J.EQ.1) GO TO 219
      IF(CHFB(J).LT.CRITB) CRITB=CHFB(J)
```

```
      GO TO 220
  219 CRITB=CHFB(J)
  220 CONTINUE
      IF(DATA(6).LE.0.) CRITB=CRITB/3169.781
      WRITE(6,230) CRITB
  230 FORMAT(//10X,'BARNETT CHF PREDICTION:',E12.6)
      RETURN
      END
```

1.4.12 Listing of Subroutine CHEN

```
      SUBROUTINE CHEN
      COMMON /UNI/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,P
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,ULAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX
      COMMON/ARP/QTR(50,20),ALF(50,20),HEL(50,20),GR(50,20),
     1TQUAL(50,20),XQUAL(50,20)
      COMMON DATA(2200)
      COMMON/CH1/ HTCAVG(50,25),TWAVG(50,25),TFAVG(50,25),KFLAG(50,25)
      COMMON /FUEL2/ JJ1,JJ2,JINC,MROD,KCHAN(4,25)
      DIMENSION HTCO(50,20),TW(50,20),TF(50,20)
      DO 1 J=1,50
      DO 1 I=1,20
      HTCO(J,I)=0.
      TW(J,I)=0.
    1 TF(J,I)=0.
      DO 28 K=1,4
      I=KCHAN(K,MROD)
      IF(I.LE.0)GO TO 28
      DO 28 J=JJ1,JJ2,JINC
      TF(J,I)=TSAT+HEL(J,I)/CP
      IF(TQUAL(J,I).GT.0.) GO TO 3
    7 IF(GR(J,I).LE.0.) GO TO 4
    5 HTCO(J,I)    =0.023*((GR(J,I)*HYD(I)/AMU)**0.8)*(PRAND**0.4)*
     1WCON/HYD(I)
      GO TO 2
    4 HTCO(J,I)=50.
      GO TO 2
    3 HSP=0.023*((GR(J,I)*(1.-TQUAL(J,I))*HYD(I)/AMU)**0.8)*
     1(PRAND**0.4)*WCON/HYD(I)
      BEE=2.*SIGMA*TSAT*(1./ROVAP-1./RO)/(ALAM*10.**7)
      DELTS=(4.*BEE*HF(J,MROD)/WCON)**.5
      IF(HEL(J,I).GE.0.) GO TO 6
      IF(GR(J,I).LE.0.) HSP=50.
      PHTEST=HSP*(DELTS+TSAT-TF(J,I))
      IF(PHTEST.GE.HF(J,MROD))GO TO 7
    6 XXTT=1./1.0545*(TQUAL(J,I)/(1.-TQUAL(J,I)))**0.9*(RO/ROVAP)**
     10.474
      IF(XXTT.GE.0.5) GO TO 8
      F=0.5*XXTT*XXTT+0.95*XXTT+1.
      GO TO 9
    8 F=1.6*(2*XXTT)**0.738
    9 IF(HEL(J,I).LT.0.)F=1
      HSP=HSP*F
      RETP=(GR(J,I)*(1.-TQUAL(J,I))*HYD(I)/AMU)*(F**1.25)
      IF(RETP.LE.0.) GO TO 10
      IF(RETP.GE.3.0E05) GO TO 11
      S=0.17-0.232*ALOG(RETP/3.0E05)
      GO TO 12
   11 S=0.17-0.0617*ALOG(RETP/3.0E05)
      GO TO 12
   10 S=1.
   12 B=(WCON**0.79*CP**0.45*RO**0.49)/(SIGMA**0.5*AMU**0.29*ALAM**0.24
     1*ROVAP**0.24)
      ACHEN=0.00122*B*S
      TNEW=TSAT+DELTS
```

```
      PSAT=P*1000000.
      IC=0
      IFLAG=0
   13 TFAC=ABS(0.65-(0.01*TNEW))
      PNEW=220.88*EXP((1000./(TNEW+273.15))*1.0E-5*(374.136-TNEW)*((
     1-741.9242)+(29.72100*TFAC)+(-11.55286*(TFAC**2.))+(0.8685635*
     2(TFAC**3.))+(0.1094098*(TFAC**4.))+(-0.439993*(TFAC**5.))+
     3(0.2520658*(TFAC**6.))+(-5.218684E-2*(TFAC**7.))))
      IC=IC+1
      IF(IC.GT.100) GO TO 26
      PNEW=PNEW*1000000.
      HTP=ACHEN*(TNEW-TSAT)**0.24*(PNEW-PSAT)**0.75
      IF(GR(J,I).LE.0.) HSP=0.
      IF(HEL(J,I).GE.0.) GO TO 14
      PHINEW=HSP*(TNEW-TF(J,I))+HTP*(TNEW-TSAT)
      GO TO 15
   14 PHINEW=(HSP+HTP)*(TNEW-TSAT)
   15 TESTPH=(ABS(PHINEW-HF(J,MROD)))/HF(J,MROD)
      IF(TESTPH.LE.0.01) GO TO 16
      IF(IC.GT.1) GO TO 17
   18 PHIOLD=PHINEW
      TOLD=TNEW
      IF(PHINEW-HF(J,MROD))19,16,20
   19 TNEW=TNEW+10.
      GO TO 13
   20 TNEW=TNEW-10.
      GO TO 13
   17 TEST2=(PHIOLD-HF(J,MROD))/(PHINEW-HF(J,MROD))
      IF(IFLAG.EQ.1) GO TO 21
      IF(TEST2.GT.0.) GO TO 18
      IFLAG=1
      IF(PHINEW-HF(J,MROD))22,22,23
   22 PHIHI=PHIOLD
      PHILO=PHINEW
      THI=TOLD
      TLO=TNEW
      GO TO 24
   23 PHILO=PHIOLD
      PHIHI=PHINEW
      THI=TNEW
      TLO=TOLD
   24 SLOPE=(PHIHI-PHILO)/(THI-TLO)
      TNEW=(HF(J,MROD)+(SLOPE*THI)-PHIHI)/SLOPE
      GO TO 13
   21 IF(PHINEW.GT.HF(J,MROD))GO TO 25
      PHILO=PHINEW
      TLO=TNEW
      GO TO 24
   25 PHIHI=PHINEW
      THI=TNEW
      GO TO 24
   16 TW(J,I)=TNEW
      IF(HEL(J,I).GE.0.) GO TO 26
      PHITRU=HSP*(TW(J,I)    -TF(J,I))+HTP*(TW(J,I)     -TSAT)
      HTCO(J,I)    =PHITRU/(TW(J,I)    -TF(J,I))
      GO TO 2
   26 HTCO(J,I)    =HSP+HTP
    2 CONTINUE
      IF(DATA(5).LE.0.)GO TO 27
      HTCO(J,I)=HTCO(J,I)*1761.545
      TW(J,I)=TW(J,I)*1.8+32.
```

```
   27 IF(HTCO(J,I).GT.0.)KFLAG(J,MROD)=KFLAG(J,MROD)+1
      HTCAVG(J,MROD)=HTCAVG(J,MROD)+HTCO(J,I)
      TWAVG(J,MROD)=TWAVG(J,MROD)+TW(J,I)
   28 CONTINUE
      DO 100 J=JJ1,JJ2,JINC
      HTCAVG(J,MROD)=HTCAVG(J,MROD)/KFLAG(J,MROD)
      TWAVG(J,MROD)=TWAVG(J,MROD)/KFLAG(J,MROD)
  100 TFAVG(J,MROD)=TWAVG(J,MROD)-HF(J,MROD)/HTCAVG(J,MROD)
      WRITE(6,1000) MROD
 1000 FORMAT(//5X,'ROD NO.',I4,//5X,'AX NODE',5X,'AVG HTC',5X,'AVG TW',
     1 5X,'AVG TF'/)
      DO 200 J=JJ1,JJ2,JINC
  200 WRITE(6,500)J,HTCAVG(J,MROD),TWAVG(J,MROD),TFAVG(J,MROD)
  500 FORMAT(/7X,I2,5X,F9.3,3X,F8.3,4X,F8.3)
      WRITE(6,2000)
 2000 FORMAT(//5X,'SUBCH',5X,'AX NODE',5X,'LOC HTC',5X,'LOC TW'/)
      DO 400 J=JJ1,JJ2,JINC
      DO 400 K=1,4
  400 WRITE(6,700)KCHAN(K,MROD),J,HTCO(J,I),TW(J,I)
  700 FORMAT(/7X,I2,8X,I2,5X,F9.3,3X,F8.3)
      RETURN
      END
```

1.4.13 Listing of Subroutines FUEL and FVS12

```
      SUBROUTINE FVS12 (F,K,X,V)
      IF(X) 10,20,20
   10 C=-1.
      GO TO 30
   20 C=1.
   30 IF(K-1) 40,50,60
   40 V=ABS(F-1.)*(1.-3.*X**2+C*2.*X**3)+ABS(F-2.)*(X*(1.-C*X)**2)
      GO TO 100
   50 V=ABS(F-1.)*(-6.*X+C*6.*X**2)+ABS(F-2.)*(1.-C*X)*(1.-3.*C*X)
      GO TO 100
   60 V=ABS(F-1.)*(12.*C*X-6)+ABS(F-2.)*C*(6.*C*X-4.)
  100 RETURN
      END
      SUBROUTINE FUEL
C *** CALCULATES FUEL TEMPERATURE DISTRIBUTION IN THE RADIAL DIRECTION
      COMMON /UNT/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,P
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FFLC(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PFDAC,DERP,NCHAN,JMAX
      COMMON /DISP/ ISHAP,AXPKF,ZTOT,DIAR,NDRIFT
      COMMON/TABL/PEAKF(25),AXSHF(50),IPRESS,CPRESS(5),IVINL,CVIN(5),
     1ITIN,CTIN(5),IPOW,CPOW(5),PTAB(100),QTAB(100),HTAB(100),PWTAB(100)
      COMMON DATA(2200)
      COMMON/PRINT/T,ICON,RDPW(25) ,THIN,PERI
      COMMON/CH1/ HTCAVG(50,25),TWAVG(50,25),TFAVG(50,25),KFLAG(50,25)
      COMMON /FUEL1/ NF,NC,KF,KC,CPF,CPC,RHOF,RHOC,HGAP,RC,RG,RCS,RFS,
     1 RCI,Q1
      COMMON /FUEL2/ JJ1,JJ2,JINC,MROD,KCHAN(4,25)
      COMMON /FUEL3/ TPRI,PRN
      DOUBLE PRECISION CNEW(20)
      REAL KF,KC
      L=MROD
      PRN=PRIN
      NF1=NF+1
      DELF=RFS/NF
      DELC=(RCS-RCI)/NC
      DT=DT/3600.
      JC=2
      NPF=45
      NPA=50
      DDF=RFS/(NPF-1)
      IF(TPRI.EQ.PRIN) WRITE(6,460)
  460 FORMAT(//,30X,' FUEL TEMPERATURE PROFILE'//13X,'R',15X,'T',15X,
     1 'DT/DP',12X,'HF'/)
      DDC=(RCS-RCI)/(NPA-NPF-1)
      DO 21 J=JJ1,JJ2,JINC
      Q1=HF(J,L)*DIAR*3.14159
      CALL TRANST(CNEW,J,L)
      DO 21 I=1,NPA
      IF(I.GT.NPF) GO TO 300
      D=(I-1)*DDF
      IJ=D/DELF
      XHF=DELF*FLOAT(IJ)
      SMALL=ABS(D-XHF)
      IF(D.EQ.0.) GO TO 22
      IF(SMALL.LE.1.0E-10) GO TO 23
      I1=IJ+1
      X=(D-IJ*DELF)/DELF
      Y=(D-(IJ+1)*DELF)/DELF
```

```
      T1=T1*1.8*30.48
      Q2=Q2*3.412*(30.48**2)
  200 WRITE(6,450)D,AT,T1,Q2
  450 FORMAT(6(5X,E12.5))
   21 CONTINUE
      RETURN
      END
```

1.4.14 Listing of Subroutine EDIT

```
      SUBROUTINE EDIT
C *** PRINTOUT ROUTINE
      LOGICAL ICON
      COMMON /UNIT/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAP,ZUBER,P
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,ULAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      COMMON/GEN/NAROD(20),KROD(4,20),HF(50,25),VINLET(20),GINLET(20),
     1HINLET,GTOT,POWER,CHANN(20),A(20),FF_C(10,20),
     2NRODS,GTFAC,GTUR,AVHYD,VIZERO,TFIN,PZERO,HZERO,POWO,IBLOC,
     3LBLOC,T1BL,T2BL,FBL1,FBL2,PRIN,MDPR,
     4HYD(20),LOC(10),HPER(4,20),PEDAC,DERP,NCHAN,JMAX
      COMMON/RESVE/VEAV(20),GOUT(20),GOUTV(20),GOUTL(20),XOUT(20),
     1 EOUT(20),RAL(20)
      COMMON/RES/ ITER(50),PDROP(50),TEOUT,FMOUT,PACC,TBAL,AVX,DPTOT
      COMMON /ARR/   QTR(50,20),ALF(50,20),HFL(50,20),GP(50,20),
     1 TQUAL(50,20),XQUAL(50,20)
      COMMON/PRINT/T,ICON,PDPW(25) ,THIN,PERI
      COMMON/GEOM/JOIN(20),NJOIN(20,4),MCIRC(20),SL(4,20),NOCIR,
     1PODM(25),AREA,IDOP
      DIMENSION STRING(10),FNI(20)
C ***  OUTPUT ROUTINE
      DATA HCONF,GCONF,FICONF,FCONF,PCONF,DCONF
     1 /0.4304,0.007373,0.003173,0.007937,14.503,62.383/
      DATA VCONF/0.1271/
      PRESS=P
      TST=TSAT
      IF(ICON)TST=32.+1.8*TST
      IF(ICON)PRESS=PCONF*P
      GAVST=GTOT/AREA
      IF(ICON)GAVST=GCONF*GAVST
      WRITE(6,1)T,PRESS,TST,GAVST
    1 FORMAT(1H0,//15X,'TIME=',F10.4,' SEC',2X,'PRESSURE',F9.3,
     1 '  TSAT',F8.2,'  GAV',F11.4)
      TOAVVF=0.
      DO 3 I=1,NCHAN
    3 TOAVVF=TOAVVF+A(I)*VEAV(I)*CHANN(I)
      TOAVVF=TOAVVF/AREA
      AVDEN=RO*(1.-TOAVVF*(1.-GAMMA))
      WRITE(6,2)
    2 FORMAT(1H0,2X,'POWER',8X,'GTOT',7X,'FMOUT',8X,'TBAL',9X,'AVX',7X,
     1 'DPTOT',6X,'TOAVVF',7X,'AVDEN',6X,'HINLET')
      IF(ICON)GO TO 102
      WRITE(6,101)
  101 FORMAT(1H ,3X,'WATT',8X,'KG/SEC',6X,'KG/SEC',7X,'WATT',20X,'BAR',
     1 19X,'G/CU-CM',3X,'JOULE/G')
      GO TO 104
  102 WRITE(6,103)
  103 FORMAT(1H ,3X,'WATT',6X,'MLB/HR',6X,'MLB/HR',7X,'WATT',20X,'PSI',
     1 19X,'LB/CU-FT',3X,'BTU/LB')
  104 CONTINUE
      STRING(1)=POWER
      STRING(2)=GTOT
      STRING(3)=FMOUT
      STRING(4)=TBAL
      STRING(5)=AVX
      STRING(6)=DPTOT
      STRING(7)=TOAVVF
      STRING(8)=AVDEN
      STRING(9)=HINLET
      STRING(2)=0.001*STRING(2)
```

```
      STRING(3)=0.001*STRING(3)
      STRING(6)=0.000001*STRING(6)
      IF(.NOT.ICON)GO TO 23
   21 STRING(2)=ECONF*STRING(2)
      STRING(3)=ECONF*STRING(3)
      STRING(6)=PCONF*STRING(6)
      STRING(8)=QCONF*STRING(8)
      STRING(9)=HCONF*STRING(9)
   23 WRITE(6,22)(STRING(N),N=1,9)
   22 FORMAT(9E12.5)
      WRITE(6,50)
   50 FORMAT(1H0,' CHAN',5X,'XOUT',8X,'GOUT',7X,'GOUTV',7X,'GOUTL',6X,
     1 'GINLET',9X,'BAL',9X,'ENI',8X,'VFAV')
      DO 150 I=1,NCHAN
      KR=NAROD(I)
      SAVE=0.
      DO 151 K=1,KR
      KRO=KROD(K,I)
  151 SAVE=SAVE+RDPW(K)*HPER(K,I)/PERI
  150 ENI(I)=SAVE
      IF(.NOT.ICON)GO TO 25
      DO 26 I=1,NCHAN
      GOUT(I)=GCONF*GOUT(I)
      GOUTV(I)=GCONF*GOUTV(I)
      GOUTL(I)=GCONF*GOUTL(I)
      GINLET(I)=GCONF*GINLET(I)
   26 CONTINUE
   25 CONTINUE
      WRITE(6,5)(I,XOUT(I),GOUT(I),GOUTV(I),GOUTL(I),GINLET(I),BAL(I),
     1 ENI(I),VFAV(I),I=1,NCHAN)
    5 FORMAT(I5,9E12.5)
      RETURN
      ENTRY EDIT2
      DO 10 I=1,NCHAN
      KR=NAROD(I)
      WRITE(6,11)I,T
   11 FORMAT(1H1,20X,'SUBCH',I4,5X,'TIME',F10.4/
     1 2X,'NODE',6X,'HL',10X,'TQ',11X,'G',9X,'QTR',7X,'ALPHA',7X,
     2 'FIMAX',11X,'X',7X,'PDROP',6X,'ITER')
      IF(ICON)GO TO 13
   12 WRITE(6,14)
   14 FORMAT(1H ,8X,'JOULE/G',16X,'G/SQ-CM S  CU-CM/SEC ',14X,
     1 'WATT/SQ-CM',16X,'BAR')
      GO TO 15
   13 WRITE(6,141)
  141 FORMAT(1H ,9X,'BTU/LB',15X,'MLB/SQ-FT H CU-FT/HR',16X,
     1 'BTU/SQ-FT HR',14X,' PSI')
   15 DO 15 J=1,IMAX
      STRING(1)=HFL(J,I)
      STRING(2)=TQUAL(J,I)
      STRING(3)=GR(J,I)
      STRING(4)=QTR(J,I)
      STRING(5)=ALF(J,I)
      FIMAX=0.
      DO 200 K=1,KR
      KRO=KROD(K,I)
      IF(HF(J,KRO).GT.FIMAX)FIMAX=HF(J,KRO)
  200 CONTINUE
      STRING(6)=FIMAX
      STRING(7)=XQUAL(J,I)
      STRING(8)=PDROP(J)
```

```
STRING(6)=1.E-6*STRING(6)
IF(.NOT.ICON)GO TO 20
STRING(1)=HCONE*STRING(1)
STRING(4)=VECON*STRING(4)
STRING(3)=GCONE*STRING(3)
STRING(5)=FICONE*STRING(5)

RETURN
END
```

1.4.15 Listings of Subroutines WATER and HYDP

```
      SUBROUTINE WATER(P)
C *** WATER PROPERTIES FITTING FUNCTIONS
      COMMON /UNT/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,PR
      COMMON /PROP/RO,ROVAP,HVAP,HSAT,ALAM,DLAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,PROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      EQUIVALENCE (VISC,AMU),(HLAT,ALAM),(SURT,SIGMA)
C *** WATER PROPERTIES FITTINGS
      PP=1.01972*P
      TSAT=285.8+(P-70.)-0.00555*(P-70.)*(P-70.)
      HSAT=787.428*(1.+9.366E-3*PP-1.279E-5*PP*PP)
      HVAP=2793.36*(1.+2.717E-4*PP-5.3E-6*PP*PP)
      ROVAP=0.03664+0.59E-3*(P-70.)+1.2E-6*(P-70.)*(P-70.)
      WCON=0.006963*(1.-3.042E-3*PP+5.672E-6*PP*PP)
      VISC=0.15098E-2*(1.-8.6437E-3*PP+4.61E-5*PP*PP)
      CP=4.64+0.014*(P-30.)+0.00004*(P-30.)*(P-30.)
      GAMMA=ROVAP/RO
      HLAT=HVAP-HSAT
      TT=315.55-TSAT
      SURT=11.7+0.235*TT-0.5E-5*TT**3.
      GAMLA=GAMMA*HLAT
C *** OTHER PRESSURE DEPENDENT PARAMETERS
      DATA PPC/221.9/
      DATA  BANK /0.815/
      AFRIC=155.044*(1.-1.4517E-2*PP+5.021E-5*PP*PP)
      BFRIC=-132.322*(1.-1.135E-2*PP+4.3716E-5*PP*PP)
      AK=BANK+(1.-BANK)*P/PPC
      VDRIFT=ZUBER*(GRAD*SURT*(1.-GAMMA)/RO)**.25
      IF(IDOWN.GT.0)VDRIFT=-VDRIFT
      HB=2.54E-04*EXP(0.0632*PP)
      PRAND=CP*VISC/WCON
      HCO=0.023*WCON*PRAND**0.4
      RETURN
      END
```

```
      SUBROUTINE HYDP(REY,DIAH,GG)
C *** EVALUATES HYDRAULIC PROPERTIES
      LOGICAL IBB,IREV,IFREV,ITRA,ILOC
      COMMON /UNI/DZ,DT,VZERO,AN,AN1,ZE,R,FL,FV,CPAR,ZUBER,P
      COMMON /PROP/PO,ROVAP,HVAP,HSAT,ALAM,ULAM,DHSAT,GAMMA,GAMLA,ROVRA,
     1HCO,GRAD,IDOWN,TSAT,PRAND,HB,RROUGH,AFRIC,BFRIC,ANM,
     2AK,AMU,WCON,SIGMA,VDRIFT,ROGRAV,DZUMG,CP,RERGH(20)
      COMMON/CONT/FI(4),IBB,IREV,IFREV,ITRA,ILOC,TETA,APAR,TIN,H,HP,TW,
     1PSI,HOLD,VFOLD,VFIN,HBAR,TD,AA,AJIN,AJVIN,HLINJ,HIN,GFLIN,GOLD,Q,
     2OV,OL,FFAC,FFLOC,AJ,AJV,AJL,VF,HL,G,DPF,DP,DPEXC,SAVEN,QP,PH(4),
     3XT,KR,GFLUX
      HP=HB
      HC=HCO*REY**0.8
      H=HC
      TETA=(HC/HB/AN)**ANM
      FSAVE=FFACT(REY,RROUGH)
      FFAC=0.5*FSAVE/DIAH
      RETURN
      END
```

1.4.16 Listings of Functions TIMEF, FFACT, TPFM and TFLM

```
      FUNCTION TIMEF(T,I,A,X,TAB)
C *** LINEAR FITTING OF INPUT TIME TABLES
      DIMENSION A(5),TAB(100)
      GO TO (1,2,3),I
    1 K=1
    4 K=K+1
      L=K+50
      IF(TAB(K).LE.0..OR.K.EQ.51)GO TO 10
      IF(T-TAB(K))6,5,4
    5 TIMEF=X*TAB(L)
      RETURN
    6 TIMEF=X*(TAB(L-1)+(TAB(L)-TAB(L-1))*(T-TAB(K-1))/(TAB(K)-TAB(K-1))
     1 )
      RETURN
   10 TIMEF=X*TAB(L-1)
      RETURN
    2 TIMEF=X*(1.+A(1)*SIN(A(2)*T))
      RETURN
    3 TIMEF=X*(1.+A(1)*T+A(2)*T*T+A(3)*T*T*T+A(4)*T**4+A(5)*T**5 )
      RETURN
      END
```

```
      FUNCTION FFACT(REY,ROUGH)
C *** FRICTION FACTOR CORRELATION
C *** FRICTION FACTOR
      FFACT=0.0055*(1.+(20000.*ROUGH+1.E+6/REY)**0.33333)
      RETURN
      END
      FUNCTION TPFM(XT,AFRIC,BFRIC)
C *** TWO PHASE FLOW MULTIPLIER CORRELATION
      TPFM=1.
      IF(XT.LE.0)RETURN
      TPFM=1.+XT*(AFRIC+XT*BFRIC)
      RETURN
      END
      FUNCTION TFLM(Q,VF,GAM)
C *** LOCAL TWO PHASE FLOW MULTIPLIER CORRELATION
      TFLM=1.
      IF(VF.LE.0.)RETURN
      TFLM=(1.-Q)*(1.-Q)/(1.-VF)+Q*Q/VF/VF/GAM
      RETURN
      END
```

1.4.17 Listings of Subroutines INIT, INVERT and TRANSI

```
      SUBROUTINE INIT
C *** SETS THE ARRAYS IN COMMON TO ZERO
      COMMON/GEN/NAROD(20).KROD(4.20).HF(50.25).VINLET(20),GINLET(20).
     1HINLET.GTOT.POWER.CHANN(20).A(20).FFLC(10.20).
     2NRODS.GTFAC,GTUR.AVHYD.VIZERO.TFIN,PZERO.HZERO.POWO.IBLOC.
     3LBLOC.T1BL.T2BL.FBL1.FBL2.PRIN,MDPR,
     4HYD(20).LOC(10).HPER(4.20),PFDAC.DEPP.NCHAN.JMAX
      COMMON /FUEL2/ JJ1.JJ2.JINC.MROD.KCHAN(4.25)
      COMMON /FUEL3/ TPRT.PPN
      COMMON/CH1/ HTCAVG(50.25),TWAVG(50.25).TFAVG(50,25).KFLAG(50,25)
      DO 1 J=1,50
      DO 1 I=1.25
      HF(J.I)=0.
      HTCAVG(J.I)=0.
      TFAVG(J.I)=0.
      KFLAG(J.I)=0
      TWAVG(J.I)=0.
    1 CONTINUE
      DO 2 J=1.20
      NAROD(I)=0
      DO 2 K=1.4
      KROD(K.I)=0
    2 CONTINUE
      DO 3 K=1.4
      DO 3 I=1.25
      KCHAN(K.I)=0
    3 CONTINUE
      PRIN=0.
      TPRT=0.
      RETURN
      END
```

```
      SUBROUTINE INVERT(N,TMAT,A,V,KK,NERR)
C *** INVERTS THE CONNECTION MATRIX
      DIMENSION TMAT(40,40),A(40,40),WKAREA(2000)
      DOUBLE PRECISION B(40,40),BI(40,40)
      DO 1 I=1,N
      DO 1 K=1,N
    1 B(I,K)=TMAT(I,K)
      CALL LINV2F(B,N,40,BI,5,WKAREA,IER)
      DO 2 I=1,N
      DO 2 K=1,N
    2 A(I,K)=BI(I,K)
      RETURN
```

```
      SUBROUTINE TRANSI(XC,L1,L2)
C *** EVALUATES NODAL COEFFICIENTS
      COMMON /UNT/DZ,DT,VZERO,AN,AN1,ZE,P,FL,FV,CPAR,ZUBER,P
      COMMON /FUEL1/ NF,NC,KF,KC,CPF,CPC,RHOF,RHOC,HGAP,RC,RG,RCS,RFS,
     1 RCI,Q1
      COMMON/CH1/ HTCAVG(50,25),TWAVG(50,25),TFAVG(50,25),KFLAG(50,25)
      COMMON/PRINT/T,ICON,RDPW(25) ,THIN,PERI
      COMMON /FUEL3/ TPRT,PPN
      DIMENSION XNODE(20),XP(20),WKAREA(500)
      DOUBLE PRECISION XA(20,20),XC(20),XB(20),XT(20)
      REAL KF,KC
      J2=2
      ALPHAF=KF/(CPF*RHOF)
      ALPHAC=KC/(CPC*RHOC)
      DELF=RFS/NF
      DELC=(RCS-RCI)/NC
      NF1=NF+1
      NF2=NF1+1
      NT=NF+NC
      NT1=NT+1
      NT2=NT1+1
      NODE=(NF+NC)*2
      NEQS=NODE+4
      Q3=Q1/(3.14159*RFS**2)
      MGAP=NEQS-(2*NC)-1
      Q2CS=Q3*RFS**2/(2.*RCS)
      Q2GAP=Q3*RFS**2/(RFS+RCI)
      IF(T.GT.0.) GO TO 2000
      TB=TFAVG(L1,L2)
 1000 TCS=TB+Q3*RFS**2/(2.*RCS*HTCAVG(L1,L2))
      TCI=TCS+(Q3*RFS**2/(2.*KC))*ALOG(RCS/RCI)
      TFS=TCI+Q2GAP/HGAP
      XN=0.
      DO 10 I=1,NF1
   10 XNODE(I)=XN+(I-1)*DELF
      XN=XNODE(NF1)+RG
      DO 11 I=NF2,NT2
   11 XNODE(I)=XN+(I-NF2)*DELC
      K=1
      DO 12 I=1,NT1
      IF(I.EQ.NF1) GO TO 12
      DO 12 J=1,2
      CF=(-1.)**J
      XP(K)=0.5*(XNODE(I)+XNODE(I+1))+CF*(XNODE(I+1)-XNODE(I))/
     1(2.*1.732)
      K=K+1
   12 CONTINUE
 2000 DO 7 I=1,NEQS
      DO 7 J=1,NEQS
    7 XA(I,J)=0.
      L=NODE
      I=NEQS
   14 IF(I-NEQS) 15,16,16
   16 CKHD=KC/(HTCAVG(L1,L2)*DELC)
      DO 25 K=1,J2
      F=FLOAT(K)
      CALL FVS12 (F,0,0.,V0)
      CALL FVS12 (F,0,1.,V1)
      CALL FVS12 (F,1,0.,V10)
      CALL FVS12 (F,1,1.,V11)
      XA(I,(NF+NC)*J2+K)=V1+CKHD*V11
```

```
 25 XA(I,(NF+NC+1)*J2+K)=V0+CKHD*V10
    XB(I)=TB
    GO TO 13
 15 IF(I-MGAP) 17,18,19
 17 IF(I-1) 20,20,21
 19 I1=(XR(L )-RCI)/DELC
    X=(XR(L )-RCI-I1*DELC)/DELC
    Y=(XR(L )-RCI-(I1+1)*DELC)/DELC
    IF(T.GT.0.) GO TO 202
201 DO 26 K=1,J2
    F=FLOAT(K)
    CALL FVS12 (F,0,X,VX)
    CALL FVS12 (F,0,Y,VY)
    XA(I,(I1+NF+1)*J2+K)=VX
 26 XA(I,(I1+NF+2)*J2+K)=VY
    XB(I)=TCS+(Q3*RFS**2/(2.*KC))*ALOG(RCS/XR(L ))
    GO TO 203
202 CK=ALPHAC*DT/DELC
    TOLD=0.
    DO 39 K=1,J2
    F=FLOAT(K)
    CALL FVS12 (F,0,X,VX)
    CALL FVS12 (F,1,X,V1X)
    CALL FVS12 (F,2,X,V2X)
    CALL FVS12 (F,0,Y,VY)
    CALL FVS12 (F,1,Y,V1Y)
    CALL FVS12 (F,2,Y,V2Y)
    XA(I,(I1+NF+1)*J2+K)=VX-CK*((V1X/XR(L ))+(V2X/DELC))
    XA(I,(I1+NF+2)*J2+K)=VY-CK*((V1Y/XR(L ))+(V2Y/DELC))
    IJ=(I1+NF+1)*J2+K
    IJ1=(I1+NF+2)*J2+K
 39 TOLD=TOLD+XC(IJ)*VX+XC(IJ1)*VY
    XB(I)=TOLD
203 L=L-1
    GO TO 13
 18 GAPC=KC/(HGAP*DELC)
    DO 27 K=1,J2
    F=FLOAT(K)
    CALL FVS12 (F,0,1.,V1)
    CALL FVS12 (F,0,0.,V0)
    CALL FVS12 (F,0,-1.,VN1)
    CALL FVS12 (F,1,0.,V10)
    CALL FVS12 (F,1,-1.,V1N1)
    XA(I,(NF-1)*J2+K)=V1
    XA(I,NF*J2+K)=V0
    XA(I,(NF+1)*J2+K)=GAPC*V10-V0
 27 XA(I,(NF+2)*J2+K)=GAPC*V1N1-VN1
    XB(I)=0.
    I=I-1
    GAPF=KF/(HGAP*DELF)
    DO 28 K=1,J2
    F=FLOAT(K)
    CALL FVS12 (F,0,0.,V0)
    CALL FVS12 (F,0,1.,V1)
    CALL FVS12 (F,0,-1.,VN1)
    CALL FVS12 (F,1,0.,V10)
    CALL FVS12 (F,1,1.,V11)
    XA(I,(NF-1)*J2+K)=V1+GAPF*V11
    XA(I,NF*J2+K)=V0+GAPF*V10
    XA(I,(NF+1)*J2+K)=-1.*V0
 28 XA(I,(NF+2)*J2+K)=-1.*VN1
```

```
      XB(I)=0.
      GO TO 13
  21  I1=XR(L)/DELF
      X=(XR(L)-I1*DELF)/DELF
      Y=(XR(L)-(I1+1)*DELF)/DELF
      IF(T.GT.0.) GO TO 205
 204  DO 29 K=1,J2
      F=FLOAT(K)
      CALL FVS12 (F,0,X,VX)
      CALL FVS12 (F,0,Y,VY)
      XA(I,I1*J2+K)=VX
  29  XA(I,(I1+1)*J2+K)=VY
      XB(I)=TFS+Q3*(RFS**2-XR(L )**2)/(4.*KF)
      GO TO 206
 205  FK=ALPHAF*DT/DELF
      TOLD=0.
      DO 42 K=1,J2
      F=FLOAT(K)
      CALL FVS12 (F,0,X,VX)
      CALL FVS12 (F,1,X,V1X)
      CALL FVS12 (F,2,X,V2X)
      CALL FVS12 (F,0,Y,VY)
      CALL FVS12 (F,1,Y,V1Y)
      CALL FVS12 (F,2,Y,V2Y)
      XA(I,I1*J2+K)=VX-FK*((V1X/XR(L ))+(V2X/DELF))
      XA(I,(I1+1)*J2+K)=VY-FK*((V1Y/XR(L ))+(V2Y/DELF))
      IK=I1*J2+K
      IK1=(I1+1)*J2+K
  42  TOLD=TOLD+XC(IK)*VX+XC(IK1)*VY
      XB(I)=TOLD+ALPHAF*DT*Q3/KF
 206  L=L-1
  13  CONTINUE
      I=I-1
      GO TO 14
  20  DO 400 K=1,J2
      F=FLOAT(K)
      CALL FVS12 (F,1,0.,V10)
      CALL FVS12 (F,1,-1.,V1N1)
      XA(I,K)=V10
 400  XA(I,J2+K)=V1N1
      XB(I)=0.
      DO 45 I=1,NEQS
  45  XT(I)=XB(I)
      EPS=1.0E-7
      K=1
      CALL LEQT1F(XA,1,NEQS,20   ,XB,3,WKAREA,IER)
      DO 24 I=1,NEQS
  24  XC(I)=XB(I)
      RETURN
       END
```

1.5 Some Additional Remarks on the Volumetric Crossflow Coefficient Matrix and the Recirculation Loop Concept

1.5.1 Subroutine MATSET

The subroutine MATSET sets up the boundary numbering scheme and the connection matrix to be used for the solution of the net volumetric crossflows between subchannels in the subroutine SOLMAT.

1.5.1.1 Objectives and Solution Scheme

The logic of MATSET, which is of main interest for the solution, is outlined below: Note that in any case, the connection matrix, which is representative of the geometrical layout and recirculation loops, is set up only once for the given problem and is therefore inverted consequently once in the subroutine INVERT, which will be described in the next section.

a) Initialization of all arrays to be used for the inversion process.

```
   DO     12     I = 1,40
   DO     12     J = 1,40
   XLU (40,40) = 0.
   TMATI (40,40) = 0.
12 TMAT (40,40) = 0.
```

b) Set up of the maximum number of connections (common boundaries) for the given problem by:

MATDIM = NCHAN + NOCIR - 1   (1)

where

NCHAN = number of subchannels in the bundle

NOCIR = number of recirculation loops in the bundle

MATDIM is then the number of boundaries for the given problem; i.e. if NCHAN = 8

NOCIR = 3

MATDIM = 10 which is exactly the number of boundaries of the problem shown in Fig. 10.

Note that Eq. (1) is valid for any type of subchannel layout. For the bundle shown in Fig. 16 the only axis of symmetry coincides with the second column of rods. In this case where only 8 subchannels representing the thermal-hydraulic condition of the bundle are analyzed, the number of boundaries is (8 + 3 -1) = 10.

For the bundle shown in Fig. 11 where another type of subchannel layout must be selected to analyze the whole bundle, the axis of symmetry coincides with the principal diagonal. For this case the number of boundaries, i.e. also the number of volumetric cross flows, is (10 + 3 - 1) = 12.

c. IPNTR is used as an index to be incremented by the loop which sets up the boundaries. Note that the boundaries are numbered from the top to the bottom and from left to right of the array of subchannels (See Figs.).

The variable NTW (I,J.) is the gap width between channels I and J ($1 \leqslant I, J \leqslant NCHAN$). Simultaneously, the DO loop 6005 sets up the connection matrix using TMAT (I, J) as the current index for the matrix elements. ($1 \leqslant I,J \leqslant MATDIM$). Note that this is not the connection matrix used for net volumetric cross flows solution. The set up of the numbering scheme of the recirculation loops, accordin to a set of given input data and the check for consistency, is done by the following statements:

```
        DO      500     NN = 1,4
500     IF(NN) = MOD(MCIRC*C1), ID** (Z*NN))/10**(2*NN-2)
        IF (IF(4). Eq.0)     GO TO 6006
        IJ(5) = IJ(1)
        II = 5
        KK = 4
        GO TO 6007
6006    IF(4) = IJ(1)
        II = 4
        KK = 3
6007    WRITE (6,650)  (IJ(J), J = 1, KK)
```

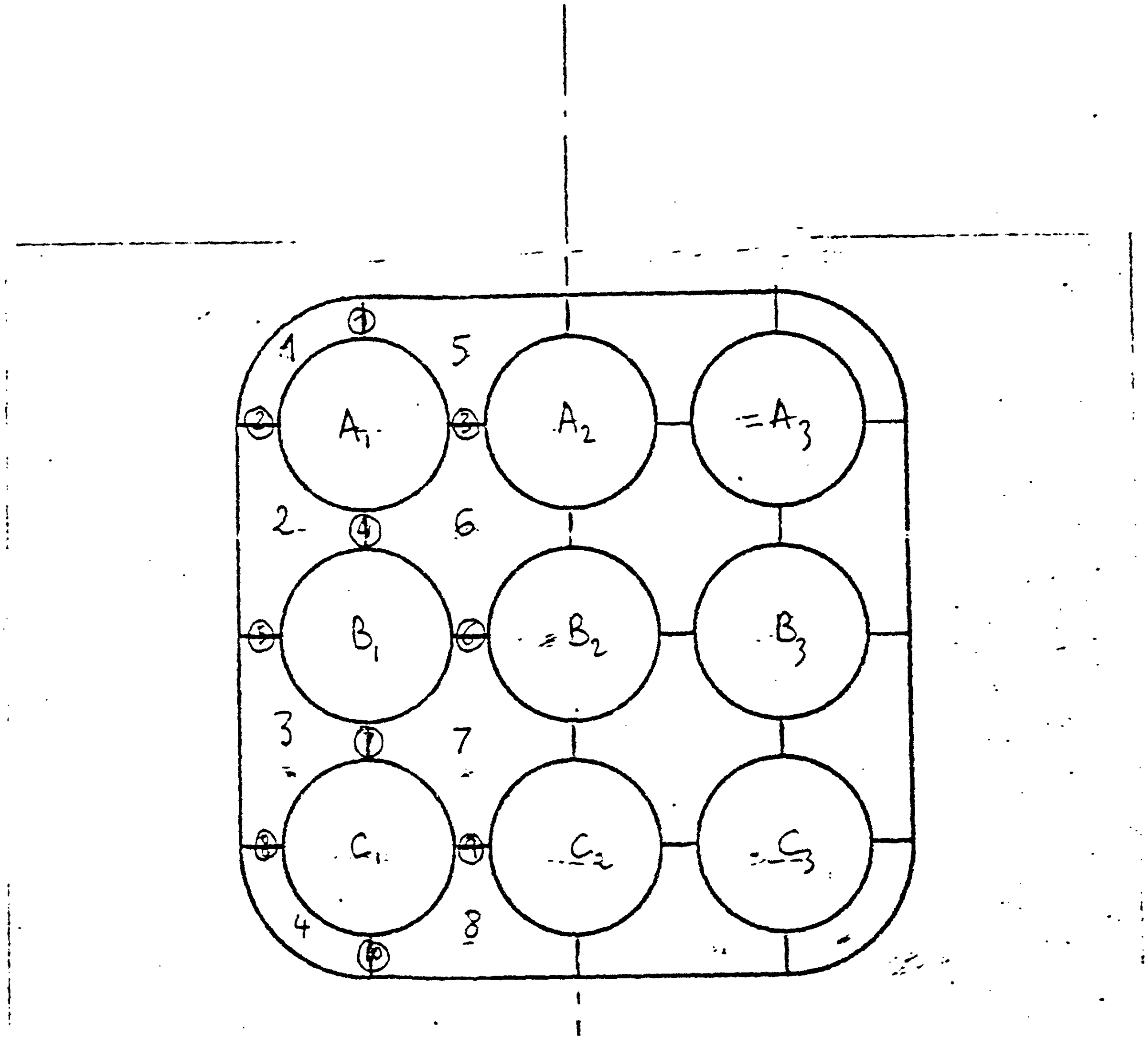

Fig. 16: 8-Subchannels Case (with axis of symmetry)

Note: 3 Recirculation loops around A_1, B_1, C_1.
8 Subchannels

MATDIM = 3 + 8 - 1 = 10 boundaries

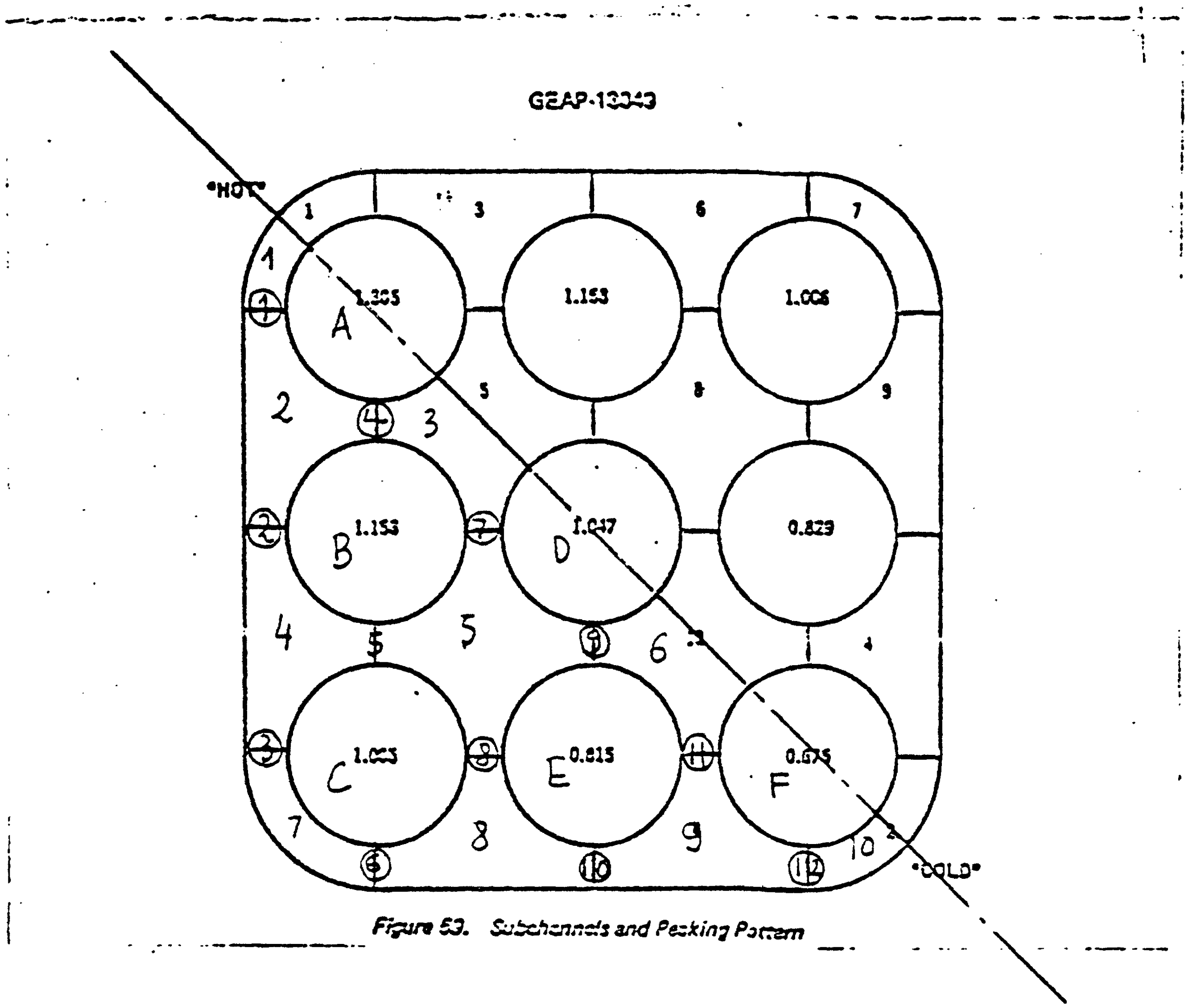

Figure 53. Subchannels and Peaking Pattern

Fig. 17: 10-Subchannels array (with axis of symmetry

Note: 3 Recirculation loops (around rods B, C, E)

10 Subchannels

MATDIM = 10 + 3 - 1 = 12 boundaries

Note that for the square geometry arrangement, a center-type subchannel has 4 neighbors. In the subroutine MATSET there is a point in the calculation sequence where a built-in procedure verifies if the first recirculation loop input data is in the correct order, (i.e. check for order of subchannel number in the loop).

Next in the calculation sequence is the modification of the crossflows entries because of the recirculation loop #1 condition (See Section).

e. The same procedure applies for the other recirculation loop: DO LOOP 600.

f. Once the connection matrix TMAT (I,J) in the (1 I,J MATDIM) is set up, the subroutine INVERT is called for inversion.

The connection matrix TMAT is presented in Table for an 8 subchannels case.

1.5.2 Subroutine INVERT

1.5.2.1 Remarks on the Connection and Coefficient Matrices

TMAT (I,J) and TMATI(I,J)($1 \leqslant I,J \leqslant$ MATDIM)

The principal characteristics of TMAT(I,J) are listed as follows:

a. Sparse

b. Non-diagonally dominant

c. Contains 0 elements on the principal diagonal

d. Is not symmetric, therefore:

e. Elements are not found within a band

domain centered around the principal diagonal.

In analyzing the matrix more closely, one deduces that the Gaussian Elimination method is the only way to invert it. No iterative procedure like a Gauss Seidel method or others are feasible since the principal diagonal contains 0 elements.

When running WOSUB-I on the IBM machine the inversion is carried out in the Subroutine INVERT by calling a standard IBM-ISML Library subroutine: LINV2F.

MINV uses a conventional pivoting technique and Gaussian Elimination techniques to solve for the coefficient matrix TMATI (I,J) (with $1 \leq I, J \leq$ MATDIM).

In addition, it should be noticed that for a run in WATFIV (special compiler version), the subroutine to be used is MINV. One must carefully check that the double precision array, included as a standard feature in that particular subroutine, must be converted to simple precision since WOSUB does not use double precision.

The inverted matrix TMATI (I,J) with ($0 < I,J \leq$ MATDIM) is the coefficient matrix to be used for the solution of the volumetric crossflows in the subroutine SOLMAT. (See Table)

1.5.2.2 <u>Role of the Subroutine INVERT and Use of Arrays</u>

The connection matrix TMAT (I,J) with (($1 \leq I,J \leq$ MATDIM) is transferred to A (I,J) with ($1 \leq I,J \leq$ MATDIM) which after inversion is stored in TMATI (I,J) ($1 \leq I,J \leq$ MATDIM).

1.5.3 Recirculation Loop Concept

1.5.3.1 Set-Up of the Problem

One of the original features in WOSUB is the use of the recirculation loop around each fuel rod. This method consists of considering the net recirculation volumetric flow around each rod to be zero.

It has been assumed that at any axial elevation in the bundle, the transverse pressure gradient is zero. In order to get a complete closed system of conditions for the problem, the flow has been assumed to recirculate around each rod in such a way that the net recirculation volume flow around each rod must be zero. Therefore, if one gets N channels, K loops one has $(N + K - 1)$ conditions to be satisfied for the flows:

a. N-1 conditions corresponding to the geometrical layout of the array of subchannels, i.e. the relations between q_i, the total volumetric flow into subchannel i, and q_{ij} the net volumetric crossflows from subchannel j to subchannel i.

b. K conditions corresponding to the recirculations loops, i.e. the relations between the q_{ij}'s around each rod surrounded by a recirculation loop.

As shown in volume 1 [3] these two sets of conditions can be written in matrix form as:

$$M\underline{R} = \underline{Q}$$

To illustrate the nature of the coefficient matrix M, consider the 8-subchannel example shown in Fig. 11. For this layout one has:

$$R = \begin{vmatrix} q_{12} \\ q_{15} \\ q_{23} \\ q_{26} \\ q_{34} \\ q_{37} \\ q_{48} \\ q_{56} \\ q_{07} \\ q_{78} \end{vmatrix} \qquad Q = \begin{vmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \\ q_5 \\ q_6 \\ q_7 \\ 0 \\ 0 \\ 0 \end{vmatrix}$$

M is shown in Table 7. Note that:

a. Row #8 satisfies loop condition for rod A.

b. Row #9 satisfies loop condition for rod B.

c. Row #10 satisfies loop condition for rod C.

Table 7 Matrix M

	1	2	3	4	5	6	7	8	9	10
1	1	1	0	0	0	0	0	0	0	0
2	-1	0	1	1	0	0	0	0	0	0
3	0	0	-1	0	1	1	0	0	0	0
4	0	0	0	0	-1	0	1	0	0	0
5	0	-1	0	0	0	0	0	1	0	0
6	0	0	0	-1	0	0	0	-1	1	0
7	0	0	0	0	0	-1	0	0	-1	1
8	-1	1	0	-1	0	0	0	1	0	0
9	0	0	-1	1	0	-1	0	0	1	0
10	0	0	0	0	-1	1	-1	0	0	1

Note that:

a. The array q_{ij} is initialized to zero before the calculation.

b. The array q_i is initialized and filled with the previously discussed loop conditions and with the known total flow for the remaining (N-1-K) subchannels.

c. The operation implied by matrix eq.-2 is then performed yielding $\underline{R}$ (net volumetric crossflow vector).

1.5.3.2 Subroutine SOLMAT: Solution for the Volumetric Crossflows

Once the matrix TMAS (I,J) has been inverted, subroutine SOLMAT solves for the net volumetric crossflows:

$$\underline{R} = M^{-1}\,\underline{Q} \tag{2}$$

The operation performed in subroutine SOLMAT is as follows:

$$\begin{vmatrix} q_{12} \\ q_{15} \\ q_{23} \\ q_{26} \\ q_{34} \\ q_{37} \\ q_{48} \\ q_{56} \\ q_{67} \\ q_{78} \end{vmatrix} = \begin{bmatrix} \text{TMATI (I,J)} \\ \text{[Inverse of TMAI(I,J)]} \\ \\ \text{(I,J = 1, MATDIM)} \end{bmatrix} \begin{vmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \\ q_5 \\ q_6 \\ q_7 \\ 0 \\ 0 \\ 0 \end{vmatrix}$$

1.6 Limitations and Execution Time

This section is devoted to an analysis of the main limitations of WOSUB-1 with respect to the calculation capabilities and structure of the code.

Note that the following remarks are not inherent to the physical model but to the code itself.

An estimate of the execution time is also presented and discussed.

1.6.1 Limitations

a. WOSUB-1 can handle a maximum of 20 subchannels: this obviously does not allow the analysis of a full (8x8) BWR fuel rod bundle, and therefore this point is a serious drawback for the calculation capabilities of the code. It should be noted that it is possible to modify the size of the arrays and common blocks of this computer code to handle such large bundles. (See Section 2 "WOSUB-2 User"s Manual".)

b. The subroutine MATSET sets up the coefficient and connection matrices for the case considered. Print outs of such matrices have shown that they are sparse and non-diagonally dominant.

No particular treatment of these matrices or reduction in a more compact array is considered in the numerical scheme of WOSUB-1. Therefore, when the inversion of the coefficient matrix is carried out, the zeros in the rows (or in the columns) are part of the calculation.

This might result, for large cases of matrices, in long computer calculation time, and therefore costly runs.

One should note though, this problem has not been a serious drawback for the cases usually treated (3, 8, 10, 16 subchannels). But for large cases, a more efficient solution scheme should be devised.

c. In its present version WOSUB-1 can handle square-rod bundles and therefore square subchannel geometry. A considerable modification of the code has to be undertaken if one wants to analyse triangular pattern or round fuel rod bundles. The maximum number of neighboring subchannels WOSUB-1 can handle is 4. For the analysis of bundles in which 6 neighbors must be considered, one must design a new topology and therefore a new numerical scheme. Besides, all the common blocks and arrays must be redimensionned. Such a change would particularly involve the subroutines MATSET, INVERT, SOLMAT, GEOMRY.

1.6.2 Execution Time

For the steady state calculation and for small-sized problems WOSUB-1 runs shortly compared to other codes. For a series of 10 problems, in one run, each one involving 16 subchannels and 50 axial elevations, the compilation time on IBM 370/168 with a GI level compiler, is of .008 minutes and the execution time is .564 minutes.

Note that the H compiler level has not been used for WOSUB-1, but that an improvement in compilation and execution time for large problems can be envisioned using it.

CHAPTER 2

USER'S MANUAL OF THE COMPUTER CODE

WOSUB-II

2.1 Introduction

The code WOSUB-II extends the calculational capabilities of the WOSUB-I code to a maximum of 45 subchannels, 36 types of rods, and features a tabulated heat flux distribution input option. Moreover, it is possible now to enter the input data either in BTU or MKSA systems and get the possible combinations for output.

Because of the above change, the input data numbering has been modified along with the routine MAIN, subroutine DISPLAY and EDIT.

The logic of the remaining subroutines has been left unchanged. This manual describes the changes in the array size, input data deck numbering, and the consequently modified MAIN, DISPLAY and EDIT.

Chapter 1 describing the WOSUB-I version should be consulted as the reference manual for WOSUB-II, too. Because in what follows, only the changes made in WOSUB-II are reported.

Furthermore, it should be noticed that WOSUB-II does not contain the subroutines CHF, CHEN and FUEL yet.

2.2 Implementation of Extensions

The WOSUB-II code is defined by the following series of modifications which have been brought to the original version, WOSUB-I.

a. Extension of all of the arrays contained in the original version, WOSUB-I, for handling a maximum of 45 subchannels, 36 rods type, and 28 recirculation loops. This allows to analyze half of an (8 x 8) BWR bundle, with respect to the principal diagonal. Previously the code could handle (WOSUB-I) a maximum of 20 subchannels type, 25 rods, and 25 recirculation loops (See Chapter 1).

b. Tabulated heat flux distribution input option: It is possible now to enter a heat flux table for each rod in the array. Each table contains as many elements as the number of axial increments selected for the problem. (Note that an interpolation procedure is not yet available for such a distribution.) See Section 2.3 for input data and Section 2.2 for changes made in the subroutines.

c. It is possible to enter data in MKSA/BTU system unit and get an output in MKSA or BTU systems. ICON is the modified logical index, and changes are reported in Section 2.6 for MAIN, DISPLAY, and EDIT.

These changes have resulted in the more general version of the code, WOSUB-II. It should be noted though that with the exception of the changes a) to c) mentioned above, WOSUB-II uses the same logic and physical models as used by WOSUB-I.

2.2.1 List of Modified Arrays

The modified arrays are given in detail in the following tables for the purpose of easy reference in case the code should get extended again. Note that the dimension types of the arrays are categorized into 5 groups.

1. means that the dimension depends on the number of subchannels (type number).
2. means that the dimension depends on the number of rods (type number).
3. means that the dimension depends on the number of subchannel boundaries (type number).
4. means that the dimension depends on the number of axial nodes.
5. means that the dimension depends on the number of axial heat flux nodes.

The dimensions of types 4 and 5 were not increased but kept constant at the same value of 50 as originally set up in WOSUB-I for the maximum number of axial increments in the bundle.

It is thought that a change in the number of increments should be coupled together with a change in the number of axial heat fluxes nodes with an interpolation scheme. For this purpose the arrays are listed (changes in columns 4 and 5), and corresponding changes can be handled very easily.

MAIN

CARD #	MODIFIED ARRAYS	1	2	3	4	5
00305	RERGH (45)	x				
00306	NAROD (45), KROD (45)	x				
	HF (36)		x			
	VINLET (45), GINLET (45)	x				
	HF (100,-)				x	
00307	CHANN (45), A (45)	x				
	FFLC (-,45)	x				
00310	HYD (45), HYPER (45)	x				
00311	JOIN (45), NJOIN (45,-),MCIRC(28)	x				
	SL (-,45)	x				
00312	ROPN (36)		x			
00313	PEAK (36)		x			
	AXSHF (100)					x
00315	RDPW (36)		x			
00318	AVHF (36)		x			

DISPLAY

CARD #	MODIFIED ARRAYS	1	2	3	4	5
00594	JOIN (45), NJOIN (45,-),MCIRC(28)	x				
	SL (-, 45)					
00595	RODN (36)		x			
00598	RERGH (45)	x				
00599	NAROD (45),KROD (45)	x				
	VINLET (45), GINLET (45)	x				
	HF (-,36)		x			
	HF (100,-)				x	
00600	CHANN (45),A(45),FFLC(-,45)	x				
00603	HYD (45), HPER (-,45)	x				
00604	PEAK (36)		x			
	AXSHF (100)					x
00606	RDPW (36)		x			
00607	WP (45)	x				

GEOMRY

CARD#	MODIFIED ARRAYS	1	2	3	4	5
00711	JOIN (45), NJOIN(45,-),MCIRC(28)	x				
	SL (45)	x				
00712	RODN (36)		x			
00715	RERGH (45)	x				
00716	NAROD (45),KROD(-,45),VINLET(45)	x				
	GINLET (45)	x				
	AF (-,36)		x			
	HF (100, -)					x
00717	CHANN (45),A(45),FFLC (45)	x				
00720	HYD (45), HPER (-,45)	x				
00721	WP (45)	x				
00722	SLIP (45), VR7 (45,-)	x				
00723	CHYD (45)	x				

MATSET

CARD #	MODIFIED ARRAYS	1	2	3	4	5
00790	NAROD(45),KROD(-,45),VINLET(45)	x				
	GINLET (45)	x				
	HF (-,36)		x			
	HF (100,-)					x
00791	CHANN (45), A(45),FFLC(-,45)	x				
00794	HYD(45), HPER(-,45)	x				
00795	JOIN(45),NJOIN(45,-),MCIRC(28)	x				
	SL (-,45)	x				
00796	RODN (36)		x			
00797	NTW (45,-)	x				
	TMATI (72,-),TMAT(72,-)			x		
	XLUC (72,-)			x		
	TMATI (-,72),TMAT (-,72)			x		
	XLU (-,72)			x		

INVERT

		1	2	3	4	5
00903	TMAT (72,-),N(72,-),VI (72),			x		
	V2 (72)			x		
	TMAT (-,72), V(-,72)			x		

STEADY

CARD #	MODIFIED ARRAYS	1	2	3	4	5
00920	NAROD (45),KROD(-,45),VINLET(45)	x				
	GINLET (45)					
	HF (-,36)		x			
	HF (100,-)				x	
00921	CHANN (45), A(45), FFLC (-,45)	x				
00924	HYD (45), HPER (-,45)	x				
00925	JOIN (45),NJOIN (45,-)MCIR (28)	x				
	SL (-,45)	x				
00926	RODN (36)		x			
00929	RERGH (45)	x				
0930	RDPW (36)		x			
00931	SLIP (45), VR7 (45,-)	x				

TRANS

CARD #	MODIFIED ARRAYS	1	2	3	4	5
00966	NAROD (45),KROD(-,45),VINLET (45)	x				
	GINLET (45)					
	HF (-, 36)		x			
	HF (100,-)				x	
00967	CHANN (45), A (45), FFLC (-,45)	x				
00970	HYD (45), HPER (-,45)	x				
00971	PEAK (36)		x			
	AXSHF (100)				x	
00973	JOIN (45),NJOIN (45,-),MCIRC(28)	x				
	SL (-,45)	x				
00974	RODN (36)		x			
00977	RERGH (45)	x				
00978	RDPW (36)		x			
00979	SLIP (45), VR7 (45,-)	x				

VMIX

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1328	AJT(45),AJVAP945), FIHLIN (45),	x				
	QT(45), QVT (45), QLT (45)	x				
1329	EXCHM (45), HLIN (45),HDIV(45)	x				
	TDH(45), GFL(45), VFI(45)	x				
	AJN(45), AJVN (45)	x				
1330	AJLN (45), DPFR (45),VFN(45)	x				
	HLN (45), GN (45), GFN (45),	x				
	GT (45), SAVN (45)	x				
1331	ENSAVE (45),FAC(45),DPS(45), EPD (45)	x				
	EDPO (45), QTO(45), AJLI(45)	x				
1332	XTR (45)	x				
1333	NAROD (45),KROD(-,45),VINLET(45)	x				
	GINLET (45)	x				
	HF (-,36)		x			
	HF (100, -)				x	
1334	CHANN (45), A(45),FFLC (-,45)	x				
1337	HYD (45), HPER (-,45)	x				
1338	JOIN(45), NJOIN(45,-),MCIRC(28)	x				
	SL (-,45)	x				
1339	RODN (36)		x			

MIXIN

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1356	SLIP(45), VR7 (45,4)	x				
1357	JOIN(45),NJOIN(45,-),MCIRC(28)	x				
	SL (-,45)	x				
1358	RODN (36)		x			
1360	NTW (45,-)	x				
	TMATI (72,-), SRMIX (72,-)				x	
	SALDD (72,-)				x	
	TMATI (-,72), SRMIX (-,72)				x	
	SALDD (-,72)				x	
1362	AJT (45), AJVAP (45), FIHLIN(45)	x				
	QT (45), QUT (45), QLT (45)	x				
1363	EXCHM (45), HLIN(45), HDIV(45)	x				
	TDH(45),GFL(45), VFI(45),AJN(45)	x				
	AJVN (45)	x				
1364	AJLN(45),DPFR(45),UFN(45)	x				
	HLN (45), GN (45), GFN (45),GT(45)	x				
	SAVN (45)	x				
1365	ENSAVE(45),FAC(45),DPS(45), EPD (45)	x				
	EDPO(45), QTO(45), AJLI(45)	x				
1366	XTR (45)	x				

MIXIN (cont'd.)

CARD#	MODIFIED ARRAYS	1	2	3	4	5
1367	NAROD (45), KROD (-,45)	x				
	HF (-,36)		x			
	HF (100,-)				x	
	VINLET (45), GINLET (45)	x				
1368	CHANN(45), A(45),FFLC(-,45)	x				
1371	HYD(45), HPER(-,45)	x				
1374	RERGH (45)	x				
1375	WP (45)	x				

SPLITD

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1440	AJT(45),AJVAP(45),FIHLIN(45)	x				
	QT(45), QUT(45), QLT(45)	x				
1441	EXCHM(45),HLIN(45),HDIV(45)	x				
	TDH(45),GFL(45),VFI(45)	x				
	AJN(45), AJVN(45)	x				
1442	AJLN(45),DPFR(45),VFN(45)	x				
	HLN(45),GN(45),GFN(45)	x				
	GT(45), SAVN(45)	x				
1443	ENSAVE(45),FAC(45),DPS(45)	x				
	EDP(45),EDPO(45), QTO(45)	x				
	AJLI(45)	x				
1444	XTR (45)	x				
1445	NAROD(45),KROD(-,45)	x				
	VINLET (45),GINLET (45)	x				
	HF(-, 36)		x			
	HF (100,-)			x		
1446	CHANN(45), A(45),FFLC(45)	x				
1449	HYD(45), HPER(-,45)	x				
1452	RERGH (45)	x				
1453	QTK(45,-), QVK(45,-),QLK(45,-)	x				

SPLITD (cont'd.)

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1454	JOIN(45),NJOIN(45,-),MCIRC(28)	x				
	SL(-,45)	x				
1455	RODN (36)		x			
1456	NTW (45,-)	x				
	TMATI (72,-),SRMIX(72,-)			x		
	SALDD (72,-)			x		
	TMATI (-,72), SRMIX (-,72)			x		
	SALDD (-,72)			x		
1458	SLIP (45), VR7 (45,-)	x				

SOLMAT

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1549	TW3(45,-), W(45)	x				
	VEC (72), RHS(72)			x		
1550	JOIN(45), NJOIN(45,-)	x				
	MCIRC (28), SL (-,45)	x				
1551	RODN (36)		x			
1552	NTW (45,-)	x				
	TMATI (72,-),TMAT(72,-),XLU(72,-)			x		
	TMATI (-,72), TMAT(-,72),XLU(-,72)			x		
1554	NAROD(45),KROD(-,45),VINLET(45)	x				
	GINLET (45)	x				
	HF (-,36)		x			
	HF (100,-)				x	
1555	CHANN(45),A(45),FFLC(10,45)	x				
1558	HYD(45), HPER(-,45)	x				

WATER

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1583	RERGH (45)	x				

HYD

CARD	MODIFIED ARRAYS	1	2	3	4	5
1728	RERGH (45)	x				

CONTI

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1622	RERGH (45)	x				

SWEEP

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1073	IB(45), IRE(45), IFRE(45)	x				
	IBN (45), IREN(45)	x				
1085	RERGH (45)	x				
1086	AJT(45), AJVAP(45),FIHLIN(45)	x				
	QT (45), QUT(45),QLT(45)	x				
1087	EXCHM(45), HLIN(45),HDIV(45)	x				
	TDH(45), GFL(45), UFI(45)	x				
	AJN (45), AJVN (45),	x				
1088	AJLN (45), DPER (45),VFN(45)	x				
	HLN (45), GN (45), GFN (45)	x				
	GT (45), SAVN (45)	x				
1089	ENSAVE (45), FAC(45), DPS (45)	x				
	EDP (45), EDPO (45), QTO (45)	x				
	AJL (45)	x				
1090	XTR (45)	x				
1091	VFAV (45), GOUT (45),GOUTV(45)	x				
	GOUTL (45),XOUT(45), EOUT(45)	x				
1092	BAL (45)	x				
1093	ITER (100), PDROP (100)				x	
1094	QTR(100,-),ALF(100,-),HEL(100,-)				x	

SWEEP (cont'd.)

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1094	GR (100,-)				x	
	QTR (-,45),ALF(-,45), HEL(-,45)	x				
	GR (-,45)	x				
1095	TQUAL (100,-), XQUAL (100,-)					
	TQUAL (-,45), XQUAL (-,45)	x				
1096	NAROD (45), KROD (-,45)	x				
	VINLET (45), GINLET (45)	x				
	HF (-,36)		x			
	HF (100,-)				x	
1097	CHANN (45), A(45), FFLC (-,45)	x				
1100	HYD (45), HPER (-,45)	x				

EDIT & EDIT 2

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1762	RERGH (45)	x				
1763	NAROD (45),KROD(-,45),VINLET(45)	x				
	GINLET (45)	x				
	HF (-,36)		x			
	HF (100,-)				x	
1764	CHANN (45), A (45),FFLC(45)	x				
1767	HYD(45), HPER(-,45)	x				
1768	VFAV (45,GOUT(45),GOUTV(45), GOUTL (45)	x				
	XOUT (45), EOUT (45)	x				
1769	BAL (45)	x				
1770	ITER (100), PDROP (100)				x	
1771	QTR(-,45),ALF(-,45),HEL(-,45)	x				
	GR (-,45)	x				
	QTR (100,-),ALF(100,-),HEL(100,-)				x	
	GR (100,-)				x	
1772	TQUAL(-,45),XQUAL (-,45)	x				
	TQUAL (100,-),XQUAL (100,-)				x	
1773	RDPW (36)		x			
1774	JOIN (45),NJOIN(45,-),MCIRC(28)	x				
	SL (-,45)	x				

EDIT & EDIT 2 (cont'd)

CARD #	MODIFIED ARRAYS	1	2	3	4	5
1775	RODN (36)		x			
1776	ENI (45)	x				

2.3 Input Data

The increase in the array sizes as well as the set up of new arrays have resulted in changes in the input, although the input data card structure has been kept the same as described in section 1.1 for WOSUB-I.

2.3.1 Order Scheme for the Input Card Deck

Group 0	Control Card
Group 1	Title Card: Identification of the run
Group 2	General input data
Group 3	Array arrangement input data
Group 4	Recirculation loop specification
Group 5	Geometrical input data for subchannels
Group 6	Array sizing
Group 7	Subchannel roughness specifications input data
Group 8	Parameters input data
Group 9	Physical parameters input data
Group 10	Relative peaking factor input data
Group 11	Axial peaking factor data Axial flux shape input
Group 12	2-D-heat flux input data
Group 13	Blockage specifications input
Group 14	Transient specifications input
Group 15	Perturbation timetables

2.3.2 List of Input Data

On the following pages instructions are given for preparing the input data card deck for the code WOSUB-II. To more easily comprehend the meaning of certain data, additional explanations are given by placing numbers into the column "Remarks," which refers the user to Section 1.1.3.2.

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
1	1		1-6	I6		0=not the last problem in the run 1=last problem in the run	
1	1		7-80	16A4	TITLE	Identification of the run	
2	1	1	1-12	E12.6	NCHAN	Number of subchannels type in the bundle	1
2	1	2	13-24	E12.6	NRODS	Number of heating rod type	2
2	1	3	25-36	E12.6	JMAX	Number of axial nodes for calculation	
2	1	4	37-48	E12.6	IHIN	Inlet Enthalpy Indicator 0=subcooled enthalpy (negative) is given 1=enthalpy is given -1=subcooled temp is given (positive if subcooled) -2=inlet temp is given	
2	1	5	49-60	E12.6	ISHAP	0=Flat Power distribution 1=Tabulated distribution -1=Chopped Cosinus distribution 2=Tabulated heat flux distribution	3
2	1	6	61-72	E12.6	ICON	0=Decimal system input/output 1=BTU input/output 2=BTU/MKSA 3=MKSA/BTU	4

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
2	2	7	1-12	E12.6	IDOP	0=hyd. dia. renormalized 1=no renormalization turbulent momentum exchange	
2	2	8	13-24	E12.6	IDOWN	0=Upwards flow 1=Downwards flow	
2	2	9	25-36	E12.6	NDRIFT	0=No vapor diffusion subchannel mixing 1=Diffusion vapor mixing model	
2	2	10	37-48	E12.6	IPAR	0=Standard parameters chosen by the code (see DATA 90(+FF) 1=same parameters are input	5
3	1	11	1-12	E12.6	JOIN(1)	Number of subchannels joining to the first	6
3	1	12	13-24	E12.6	NAROD(1)	Number of rod types heating first subchannel	7
3	1	13	25-36	E12.6	NJOIN(1,1)	(Order number of subchannel joining to the first) max = 4 subchannel joining to the first	8
3	1	14	37-48	E12.6	NJOIN(1,2)	Subchannel joining to the first	
3	1	15	49-60	E12.6	NJOIN(1,3)	Subchannel joining to the first	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
3	1	16	61-72	E12.6	NJOIN(1,4)	Subchannel joining to the first	
3	2	17	1-12	E12.6	KROD(1,1)	(Type number of rods heating first subchannel)Narod values max=4 First rod heating first subchannel	
3	2	18	13-24	E12.6	KROD(2,1)	Second rod heating first subchannel	
3	2	19	25-36	E12.6	KROD(3,1)	Third rod heating first subchannel	
3	2	20	37-48	E12.6	KROD(4,1)	Fourth rod heating first subchannel	
3	3	21	1-12	E12.6	JOIN(2)	Number of subchannel joining to the second	
3	3	22	13-24	E12.6	NAROD(2)	Number of rod types heating second subchannel	
3	3	23	25-36	E12.6	NJOIN(2,1)	(Order number of subchannel joining to the second) max=4 Subchannel joining to the second	
3	3	24	37-48	E12.6	NJOIN(2,2)	Subchannel joining to the second	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
3	3	25	49-60	E12.6	NJOIN(2,3)	Subchannel joining to the second	
3	3	26	61-72	E12.6	NJOIN(2,4)	Subchannel joining to the second	
3	4	27	1-12	E12.6	KROD(1,2)	First rod heating Second subchannel	
3	4	28	13-24	E12.6	KROD(2,2)	Second rod heating Second subchannel	
3	4	29	25-36	E12.6	KROD(3,2)	Third rod heating Second subchannel	
3	4	30	37-48	E12.6	KROD(4,2)	Fourth rod heating Second subchannel	

The input data is continued the same way for as many as 36 subchannels in the array.

NOTE: For 36 rods, 45 subchannels, last input data # in Group 3 = 460.

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
4	1	500	1-12	E12.6	NOCIR	Number of independent recirculation paths in bundle	10
4	1	501	1-12	E12.6	MCIRC(1)	Recirculation loop #1 (each subchannel is characterized by two digits:i.e. sub#1=01, either way of circulation is allowed (be consistent))	11
4	2	502	13-24	E12.6	MCIRC(2)	Recirculation loop #2	
4	2	503	25-36	E12.6	MCIR(3)	Recirculation loop #3	

maximum of 6 recirculation loops can be specified (because of the FORMAT 72 column) input recirculation loops up to MCIRC (NOCIR).

NOTE: Last input data # in Group 4: 528

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
5	1	611	1-12	E12.6	A(1)	Flow area of subchannel 1	12
5	1	612	13-24	E12.6	HYD(1)	Hydraulic diameter for same subchannel	13
5	1	613	25-36	E12.6	HPER(1,1)	Fraction of first rod perimeter heating sub-channel 1, Same order as KROD must be followed	
5	1	614	37-48	E12.6	HPER(2,1)	Fraction of second rod	
5	1	615	49-60	E12.6	HPER(3,1)	Fraction of third rod	
5	1	616	61-72	E12.6	HPER(4,1)	Fraction of fourth rod	
5	2	617	1-12	E12.6	AL(1)	Gap width corresponding to NJOIN (1,1)	15
5	2	618	13-24	E12.6	SL(2,1)	Gap width corresponding to NJOIN (1,2)	
5	2	619	25-36	E12.6	SL(3,1)	Gap width corresponding to NJOIN (1,3)	
5	2	620	37-48	E12.6	SL(4,1)	Gap width corresponding to NJOIN (1,4)	

Same for second subchannel

Note: Last input data # in Group 5:1060

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
6	1	1100 to 1190	1- 72	E12.6	CHANN(I)	Number of subchannels of type I in the bundle	
6		1151 to 1200	1-72	E12.6	RODN(L)	Number of heating rods of type L in the bundle	
7	1	1201to 1250	1-12	E12.6	RERG(I)	Relative roughness of subchannel type I	

Following parameters are input only when IPAR = 1 (DATA 10)

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
8	1	1301	1-12	E12.6	AN	Exponent in boiling heat flux correlation	
8	1	1302	13-24	E12.6	ZE	Multiplier of average hydraulic diameter to obtain relaxation length for diabatic vapor concentration profile	
8	1	1303					
8	1	1304	25-36	E12.6	R	Recondensation constant	
8	1	1305	37-48	E12.6	ZUBER	Constant for average void drift velocity	
8	1	1306	49-60	E12.6	CGRAV	Gravity corinus (positive) for upward flow	
			61-72	E12.6	CRAR	Parameter in subcooled boiling model	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
8	2	1307	1-12	E12.6	FL	Multiplier for momentum flow of the liquid	
8	2	1308	13-24	E12.6	FV	Same for vapor	
8	2	1309	25-36	E12.6	RELI	First attempt relaxation parameter	
8	2	1310	37-48	E12.6	RELZ	Second attempt relaxation parameter	
8	2	1311	49-60	E12.6	RFSTG	Multiplier for second guess choice of diverted flows	
9	1	1401	1-12	E12.6	P	Pressure	
9	1	1402	13-24	E12.6	HINLET	Inlet enthalpy or temp.	
9	1	1403	25-36	E12.6	GTOT	Total mass flow into the bundle (whole bundle)	
9	1	1404	37-48	E12.6	DIAR	Diameter of heating rods	
9	1	1405	49-60	E12.6	POWER	Total bundle power	
9	1	1406	61-72	E12.6	PFDAC	Fraction of power directly added to coolant by neutron moderation and radiation	
9	2	1407	1-12	E12.6	ZTOT	Total height of the bundle	
9	2	1408	13-24	E12.6	TDAHF	Average heat flux	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
10	1	1411 to 1447	1-12	E12.6	PEAK(K)	Relative power of rod type K-Arbitrary normalization performed by the code	
11	1	1450	1-12	E12.6	AXPKF	Axial peaking factor-only for chopped corinus distribution	
11	1	1451 to 1500	1-72	E12.6	AXSHF(S)	Axial power shape tabulation, arbitrary units give JMAX value, one for each node.	
12	1	1501	1-12	E12.6	TDHF(J,K)	Heat flux per rod and and axial increment (tabulated distribution)	
Note: last input data # for group 12: 3265.							
13	1	3301	1-72	E12.6	LOC(IL)	Nodes, where local flow restrictions exist (spaces blockages) up to 10 locations	
13	1	3400	1-72	E12.6	FFLC(I)	Local restriction coefficients at sub-channel I at LOC(1,I)	

TRANSIENT SPECIFICATION DATA

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARK
14	1	3900	1-12	E12.6	TFIN	Total time of calculation (sec) if zero only steady state calculation and end of data	
14	1	3001	13-24	E12.6	PRI	Printing time interval for summary print (sec)	
14	1	3902	25-36	E12.6	MDPR	Detailed printout every MDPR printing steps	
14	1	3903	37-48	E12.6	DT	Time increment for calculation-if omitted it will be chosen by the code	
14	2	3911	1-12	E12.6	IPRESS	Pressure transient Perturbation indicator 0=cte pressure 1=tabulated perturbation 2= sinusoidal perturbation P=PZERO*(1+C1*SIN(C2*TIME) 3=polynomial perturbation P=PZERO*(1.+C(I)*T**I)	
14	2	3912 to 3916	13-72	E12.6	CPRESS(I)	Coefficients for mass flow perturbation only where IVINL=2 or3	
14	3	3917	1-12	E12.6	IVINL	Mass flow transient perturbation indicator same code as IPRESS	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARK
14	3	3918 to 3922	13-72	E12.6	CVIN(I)	Coefficients for mass flow perturbation only when IVINL=2 or 3	
14	4	3923	1-12	E12.6	ITIN	Inlet enthalpy (or temperature) perturbation indicator-same code as above	
14	4	3924 to 3928	13-72	E12.6	CTIN(I)	Coefficients for inlet enthalpy or temperature when ITIN = 2 or 3 the definition of these coefficients is different HINLET=HZERO+C1*SIN(C2*TIME) C1 in JOVLE?G or Bru/lb HINLET=HZERO+SUM(C(I)*TIME**I)	
14	5	3929	1-12	E12.6	IPOW	Power transient perturbation indicator (same code)	
14	5	3930 to 3934	13-72	E12.6	CPOW(I)	Coefficient for power where IPOW=2 or 3. The non dimensional definition applies	
14	6	3951	1-12	E12.6	1BLOC	Subchannel where blockage occurs	
14	6	3952	12-24	E12.6	LBLOC	Order number of restriction where blockage occurs (seeLOC(IL) Data 1101 to 1120) LBLOC must correspond to the order number IL of the restriction blocked	
14	6	3953	25-36	E12.6	TIBL	Time for beginning of blockages (sec)	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
14	6	3954	37-48	E12.6	TZBL	Time for completion of blockage (sec)	
14	6	3955	49-50	E12.6	FBL1	Local friction factor at completion of blockage	
14	6	3956	61-72	E12.6	FBL2	Local friction factor at completion of blockage	

PERTURBATION TIME TABLES - Used when the corresponding option is 1. Each table is composed of 50 time values followed by 50 variable values. The first time value must be zero - any number of values may be given. The code will fix the variable at the last value given at times following the last significant time - times are in seconds.

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
15	1	4000 to 4099	1-72	E12.6	PTAB	Pressure timetable pressure values relative to nominal beginning with data 1650.	
14		4100 to 4199	1-72	E12.6	QTAB	Mass flow timetable-relative values-same rule	
14		4200 to 4299	1-72	E12.6	HTAB	Inlet enthalpy or temperature time table (see data 4) absolute values of perturbation must be given. Units are JOULE/G or C and Btu/lb or F depending on ICON Option (Data 4)	

GROUP	CARD	DATA #	COLUMN	FORMAT	VARIABLE	DESCRIPTION	REMARKS
14		4300 to 4399	1-72	E12.6	PWTAB	Power time table-relative values-same rules	

Last card (see 1.2) 4400: Dummy data may be conveniently employed as the last dara set to be kept fixed when modifying a problem at many times.

2.4 Output Description

The organization of the output of WOSUB-II is essentially the same as that used by WOSUB-I. Therefore, the user should consult Section 1.2 for details.

2.6 <u>Listing of WOSUB-II</u>

2.6.1 Listing of MAIN

```
0001          LOGICAL IPAR
0002          LOGICAL NDRIFT                                                  00000300
0003          COMMON/UNI/DZ,  DT,  VZERO,  AN,  AN1,  ZE,  R,  FL,
             1FV,  CPAR,  ZUBER,  P
0004          COMMON/PROP/RO,  ROVAP,  HVAP,  HSAT,  ALAM,  DLAM,  DHSAT,
             1GAMMA,  GAMIA,  ROVRA,  HCC,  GRAD,  IDOWN,  TSAT,  PRAND,
             2HP,  RROUGH,  AFRIC,  BFRIC,  ANS,  AK,  AMU,  WCON,
             3SIGMA,  VDRIFT,  ROGRAV,  DZUMG,  CP,  RFRGH(45)
0005          COMMON/GEN/NAROD(45),  KROD(4,45),  HF(50,36),  VINLET(45),
             1GINLET(45),  HINLET,  GTOT,  POWER,  CHANN(45),  A(45),
             2FFLC(10,45),  NRODS,  GTFAC,  GTUP,  AVHYD,  VIZERO,  TFIN,
             3PZERO,  HZERO,  POWC,  IBLOC,  L3LOC,  T1BL,  T2BL,  FBL1,
             4FBL2,  PRIN,  MDP3,  HYD(45),  LOC(10),  HPER(4,45),
             5PFDAC,  DERP,  NCHAN,  JMAX
0006          COMMON/GEOM/JOIN(45),  NJOIN(45,4),  MCIRC(45),  SL(4,45),
             1NOCIP,  RCDH(36),  AREA,  IDOP
0007          COMMON/TABI/PEAKF(36),  AYSHF(50),  IPRESS,  CPRESS(5),
             1IVINL,  CVIN(5),  ITIN,  CTIN(5),  IPOW,  CPOW(5), PTAB(100),
             2QTAB(100),  HTAB(100),  PWTAB(100),  TDHF(50,36)
0008          COMMON/PRINT/T,  ICON,  PDPW(36),  IHIN,  PERI
0009          COMMON/DISE/ISHAP,  AXPKF,  ZTOT,  DIAP,  NDRIFT
0010          COMMON/FFLAX/FEL1,  PEL2,  RESTG
0011          COMMON/ARR/QTR(50,45),  ALF(50,45),  HEL(50,45),
             1GI(50,45),  TQUAL(50,45),  XQUAL(50,45)
0012          DIMENSION AVHF(36)
0013          DIMENSION TITLE(16),DATA(4400)
0014          DATA CONFAC/3170.2/
0015          DATA HCONF,GCONF,FICONF,FCONF,PCONF,DCONF                       00000320
             1/.4304,.007373,.003173,.007937,14.503,62.383/                   00000321
0016          DO 5000 K=1,4400
0017     5000 DATA(K)=0.                                                      00000323
0018     1000 READ(5,1)LAST,TITLE                                             00000324
0019        1 FORMAT(I6,16A4)                                                 00000325
0020          WRITE(6,2)TITLE                                                 00000326
0021        2 FORMAT(1H1,/10X,45HWOSUB  PROGRAM FOR SUBCHANNEL ANALYSIS OF BWR/ 00000327
             120X,16A4)                                                       00000328
0022      100 READ(5,3)KZ,K1,K2,(DATA(K),K=K1,K2)                             00000329
0023        3 FORMAT(2I6,I12,/(6E12.6))                                       00000330
0024          WRITE(6,4)(K,DATA(K),K=K1,K2)                                   00000331
0025        4 FORMAT(5(I6,F17.8))
0026          IF(KZ.GE.0)GO TO 100                                            00000333
        C     SET DATA-GEOMETRY                                               00000334
0027          NCHAN=  INT(DATA(1)*1.001)                                      00000335
0028          NRODS=  INT(DATA(2)*1.001)                                      00000336
0029          JMAX=  INT(DATA(3)*1.001)                                       00000337
0030          IHIN=INT(DATA(4)*1.001)                                         00000338
0031          ISHAP=INT(DATA(5)*1.001)                                        00000339
0032          ICON=INT(DATA(6)*1.001)
0033          IDOP=INT(DATA(7)*1.001)+1                                       00000342
0034          IDOWN=INT(DATA(8)*1.001)                                        00000343
0035          NDRIFT=.TRUE.                                                   00000344
0036          IF(DATA(9).GT.0.)NDRIFT=.FALSE.                                 00000345
0037          IPAR=.TRUE.                                                     00000346
```

```
      AM=4.
      ZR=0.
      R=5.
      PI=1.
      PV=1.
      CRAP=1.
      ZUPER=2.5
      REL1=1.
      REL2=.7
      RESTG=.5
      HEAD=980.*ABS(CGRAV)
      AM1=1./AM
      AIM=1./(AM-1.)
      L=10
      DO 10 I=1,NCHAN
      JCIN(I)=  INT(DATA(L+1)*1.001)
      NAPOD(I)=  INT(DATA(L+2)*1.001)
      L=L+2
      DO 11 K=1,4
      LK=L+K
   11 MJCIN(I,K)=  INT(DATA(LK)*1.001)
      L=L+4
      DO 12 K=1,4
      LK=L+K
   12 KAPOD(K,I)=  INT(DATA(LK)*1.001)
   10 L=L+4
      WRITE(6,997)
  997 FORMAT(1X,'DEBUG IN MAIN :LEVEL STAT. 0067')
      NOCIR=INT(DATA(500)*1.001)
      DO 20 K=1,NOCIR
   20 MCIRC(K)=INT(DATA(K+500)+.8)
      DO 999 K =1,NOCIR
  999 WRITE(6,998) K,MCIRC(K),DATA(500+K),NOCIR
  998 FORMAT(1X,I6,2X,I19,3X,E20.9,3X,I6)
      L=610
      DO 30 I=1,NCHAN
      A(I)=DATA(L+1)
      HYD(I)=DATA(L+2)
      IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 5002
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 5001
 5002 A(I)=6.4516*A(I)
 5001 CONTINUE
      IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 5005
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 5004
 5005 HYD(I)=2.54*HYD(I)
 5004 CONTINUE
      L=L+2
      DO 31 K=1,4
      LK=L+K
   31 HPER(K,I)=DATA(LK)
      L=L+4
```

```
      DO 32 K=1,4
      LK=L+K                                                 00000391
      SL(K,I)=DATA(LK)                                       00000392
      IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 5008
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 5007
 5008 SL(K,I)=2.54*SL(K,I)
 5007 CONTINUE
   32 CONTINUE                                               00000395
   30 L=L+4
      L=1100
      DO 40 I=1,NCHAN                                        00000398
      LI=I+I                                                 00000399
   40 CHANN(I)=DATA(LI)                                      00000400
      L=1150
      DO 50 K=1,NRCDS                                        00000402
      LK=L+K                                                 00000403
   50 RCDN(K)=DATA(LK)                                       00000404
      DO 550 I=1,NCHAN                                       00000405
  550 BERGH(I)=DATA(1200+I)
      CALL GEOMRY
C     PHYSICAL DATA                                          00000408
      P=DATA(1401)
      IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 5011
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 5010
 5011 P=P/PCONF
 5010 CONTINUE
      RO=ROFUN(P)                                            00000412
      ROGRAV=RO*CGRAV*980.                                   00000413
      CALL WATER(P)                                          00000414
      SAVE=DATA(1402)
      IF(IHIN) 57,55,56                                      00000416
   55 CONTINUE
      IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 5014
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 5013
 5014 SAVE=SAVE/HCONF
 5013 CONTINUE
      HINLET=SAVE                                            00000418
      HZERO=SAVE+HSAT                                        00000419
      GO TO 59                                               00000420
   56 CONTINUE
      IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 5017
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 5016
 5017 SAVE=SAVE/HCONF
 5016 CONTINUE
      HZERO=SAVE                                             00000422
      HINLET=SAVE-HSAT                                       00000423
      GO TO 59                                               00000424
   57 IF(IHIN.LT.(-1))GO TO 58                               00000425
      IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 5020
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 5019
 5020 SAVE=.55556*SAVE
 5019 CONTINUE
      HINLET=-CP*SAVE                                        00000427
```

```
   58 CONTINUE
      IF(ICON.EQ.1.OR.ICON.EQ.2)  GO TO 5023
      IF(ICON.EQ.0.OR.ICON.EQ.3)  GO TO 5022
 5023 SAVE=.55556*(SAVE-32.)
 5022 CONTINUE
      HINLET=CP*(SAVE-TSAT)                                       00000431
      HVSUB=HINLET+HSAT                                           00000432
   59 CONTINUE                                                    00000433
      GTOT=DATA(1403)
      IF(ICON.EQ.1.OR.ICON.EQ.2)  GO TO 5026
      IF(ICON.EQ.0.OR.ICON.EQ.3)  GO TO 5025
 5026 GTOT=GTOT/CCONF
 5025 CONTINUE
      GTOT=1000.*GTOT                                             00000437
      DIAR=DATA(1404)
      IF(ICON.EQ.1.OR.ICON.EQ.2)  GO TO 5029
      IF(ICON.EQ.0.OR.ICON.EQ.3)  GO TO 5028
 5029 DIAR=2.54*DIAR
 5028 CONTINUE
      PERI=3.1416*DIAR                                            00000441
      DO 110 I=1,NCHAN                                            00000442
      KM=NAFOD(I)
      DO 110 K=1,KM
  110 HPER(K,I)=PERI*HPER(K,I)
      POWER=DATA(1405)
      PFDAC=DATA(1406)
      ZTOT=DATA(1407)
      IF(ICON.EQ.1.OR.ICON.EQ.2)  GO TO 5032
      IF(ICON.EQ.0.OR.ICON.EQ.3)  GO TO 5031
 5032 ZTOT=ZTOT*30.48
 5031 CONTINUE
      DZ=ZTOT/FLOAT(JMAX)                                         00000460
      IF(ISHAP.GT.2)  GO TO 126
C     CALCULATE AVERAGE HEAT FLUX IF ISHAP IS 0,-1,OR 1
      PKR=0.
      TOTNR=0.
      DO 120 K=1,NPCDS
      PEAKF(K)=DATA(1410+K)
      TOTNR=TOTNR+PCDN(K)                                         00000452
  120 PNOR=PEAKF(K)*PCDN(K)+PNOR                                  00000453
      PNOR=POWER/PNOR                                             00000454
      DO 121 K=1,NPCDS                                            00000455
  121 PDPW(K)=PNOR*PEAKF(K)                                       00000456
      AFAC=ZTOT*PERI                                              00000461
      AFAC=1./AFAC*(1.-PFDAC)                                     00000462
      DO 122 K=1,NPCDS                                            00000463
  122 AVHF(K)=AFAC*PDPW(K)                                        00000464
C     AXIAL POWER SHAPE SPECIFICATION                             00000465
      IF(ISHAP.EQ.-1)  GO TO 125
      IF(ISHAP.EQ.0)  GO TO 123
      IF(ISHAP.EQ.1)  GO TO 124
```

```
C      FLAT POWER PROFILE
   123 DO 1230 J=1,JMAX
  1230 AXSHF(J)=1.
       GO TO 130
C      TABULATED FUNCTION FOR POWER PROFILE
   124 L=1450
       FNOR=0.
       DO 1240 J=1,JMAX
       LJ=I+J
       SAVE=DATA(LJ)
       FNOR=FNOR+SAVE
  1240 AXSHF(J)=SAVE
       FNOR=FLOAT(JMAX)/FNOR
       DO 1241 J=1,JMAX
  1241 AXSHF(J)=FNOR*AXSHF(J)
       GO TO 130
C      COSINUS SHAPE POWER PROFILE
   125 AXPKF=DATA(1450)
       ARG=1.5
       DO 1250 M=1,10
       SARG=SIN(ARG)
       SPF=ARG/SARG
       DELT=AXPKF-SPF
       IF(ABS(DELT).LT.0.001)GO TO 1251
       SAVE=(SARG-ARG*COS(ARG))/SARG**2
       ARG=ARG+DELT/SAVE
       IF(ARG.GT.1.57) ARG=1.57
       IF(ARG.LT.0.01) ARG=0.01
  1250 CONTINUE
  1251 J1=JMAX/2
       DARG=2.*ARG/FLOAT(JMAX)
       SAVE=ARG-.5*DARG
       SUM=0.
       DO 1252 J=1,J1
       SAV1=COS(SAVE)
       AXSHF(J)=SAV1
       JMJ=JMAX+1-J
       AXSHF(JMJ)=SAV1
       SUM=SUM+SAV1
  1252 SAVE=SAVE-DARG
       IF(2*J1.EQ.JMAX)GO TO 1253
       AXSHF(J1+1)=1.
       SUM=SUM+1.
  1253 FNOR =FLOAT(JMAX)/SUM
       DO 1254 J=1,JMAX
  1254 AXSHF(J)=FNOR*AXSHF(J)
       GO TO 130
C      TWO DIMENSIONAL HEAT FLUXES
   126 L=1500
       TDAHF=DATA(1400)
       IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 6001
       IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 6002
  6001 TDAHF=TDAHF/CONFAC[illegible]
```

```
      DO 128 K=1,NRODS
      KT=K-1
      LC=L+J+(KT*50)
      TDHF(J,K)=DATA(LC)
  128 HF(J,K)=TDAHF*TDHF(J,K)
      GO TO 141
  130 DO 140 J=1,JMAX                                         00000510
      DO 140 K=1,NRODS                                        00000511
      HF(J,K)=AXSHF(J)*AVHF(K)
  140 CONTINUE
  141 CONTINUE
C     SPACER GRIDS AND BLOCKAGE SPECIFICATION                 00000513
      L=1300
      DO 150 IL=1,10
      LIL=L+IL                                                00000516
  150 LOC(IL)=INT(DATA(LIL)+0.1)                              00000517
      L=1400
      DO 160 IL=1,10                                          00000519
      DO 170 I=1,NCHAN                                        00000520
      LI=L+I                                                  00000521
  170 PFLOSS(IL,I)=DATA(LI)                                   00000522
  160 L=L+50
      IF(IFAP)GO TO 2000                                      00000524
      IF(DATA(1301).GT.0.) AN=DATA(1301)
      ZF=DATA(1302)
      H=DATA(1303)
      ZHSTT=DATA(1304)
      CGRAV=DATA(1305)
      IF(DATA(1306).GT.0.) CPAP=DATA(1306)
      IF(DATA(1307).GT.0.) PL=DATA(1307)
      IF(DATA(1308).GT.0.) PV=DATA(1308)
      IF(DATA(1309).GT.0.) REL1=DATA(1309)
      IF(DATA(1310).GT.0.) PFL2=DATA(1310)
      IF(DATA(1311).GT.0.) PFSTG=DATA(1311)
      AN1=1./AN                                               00000536
      AN2=1./(AN-1.)                                          00000537
 2000 ZF=ZF*AVHTD                                             00000538
C     TRANSIENT SPECIFICATION                                 00000539
      TFIN=DATA(3900)
      IF(TFIN.LE.0.)GO TO 300                                 00000541
      DTIN=DATA(3901)
      NDTP=INT(DATA(3902)+.1)
      DT=DATA(3903)
C     FLOW/POWER TRANSIENT SPECIFICATION                      00000545
      IP HT=INT(DATA(3911)*1.001)
      DO 180 M=1,5                                            00000547
  180 CHPSS(M)=DATA(M+3911)
C     FLOW TRANSIENT SPECIFICATION                            00000549
      ITINI=INT(DATA(3917)*1.001)
      DO 190 M=1,5                                            00000551
  190 CVIN(M)=DATA(3917+M)
```

```
C      INLET PEIHALPY SPECIFICATION
       ITIN=INT(DATA(3923)*1.001)
       DO 200 M=1,5
  200  CTIN(M)=DATA(3923+M)
C      POWER TRANSIENT SPECIFICATION
       IPOW=INT(DATA(3929)*1.001)
       DO 210 M=1,5
  210  CPOW(M)=DATA(M+3929)
C      TIME TABLES FOR TRANSIENT
       DO 230 M=1,100
       PTAB(M)=DATA(M+3999)
       QTAB(M)=DATA(M+4099)
       HTAB(M)=DATA(M+4199)
  230  PWTAB(M)=DATA(M+4299)
C      CHANNEL BLOCKAGE SPECIFICATION
       IBLOC=INT(DATA(3951)*1.001)
       LBLOC=INT(DATA(3952)*1.001)
       T1BL=DATA(3953)
       T2BL=DATA(3954)
       FBL1=DATA(3955)
       FBL2=DATA(3956)
       SAVE=DT/DZ
C      FIX DT IF NOT GIVEN IN INPUT
       IF(SAVE.LE.0.)SAVE=.05 *AREA *RO/GTCT
       VZERO=1./SAVE
       DT=DZ/VZERO
       PRIN=PRIN-.1*DT
  300  CONTINUE
       CALL DISPL
       PFDAC=1./(1.-PFDAC)
       DO 269 J =1,JMAX
       DO 269 I =1,NCHAN
       HFL(J,I)=0.
       ALF(J,I)=0.
       GP(J,I)=0.
  269  CONTINUE
       CALL STEADY
       IF (TPIN.LE.0.)GO TO 250
       CALL TRANS
  250  IF (LAST.GT.0)CALL EXIT
       GO TO 1000
       END
```

2.6.2 Listing of DISPL

```
0001            SUBROUTINE DISPL                                              00000589
          C            INPUT DISPLAY                                          00000590
0002            LOGICAL NDRIFT
0003            COMMON/UNI/DZ,   DT,   VZERO,   AN,   AN1,   ZE,   R,   FL,
               1FV,   CPAR,   ZUBER,   P
0004            COMMON/DISP/ISHAP,   AXPKF,   ZTOT,   DIAF,   NDRIFT
0005            COMMON/GEOM/JOIN(45),  NJOIN(45,4),   NCIRC(45),   SL(4,45),
               1NOCIR,   RODN(36),   AREA,   IDOP
0006            COMMON/PROP/PO,   ROVAP,   HVAP,   HSAT,   ALAM,   DLAM,   DHSAT,
               1GAMMA,   GAMLA,   ROVRA,   HCO,   GRAD,   IDOWN,   TSAT,   PRAND,
               2HP,   PROUGH,   AFRIC,   BFRIC,   ANM,   AK,   AMU,   WCON,
               3SIGMA,   VDRIFT,   ROGRAV,   DZUMG,   CP,   PERGH(45)
0007            COMMON/GEN/NAROD(45),   KROD(4,45),   HF(50,36),   VINLET(45),
               1GINLET(45),   HINLET,   GTOT,   POWER,   CHANN(45),   A(45),
               2FILC(10,45),   NRODS,   GTFAC,   GTUR,   AVHYD,   VIZERO,   TEIN,
               3PZERO,   HZERO,   POWO,   IBLOC,   LBLOC,   T1BL,   T2BL,   FBL1,
               4FBL2,   PRIN,   MDPR,   HYD(45),   LOC(10),   HPER(4,45),
               5PEDAC,   DFRE,   NCHAN,   JMAX
0008            COMMON/TABL/PEAKF(36),   AXSHF(50),   IPRESS,   CPRESS(5),
               1IVINL,   CVIN(5),   ITIN,   CTIN(5),   IPOW,CPOW(5),   PTAB(100),
               2QTAB(100),   HTAB(100),   PWTAB(100),   TDHF(50,36)
0009            COMMON/PRINT/T,   ICON,   RDPW(36),   IHIN,   PERI
0010            COMMON/WFTE/WP(45)
0011            WRITE(6,1)                                                    00000608
0012          1 FORMAT(1H1,20X,13HINPUT DISPLAY//)                            00000609
0013            WRITE(6,2)NCHAN,NRODS                                         00000610
0014          2 FORMAT(1H ,5X,33HNCHAN-NUMBER OF SUBCHANNELS TYPESI6/6X,      00000611
               134HNRODS-NUMBER OF HEATING RODS TYPESI6//)                    00000612
0015            WRITE(6,3)                                                    00000613
0016          3 FORMAT(20X,18HSUBCHANNELS LAYOUT//6H  CHAN,5X,5HCHANN,9X,11HJOIN.C00000614
               1HANN.,11X, 9HJOIN.RODS)                                       00000615
0017            DO 10 I=1,NCHAN                                               00000616
0018            WRITE(6,4) I,CHANN(I),(NJOIN(I,N),N=1,4),(KROD(M,I),M=1,4)    00000617
0019          4 FORMAT(I6,F12.2,4I5,1X,4I5)                                   00000618
0020         10 CONTINUE                                                      00000619
0021            WRITE(6,5) NOCIR,(NCIRC(I),I=1,NOCIR)
0022          5 FORMAT(1H0/3X,35HNOCIR-NUMBER OF RECIRCULATION PATHSI6/17H    RECIR00000621
               1CULATIONS4I15,/(17X,4I15/))                                   00000622
0023            IF(ISHAP.GE.2) GO TO 320
0024            WRITE(6,6)                                                    00000623
0025          6 FORMAT(1H0,20X,16HROD PEAK FACTORS/)                          00000624
0026            WRITE(6,7) (K,PEAKF(K),K=1,NRODS)                             00000625
0027          7 FORMAT(4(6H    RODI4,6H PEAKFF8.4))                           00000626
0028        320 CONTINUE
0029            WRITE(6,8)                                                    00000627
0030          8 FORMAT(1H0/20X,20HSUBCHANNELS GEOMETRY/6H  CHAN,6X,2HHD,11X,1HA,2000000628
               1X,10HGAP WIDTHS/)                                             00000629
0031            DO 20 I=1,NCHAN                                               00000630
0032          9 FORMAT(I6,2E12.5,2X,4E12.5)                                   00000631
0033            WRITE(6,9) I,HYD(I),A(I),(SL(K,I),K=1,4)                      00000632
0034         20 CONTINUE                                                      00000633
0035            WRITE(6,11)                                                   00000634
0036         11 FORMAT(1H0/20X7HOPTIONS)                                      00000635
```

```
      IF(ISHAP.GE.2) GO TO 41
      IF(ISHAP)31,30,40                                                 00000636
   31 WRITE(6,12)AXPKF                                                  00000637
   12 FORMAT(55H CHOPPED COSINUS AXIAL POWER DISTRIBUTION - PEAK FACTOR 00000638
     1F8.5)                                                             00000639
      GO TO 50                                                          00000640
   30 WRITE(6,13)                                                       00000641
   13 FORMAT(30H FLAT AXIAL POWER DISTRIBUTION)                         00000642
      GO TO 50                                                          00000643
   40 WRITE(6,14)(AXSHF(J),J=1,JMAX)                                    00000644
   14 FORMAT(18H AXIAL POWER SHAPE/(8E12.4))                            00000645
   41 WRITE(6,42)
   42 FORMAT(1X,'OPTION 2=HEAT FLUXES PER ROD AND PER AXIAL STEP')
      DO 333 J=1,JMAX
      DO 333 K=1,NRODS
      WRITE(6,43) J,K,HF(J,K)
   43 FORMAT(1X,I5,I5,F14.5)
  333 CONTINUE
   50 CONTINUE                                                          00000646
      IF(ICON.EQ.0) GO TO 601
      IF(ICON.EQ.1) GO TO 602
      IF(ICON.EQ.2) GO TO 603
      IF(ICON.EQ.3) GO TO 604
  601 WRITE(6,301)
  301 FORMAT(1X,'EDIT GIVES:MKSA SYSTEM FOR INPUT/OUTPUT')
      GO TO 70
  602 WRITE(6,307)
      WRITE(6,302)
  307 FORMAT(1X,'****DISPLAY ALWAYS PRINTS PHYSICAL PARAMETERS IN MKSA')
  302 FORMAT(1X,'EDIT GIVES:BTU SYSTEM INPUT/MKSA SYSTEM OUTPUT')
      GO TO 70
  603 WRITE(6,307)
      WRITE(6,303)
  303 FORMAT(1X,'EDIT GIVES:BTU SYSTEM INPUT/OUTPUT')
      GO TO 70
  604 WRITE(6,307)
      WRITE(6,304)
  304 FORMAT(1X,'EDIT GIVES:MKSA SYSTEM INPUT/BTU OUTPUT')
   70 CONTINUE                                                          00000653
      GO TO(80,90),IDOP                                                 00000654
   80 WRITE(6,17)                                                       00000655
   17 FORMAT(33HCHYDRAULIC DIAMETERS RENORMALIZED)                      00000656
   90 CONTINUE                                                          00000657
      IF(NDRIFT) WRITE(6,22)                                            00000658
   22 FORMAT(24HONO VAPOUR MIXING EFFECT)                               00000659
      IF(.NOT.NDRIFT)WRITE(6,221)                                       00000660
  221 FORMAT(29HCVAPOUR MIXING MODEL INCLUDED)                          00000661
      IF(IDOWN)100,100,110                                              00000662
  100 WRITE(6,18)                                                       00000663
   18 FORMAT(13HOUPWARDS FLOW)                                          00000664
      GO TO 120                                                         00000665
  110 WRITE(6,19)                                                       00000666
   19 FORMAT(15HODOWNWARDS FLOW)                                        00000667
```

```
 24 FORMAT(1H0        TRANSIENT SPECIFICATION ... 
   1TED  2=SINUSOIDAL  3=POLYNOMIAL/10H  PRESSUREI5,1X, 9HMASS FLOWI5,
   23X,14HINLET ENTHALPYI5,3X,5HPOWERI5)
    WRITE(6,23)P,GTOT,POWER,PPDAC,ZTOT,HINLET
 23 FORMAT(46H0           PHYSICAL PARAMETERS FOR STEADY STATE/,
   111H   PRESSUREE12.5,20HBAR  TOTAL MASS FLOWE12.5,25HG/SEC  TOTAL B
   2UNDLE POWERE12.5,4HWATT/3X,25HPOWER FRACTION TO COOLANTF10.5/
   31H   TOTAL HEIGTHF10.2,24HCM  INLET ENTHALPY SUBC.E12.5)
    WRITE(6,24)RO,TSAT,HSAT,ALAM,ROVAP,GAMMA,AMU,WCON,SIGMA
 24 FORMAT(56H0           COOLANT PROPERTIES(CGS UNITS,JOULE/G FOR ENGY)
   1/17H   LIQUID DENSITYF10.5, 6H  TSATF10.3,6H  HSATF10.2,10H  LAT.H
   2EATF10.2/14H  VAPOUR DENS.F12.5,7H  GAMMAF10.7,6H  VISCE10.4,10H
   3TH.COND.F10.4,12H  SURF.TENS.E10.4)
    WRITE(6,25)DIAP,DZ,DT
 25 FORMAT(25H0   HEATING RODS DIAMETERF8.4,2HCM/17H   NODE HEIGTH DZ
   1F10.2,16HCM  TIME STEP DTF10.4,3HSEC)
    WRITE(6,26)
 26 FORMAT(1H0,20X,18HLOCAL RESTRICTIONS/6H  NODE,8X,31HLOCAL LOSS COE
   1FF.IN SUBCHANNELS)
    DO 200 I=1,10
    IF(LOC(I).LE.0) GO TO 201
    WRITE (6,27) LOC(L),(PFLC(L,I),I=1,NCHAN)
 27 FORMAT(I6,10F10.3/6X,10E10.3)
200 CONTINUE
    GO TO 202
201 IF(L.EQ.1) WRITE(6,28)
 28 FORMAT(6H  NONE)
    RETURN
202 IF(IBLOC.EQ.0) RETURN
    WRITE(6,29)IBLOC,LBLOC,T1BL,FBL1,T2BL,FBL2
 29 FORMAT(1H0/30H   TRANSIENT BLOCKAGE IN SUBCHI5,8H AT NODEI5/
   125H   INITIAL TIME FOR BLOCKF8.2,12HRESTR.COEFF.F10.3/
   223H   FINAL TIME FOR BLOCKF8.2,12HRESTR.COEFF.F10.3)
    RETURN
    END
```

2.6.3 Listing of EDIT

```
     1FV,    CMAP,    ZUBEF,    P
      COMMON/PROP/PC,    ROVAP,    HVAP,    HSAT,    ALAM,    DLAM,    DHSAT,
     1GAMMA,    GAMLA,    ROVPA,    HCO,    GRAD,    IDOWN,    TSAT,    PRAND,
     2HB,    RROUGH,    APRIC,    BPRIC,    AMM,    AK,    AMU,    WCON,
     3SIGMA,    VDRIFT,    ROGPAV,    DZUMG,    CP,    RERGH(45)
      COMMON/GEN/NAROD(45),    KRCD(4,45),    HF(50,36),    VINLET(45),
     1TINLET(45),    HINLET,    GTOT,    POWER,    CHANN(45),    A(45),
     2PLC(10,45),    NRODS,    GTFAC,    GTHR,    AVHYD,    VIZERO,    TPIN,
     3PERPC,    HZERO,    POWO,    IBLOC,    LBLOC,    T1BL,    T2BL,    PBL1,
     4ITLP,    PRIN,    MDPR,    HYD(45),    LOC(10),    HPER(4,45),
     5PFRAC,    DERP,    NCHAN,    JMAX
      COMMON/RESVE/VFAV(45),    GCUT(45),    GOUTV(45),    GOUTL(45),
     1XOUT(45),    FOUT(45),    BAL(45)
      COMMON/RES/ITER(50),    PDROP(50),    TEOUT,    FMOUT,    PACC,
     1TBAL,    AVX,    DPTOT
      COMMON/AFF/DTF(50,45),    ALF(50,45),    HEL(50,45),
     1GF(50,45),    TQUAL(50,45),    XQUAL(50,45)
      COMMON/IPINT/T,    ICON,    RDPW(36),    IHIN,    PERI
      COMMON/GEOM/JCIN(45),    NJOIN(45,4),    KCINC(45),    SL(4,45),
     1NCCIN,    FCDN(36),    AREA,    IDOP
      DIMENSION STRING(10),    EFI(45)
C     OUTPUT ROUTINE                                                    00001777
      DATA HCONF,GCONF,FICONF,FCONF,PCONF,DCONF                         00001778
     1/.4304,.007373,.003173,.007937,14.503,62.383/                     00001779
      DATA VFCON/.1271/                                                 00001780
      PRESS=P                                                           00001781
      TST=TSAT                                                          00001782
      GAVST=GTOT/AREA                                                   00001785
      IF(ICON.EQ.0.OR.ICON.EQ.1) GO TO 301
      IF(ICON.EQ.2.OR.ICON.EQ.3) GO TO 302
  302 TST=32.+1.8*TST
      PRESS=PCONF*P
      GAVST=GAVST*GCONF
  301 CONTINUE
      WRITE(6,1)T,PRESS,TST,GAVST                                       00001787
    1 FORMAT(1H0//15X,5HTIME=F10.4,4H SEC,2X,8HPRESSURE=F09.3,6H  TSAT=F8.00001788
     12,5H  GAVE11.4)                                                   00001789
      TOAVVF=0.                                                         00001790
      DO 3 I=1,NCHAN                                                    00001791
    3 TOAVVF=TOAVVF+A(I)*VFAV(I)*CHANN(I)                               00001792
      TOAVVF=TOAVVF/AREA                                                00001793
      AVDEN=RC*(1.-TOAVVF*(1.-GAMMA))                                   00001794
      WRITE(6,2)                                                        00001795
    2 FORMAT(1H0,2X,5HPOWER8X,4HGTOT,7X,5HFMOUT,8X,4HTBAL,9X,3HAVX,7X,5H00001796
     1DPTOT,6X,6HTOAVVF,7X,5HAVDEN,6X,6HHINLET)                         00001797
      IF(ICON.EQ.0.OR.ICON.EQ.1) GO TO 1101
      IF(ICON.EQ.2.OR.ICON.EQ.3) GO TO 1102
 1101 WRITE(6,101)
  101 FORMAT(1H ,3X,4HWATT,8X,6HKG/SEC,6X,6HKG/SEC,7X,4HWATT,20X,3HBAR1900001800
     1X,7HG/CM-CM,3X,7HJOULE/G)                                         00001801
      GO TO 104
```

```
 1102 WRITE(6,103)
  103 FORMAT(1H ,3X,4HWATT,8X,6HMLB/HR,6X,6HMLB/HR,7X,4HWATT,20X,3HPSI1900001804
     1X8HLB/CU-FT,3X,6HBTU/LB)                                          00001805
  104 CONTINUE                                                          00001806
      STRING(1)=POWER                                                   00001807
      STRING(2)=GTOT                                                    00001808
      STRING(3)=FMOUT                                                   00001809
      STRING(4)=TRAI                                                    00001810
      STRING(5)=AVX                                                     00001811
      STRING(6)=DPTOT                                                   00001812
      STRING(7)=TOAVVF                                                  00001813
      STRING(8)=AVDEN                                                   00001814
      STRING(9)=HINLET                                                  00001815
      STRING(2)=.001 *STRING(2)                                         00001816
      STRING(3)=.001 *STRING(3)                                         00001817
      STRING(6)=0.000001*STRING(6)                                      00001819
      IF(ICON.EQ.0.OR.ICON.EQ.1) GO TO 23
      IF(ICON.EQ.2.OR.ICON.EQ.3) GO TO 21
   21 STRING(2)=FCONF*STRING(2)                                         00001820
      STRING(3)=FCONF*STRING(3)                                         00001821
      STRING(6)=PCONF*STRING(6)                                         00001822
      STRING(8)=DCONF*STRING(8)                                         00001823
      STRING(9)=HCONF*STRING(9)                                         00001824
      GO TO 23
   23 WRITE(6,22) (STRING(N),N=1,9)                                     00001825
   22 FORMAT(9F12.5)                                                    00001826
      WRITE(6,50)                                                       00001827
   50 FORMAT(1H0,5H CHAN,4X,4HXOUT,8X,4HGOUT,7X,5HGOUTV,7X,5HGOUTL,6X,6H00001828
     1GINLET,9X,3HBAL,9X,3HENT,8X,4HVFAV)                               00001829
      DO 150 I=1,NCHAN                                                  00001830
      KF=NAFCD(I)                                                       00001831
      SAVE=0.                                                           00001832
      DO 151 K=1,KF                                                     00001833
      KFO=KFCD(K,I)                                                     00001834
      IF(ISHAP.EQ.-1) GO TO 1505
      IF(ISHAP.EQ.0) GO TO 1505
      IF(ISHAP.EQ.1) GO TO 1505
      IF(ISHAP.GE.2) GO TO 1503
 1503 DO 1504 J=1,JMAX
 1504 SAVE=SAVE+HF(J,K)*HPER(K,I)
      GO TO 151
 1505 CONTINUE
      SAVE=SAVE+RDPW(K)*HPER(K,I)/PEPI
  151 CONTINUE
  150 ENT(I)=SAVE                                                       00001836
      IF(ICON.EQ.0.OR.ICON.EQ.1) GO TO 25
      IF(ICON.EQ.2.OR.ICON.EQ.3) GO TO 27
   27 DO 26 I=1,NCHAN
      GOUT(I)=GCONF*GOUT(I)                                             00001839
      GOUTV(I)=GCONF*GOUTV(I)                                           00001840
      GOUTL(I)=GCONF*GOUTL(I)                                           00001841
      GINLET(I)=GCONF*GINLET(I)                                         00001842
   26 CONTINUE                                                          00001843
```

```
      WRITE(6,5)(I,XOUT(I),HOUT(I),GOUT(I),GOUTL(I),GTHLBT(I),XUAL(I),WNU
     1I(I),VPAV(I),I=1,NCHAN)
    5 FORMAT(I6,8E12.5)
      RETURN
      ENTRY EDIT2
      DO 10 I=1,NCHAN
      KP=NARCD(I)
      WRITE(6,11)I,T
   11 FORMAT(1H1,20X,5HSUBCHIN,5X,4HTIMEF10.4/
     12X,4HNODE,6X,2HL,10X,2HTQ,11X,1HG,9X,3HQTR,7X,5HALPHA,7X,5HFIMAX,
     211X,1HX,7X,5HDPDCP,6X,4HITER)
      IF(ICON.EQ.2.OR.ICON.EQ.3) GO TO 13
      IF(ICON.EQ.0.OR.ICON.EQ.1) GO TO 12
   12 WRITE(6,14)
   14 FORMAT(1H , 8X,8HJOULE/GR,15X,21HGR/SQ-CM S  CU-CM/SEC,14X,10HWATT
     1/SQ-CM,16X,3HBAR)
      GO TO 15
   13 WRITE(6,141)
  141 FORMAT(1H , 9X,6HBTU/LB,15X,20HMLB/SQ-FT H CU-FT/HR,16X,12HBTU/SQ-
     1FT HR,18X,4H PSI)
   15 DO 16 J=1,JMAX
      STRING(1)=PEL(J,I)
      STRING(2)=TQUAL(J,I)
      STRING(3)=GP(J,I)
      STRING(4)=QPP(J,I)
      STRING(5)=ALF(J,I)
      FIMAX=0.
      DO 200 K=1,KP
      KRO=KRPD(K,I)
      IF(HF(J,KRO).GT.FIMAX)FIMAX=HF(J,KRO)
  200 CONTINUE
      STRING(6)=FIMAX
      STRING(7)=XQUAL(J,I)
      STRING(8)=DPDCP(J)
      STRING(8)=1.E-05*STRING(8)
      IF(ICON.EQ.0.OR.ICON.EQ.1) GO TO 1108
      IF(ICON.EQ.2.OR.ICON.EQ.3) GO TO 1106
 1106 STRING(1)=HCONF*STRING(1)
      STRING(4)=VPCON*STRING(4)
      STRING(3)=GCONF*STRING(3)
      STRING(6)=FICONF*STRING(6)
      STRING(8)=ECONF*STRING(8)
 1108 CONTINUE
   20 WRITE(6,18)J,(STRING(N),N=1,8),ITER(J)
   18 FORMAT(I6,8E12.5,I6)
   16 CONTINUE
   10 CONTINUE
      RETURN
      END
```

2.6.4 Listings of Functions ROFUN and Subroutine GEOMRY

```
FUNCTION ROFUN(P)
PP=1.01972*P
Q=1.1025*(1.+3.464E-3*PP-4.13E-6*PP*PP)
ROFUN=1./Q
RETURN
END
```

```
      SUBROUTINE GEOMRY
      COMMON/GEOM/JOIN(45),  NJOIN(45,4),   MCIRC(45),    SL(4,45),
     1NOCIR,    RODN(36),    AREA,    IDOP
      COMMON/PROP/RO,    ROVAP,    HVAP,    HSAT,    ALAM,    DLAM,    DHSAT,
     1GAMMA,    GAMLA,    ROVRA,    HCO,    GRAD,    IDOWN,    TSAT,    PRAND,
     2HB,    PROUGH,    AFRIC,    BFRIC,    ANM,    AK,    AMU,    WCON,
     3SIGMA,    VDRIFT,    ROGRAV,    D7UMG,    CP,    RERGH(45)
      COMMON/GEN/NAROD(45),    KROD(4,45),    HF(50,36),    VINLET(45),
     1GINLET(45),    HINLET,    GTOT,    POWER,    CHANN(45),    A(45),
     2EFLC(10,45),    NRODS,    GTFAC,    GTUR,    AVHYD,    VIZERO,    TFIN,
     3P7ERO,    H7ERO,    POWO,    IBLOC,    LBLOC,    T1BL,    T2BL,    FBL1,
     4FBL2,    PRIN,    MDPR,    HYD(45),    LOC(10),    HPER(4,45),
     5PFDAC,    DERP,    NCHAN,    JMAX
      COMMON/WETP/WP(45)
      COMMON/MIX/ALFDD,      RMIX,      SLIP(45),      TURMT,      VEX,
     1VP7(45,4)
      DIMENSION CHYD(45)
C     CHECK GEOMETRY
      SAVE=0.
      DO 60 I=1,NCHAN
      K=NAROD(I)
      DO 60 M=1,K
   60 SAVE=SAVE+CHANN(I)*HPER(M,I)
      TOTROD=0.
      DO 70 K=1,NRODS
   70 TOTROD=TOTROD+RODN(K)
      CHECK=ABS(TOTROD-SAVE)
      IF(CHECK/SAVE.GT.0.001)WRITE(6,5)
    5 FORMAT(1H0,2X40HWARNING-PERIMETER BALANCE IS NOT CORRECT)
      DO 80 I=1,NCHAN
      KM=JOIN(I)
      DO 90 K=1,KM
      L=NJOIN(I,K)
      IF(L.LE.0.OR.L.GT.NCHAN) GO TO 93
      IF(L.LT.I)GO TO 90
      MM=JOIN(L)
      DO 91 M=1,MM
      IF(NJOIN(L,M).EQ.I)GO TO 90
   91 CONTINUE
      DO 92 M=1,MM
```

```
      IF(NJOIN(L,M).NE.0)GO TO 92
      NJOIN(L,M)=I
      SL(M,L)=SL(K,I)
      GO TO 90
   92 CONTINUE
   93 CONTINUE
      WRITE(6,6)L
    6 FORMAT(1H0,2X,52HADJOINING CHANNELS SPECIFICATION WRONG FOR SUBCHA
     1NELI5)
      STOP
   90 CONTINUE
   80 CONTINUE
      DO 15 I=1,NCHAN
      M= JOIN(I)
      DO 16 K=1,M
   16 VR7(I,K)=(SL(K,I)/HYD(I))**(1./7.)
   15 CONTINUE
C     HYDRAULIC DIAMETER RENORMALIZATION OPTION
      GO TO(1,2),IDOP
    1 DO 11 I=1,NCHAN
      WP(I)=4.*A(I)/HYD(I)
      SAVE=0.
      TOTP=WP(I)
      L=JOIN(I)
      DO 12 K=1,L
   12 TOTP=TOTP+SL(K,I)
      DO 13 K=1,L
      M=NJOIN(I,K)
   13 SAVE=SAVE+SL(K,I)/TOTP*HYD(M)
   11 CHYD(I)=SAVE+WP(I)/TOTP*HYD(I)
      DO 14 I=1,NCHAN
   14 HYD(I)=CHYD(I)
    2 GTFAC=0.25*SQRT(0.005/2.)/72.
      AREA=0.
      TOTWP=0.
      DO 21 I=1,NCHAN
      AREA=AREA+CHANN(I)*A(I)
   21 TOTWP=TOTWP+CHANN(I)*WP(I)
      AVHYD=4.*AREA/TOTWP
      GTFAC=GTFAC/(0.0392*AVHYD)
      CALL MATSET
      RETURN
      END
```

2.6.5 Listing of Subroutine STEADY

```
      SUBROUTINE STEADY
      LOGICAL IBB,IREV,IFREV,ITRA,ILOC                                  00000914
      COMMON/UNI/DZ,    DT,    VZERO,    AN,    ANI,    ZE,    R,    FI,
     1EV,    CPAR,    ZUBER,    P
      COMMON/CONT/FI(4),    IBB,    IREV,    IFREV,    ITRA,    ILOC,
     1TETA,    APAR,    TIN,    H,    HP,    TW,    PSI,    HOLD,    VFOLD,
     2VFIN,    HBAR,    TD,    AA,    AJIN,    AJVIN,    HLINJ,    HIN,
     3GFLIN,    GOLD,    Q,    QV,    QL,    FFAC,    FFLOC,    AJ,    AJV,
     4AJL,    VF,    HL,    G,    DPF,    DP,    DPEXC,    SAVEN,    QP,
     5PH(4),    XT,    KR,    GFLUX
      COMMON/GEN/NAROD(45),    KROD(4,45),    HF(50,36),    VINLET(45),
     1GINLET(45),    HINLET,    GTOT,    POWER,    CHANN(45),    A(45),
     2FFLC(10,45),    NRODS,    GTFAC,    GTUR,    AVHYD,    VIZERO,    TFIN,
     3PZERO,    HZERO,    POWO,    IBLOC,    LBLOC,    T1BL,    T2BL,   FBL1,
     4FBL2,    PRIN,    MDPR,    HYD(45),    LOC(10),    HPER(4,45),
     5PFDAC,    DFRP,    NCHAN,    JMAX
      COMMON/GEOM/JOIN(45),    NJOIN(45,4),    MCIRC(45),    SL(4,45),
     1NOCIR,    RODN(36),    AREA,    IDOP
      COMMON/PROP/RO,    ROVAP,    HVAP,    HSAT,    ALAM,    DLAM,    DHSAT,
     1GAMMA,    GAMLA,    ROVRA,    HCO,    GRAD,    IDOWN,    TSAT,    PRAND,
     2HB,    RROUGH,    AFRIC,    BFRIC,    ANM,    AK,    AMU,    WCON,
     3SIGMA,    VDRIFT,    ROGRAV,    DZUMG,    CP,    RERGH(45)
      COMMON/PRINT/T,    ICON,    RDPW(36),    IHIN,    PERI
      COMMON/MIX/ALFDD,    RMIX,    SLIP(45),    TURMT,    VEX,
     1VRZ(45,4)
C     CONTROLS STEADY STATE CALCULATION                                 00000932
      ITRA=.FALSE.                                                      00000933
      DERP=0.                                                           00000934
      DLAM=0.                                                           00000935
      DHSAT=0.                                                          00000936
      ROVRA=1.                                                          00000937
      DZUMG=DZ*(1.-GAMMA)                                               00000938
      POWO=POWER                                                        00000939
      PZERO=P                                                           00000940
      GZERO=GTOT                                                        00000941
      VIZERO=GTOT/RO/AREA                                               00000942
      VEX=EXP(-SQRT(VIZERO/100.))                                       00000943
      T=0.                                                              00000944
      DO 1 I=1,NCHAN                                                    00000945
    1 VINLET(I)=VIZERO                                                  00000946
```

```
      AVREY=RO*AVHYD*VIZERO/AMU
      GTUR=GTFAC*AVREY*AMU
      CALL SWEEP
      WRITE(6,100)
  100 FORMAT(1H1//20X,20HSTEADY STATE RESULTS)
      CALL EDIT
      CALL EDIT2
      WRITE(6,101)
  101 FORMAT(34H0  END OF STEADY STATE CALCULATION)
      RETURN
      END
```

2.6.6 Listing of Subroutine TRANS

```
      SUBROUTINE TRANS
      LOGICAL IBR,IREV,IFREV,ITRA,ILOC                                  00000960
      COMMON/UNI/DZ,   DT,   VZERO,   AN,   AN1,   ZE,   R,   FI,
     1FV,   CPAR,   ZUBER,   P
      COMMON/CONT/FI(4),   IBR,  IREV,   IFREV,   ITRA,   ILOC,
     1TETA,   APAR,   TIN,   H,   HP,   TW,   PSI,   HOLD,   VFOLD,
     2VFIN,   HBAR,   TD,   AA,   AJIN,   AJVIN,   HLINJ,   HIN,
     3GFLIN,   GOLD,   Q,   QV,   QL,   FFAC,   FFLOC,   AJ,   AJV,
     4AJL,   VF,   HL,   G,   DPF,   DP,   DPEXC,   SAVEN,   QP,
     5PH(4),   XT,   KR,   GFLJX
      COMMON/GEN/NAROD(45),   <ROD(4,45),   HF(50,36),   VINLET(45),
     1GINLET(45),   HINLET,   GTOT,   POWER,   CHANN(45),   A(45),
     2FFLC(10,45),   NRODS,   GTFAC,   GTUR,   AVHYD,   VIZERO,   TFIN,
     3PZERO,   HZERO,   POWO,   IBLOC,   LBLOC,   T1BL,   T2BL,  FBL1,
     4FBL2,   PRIN,   MDPR,   HYD(45),   LOC(10),   HPER(4,45),
     5PFDAC,   DFRP,   NCHAN,   JMAX
      COMMON/TABL/PEAKF(36),   AXSHF(50),   IPRESS,   CPRESS(5),
     1IVINL,  CVIN(5),  ITIN,  CTIN(5),  IPOW,CPOW(5),  PTAB(100),
     2QTAB(100),   HTAB(100),   PWTAB(100),   TDHF(50,36)
      COMMON/GEOM/JOIN(45),  NJOIN(45,4),   MCIRC(45),   SL(4,45),
     1NOCIR,   RODN(36),   AREA,   IDOP
      COMMON/PROP/RO,   ROVAP,   HVAP,   HSAT,   ALAM,   DLAM,   DHSAT,
     1GAMMA,   GAMLA,   ROVRA,   HCO,   GRAD,   IDOWN,   TSAT,   PRAND,
     2HB,   RROUGH,   AFRIC,   BFRIC,   ANM,   AK,   AMU,   WCON,
     3SIGMA,   VDRIFT,   ROGRAV,   DZUMG,   CP,   RERGH(45)
      COMMON/PRINT/T,   ICON,   RDPW(36),   IHIN,   PERI
      COMMON/MIX/ALFOD,     RMIX,     SLIP(45),     TURMT,     VEX,
     1VRZ(45,4)
C     CONTROLS TRANSIENT CALCULATION                                    00000980
      DATA HCONF /.4304/                                                00000981
      WRITE(6,500)                                                      00000982
  500 FORMAT(1H1,20X,9HTRANSIFNT)                                       00000983
      ITRA=.TRUF.                                                       00000984
      TPRI=0.                                                           00000985
      MP=0                                                              00000986
      VIN=VIZERO                                                        00000987
      AVREY=RO*AVHYD*VIZERO/AMJ                                         00000988
      DPTAC=0.                                                          00000989
      ROVAP1=ROVAP                                                      00000990
  100 T=T+DT                                                            00000991
```

```
      IF(T.GT.TFIN)RETURN                                          00000992
      PRESS1=P                                                     00000993
      IF(IPRESS.LE.0)GO TO 1                                       00000994
      P=TIMEF(T,IPRESS,CPRESS,PZERO,PTAB)                          00000995
      DERP=0.1*(P-PRESS1)/DT                                       00000996
      ROVAP1=ROVAP                                                 00000997
      HVAP1=HVAP                                                   00000998
      ALAM1=ALAM                                                   00000999
      HSAT1=HSAT                                                   00001000
      CALL WATER(P)                                                00001001
      DLAM=ALAM-ALAM1                                              00001002
      DHSAT=HSAT-HSAT1                                             00001003
      ROVRA=ROVAP1/ROVAP                                           00001004
      DZUMG=DZ*(1.-GAMMA)                                          00001005
    1 CONTINUE                                                     00001006
      IF(ITIN.LE.0)GO TO 2                                         00001007
      SAVE=TIMEF(T,ITIN,CTIN,1.,HTAB)                              00001008
      IF(ITIN.GT.1)SAVE=SAVE-1.                                    00001009
      IF(IHIN)22,21,21                                             00001010
   21 CONTINUE
      IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 202
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 201
  202 SAVE=SAVE/HCONF
  201 CONTINUE
      GO TO 23
   22 IF(ICON.EQ.1.OR.ICON.EQ.2) GO TO 302
      IF(ICON.EQ.0.OR.ICON.EQ.3) GO TO 301
  302 SAVE=.55556*SAVE
  301 CONTINUE
      SAVE=CP*SAVE                                                 00001014
   23 HINLET=HZERO+SAVE                                            00001015
    2 CONTINUE                                                     00001016
      IF(IVINL.LE.0)GO TO 3                                        00001017
      VIN1=VIN                                                     00001018
      VIN=TIMEF(T,IVINL,CVIN,VIZERO,QTAB)                          00001019
      VEX=EXP(-SQRT(VIN/100.))                                     00001020
      VFAC=VIN/VIN1                                                00001021
      DO 4 I=1,NCHAN                                               00001022
    4 VINLET(I)=VFAC*VINLET(I)                                     00001023
      AVRFY=VFAC*AVRFY                                             00001024
      GTUR=GTFAC*AVRFY*AMU                                         00001025
      GTOT=RO*VIN*AREA                                             00001026
    3 IF(IPOW.LE.0)GO TO 5                                         00001027
      POW1=POWER                                                   00001028
      POWER=TIMEF(T,IPOW,CPOW,POWO,PWTAB)                          00001029
      PWFAC=POWER/POW1                                             00001030
      DO 6 J=1,JMAX                                                00001031
```

```
      DO 6 K=1,NPODS
    6 HF(J,K)=P*FAC*HF(J,K)
    5 CONTINUE
      IF(IBLOC.EQ.0)GO TO 7
      IF(T.LT.T1BL)GO TO 7
      FFLC(LBLOC,IBLOC)=FBL2
      IF(T.LT.T2BL)FFLC(LBLOC,IBLOC)=FBL1+(FBL2-FBL1)*(T-T1BL)/(T2BL-T1B
     1L)
    7 CONTINUE
      CALL SWEEP
      TPRI=TPRI+DT
      IF(TPRI.LT.PRIN)GO TO 100
      CALL EDIT
      TPRI=0.
      MP=MP+1
      IF(MP.LT.MOPR)GO TO 100
      CALL EDIT2
      MP=0
      GO TO 100
      END
```

2.6.7 Listings of Subroutines VMEX and MIXIN

```
      SUBROUTINE VMIX
      LOGICAL NDRIFT
      COMMON/DISP/ISHAP,    AXPKF,    ZTOT,    DIAR,    NDRIFT
      COMMON/SCVEC/AJT(45),    AJVAP(45),    FIHLIN(45),    QT(45),
     1QVT(45),    QLT(45),    FXCHM(45),    HLIN(45),    HDIV(45),
     2TDH(45),    GFL(45),    VFI(45),    AJN(45),    AJVN(45),    AJLN(45),
     3DPFP(45),    VFN(45),    HLN(45),    GN(45),    GFN(45),    GT(45),
     4SAVH(45),    ENSAVE(45),    FAC(45),    DPS(45),    EDP(45),
     5EDPO(45),    QTO(45),    AJLI(45),    XTR(45)
      COMMON/GEN/NAROD(45),    KROD(4,45),    HF(50,36),    VINLET(45),
     1GINLET(45),    HINLET,    GTOT,    POWER,    CHANN(45),    A(45),
     2FFLC(10,45),    NRODS,    GTFAC,    GTUR,    AVHYD,    VIZERO,    TFIN,
     3PZERO,    HZERO,    POWO,    IBLOC,    LBLOC,    T1BL,    T2BL,    FBL1,
     4FBL2,    PRIN,    MDPR,    HYD(45),    LOC(10),    HPER(4,45),
     5PFDAC,    DFRP,    NCHAN,    JMAX
      COMMON/GEOM/JOIN(45),    NJOIN(45,4),    MCIRC(45),    SL(4,45),
     1NOCIR,    RODN(36),    AREA,    IDOP
      COMMON /MIKE/ KI
      DO 1 I=1,NCHAN
    1 CALL SLIPF(I,JJ)
      DO 10 I=1,NCHAN
      KS=JOIN(I)
      DO 20 K=1,KS
      JJ=NJOIN(I,K)
      KI=K
      CALL MIXIN(I,JJ)
   20 CONTINUE
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MIXIN(I,JJ)
      LOGICAL NDRIFT
      COMMON/UNI/DZ,    DT,    VZERO,    AN,    AN1,    ZE,    R,    FL,
     1FV,    CPAR,    ZUBER,    P
      COMMON/MIX/ALFDD,      RMIX,      SLIP(45),      TURMT,      VEX,
     1VR7(45,4)
      COMMON/GEOM/JOIN(45),  NJOIN(45,4),   MCIRC(45),    SL(4,45),
     1NOCIR,    RODN(36),    AREA,    IDOP
      COMMON/DISP/ISHAP,    AXPKF,    ZTOT,    DIAR,    NDRIFT
      COMMON/MAT/MATDIM,    NEQ,    NTW(45,4),    TMATI(80,80),
     1TMAT(80,80),    XLU(80,80),    SRMIX(80,80),    SALDD(80,80)
      COMMON/SCVFC/AJT(45),    AJVAP(45),    FIHLIN(45),    QT(45),
     1QVT(45),    QLT(45),    EXCHM(45),    HLIN(45),    HDIV(45),
     2TDH(45),    GFL(45),    VFI(45),    AJN(45),    AJVN(45),    AJLN(45),
     3DPFR(45),    VFN(45),    HLN(45),    GN(45),    GFN(45),    GT(45),
     4SAVN(45),    ENSAVE(45),    FAC(45),    DPS(45),    EDP(45),
     5EDPO(45),    QTO(45),    AJLI(45),    XTR(45)
      COMMON/GEN/NAROD(45),    KROD(4,45),    HF(50,36),    VINLET(45),
     1GINLET(45),    HINLET,    GTOT,    POWER,    CHANN(45),    A(45),
     2FFLC(10,45),    NRODS,    GTFAC,    GTUR,    AVHYD,    VIZERO,    TFIN,
     3PZERO,    HZERO,    POWO,    IBLOC,    LBLOC,    T1BL,    T2BL,   FBL1,
     4FBL2,    PRIN,    MDPR,    HYD(45),    LOC(10),    HPER(4,45),
     5PFDAC,    DFRP,    NCHAN,    JMAX
      COMMON/PROP/RO,    ROVAP,    HVAP,    HSAT,    ALAM,    DLAM,    DHSAT,
     1GAMMA,    GAMLA,    ROVRA,    HCO,    GRAD,    IDOWN,    TSAT,    PRAND,
     2HB,    RROUGH,    AFRIC,    BFRIC,    ANM,    AK,    AMU,    WCON,
     3SIGMA,    VDRIFT,    ROGRAV,    DZUMG,    CP,    RERGH(45)
      COMMON/WETP/WP(45)
      COMMON /MIKE/ KI
      DATA EFFAC,AKPAR,GCRIT,GCR1/0.005,2.,3.8,1./
      DATA GCONF/.007373/
      DATA PARK/100./
      AKTP=0.0264*SQRT(.5*EFFAC)
C     VOID DRIFT CALCULATION
      IF(NDRIFT)GO TO 100
      AVALF=VFI(I)
      IF(AVALF.LE.0.)GO TO 100
      CMIXM=SQRT(1./GAMMA)
      DAV=HYD(I)
      GAV=ABS(GT(I))
```

```
      GBU=GCONF*GAV
      U=ABS(AJI(I))
      ALCZ=0.
      ALFC1=0.37
      ALFC2=.775-.0504*GBU-.0171*GBU*GBU
C     VOID DRIFT
      ALC2=ALFC2
      IF(GBU.GT.GCRIT)ALC2=ALFC1
      XI=1.
      IF(AVALF.LE.ALCZ)GO TO 2
    1 IF(AVALF-ALFC1)3,4,4
    3 XI=1.+(CMIXM-1.)*(AVALF-ALCZ)/(ALFC1-ALCZ)
      GO TO 5
    4 IF(AVALF-ALC2)6,6,7
    6 XI=CMIXM
      GO TO 5
    7 XI=1.+(CMIXM-1.)*.5*(1.+COS(3.1416*(AVALF-ALC2)/(1.-ALC2)))
    5 IF(GBU.GT.GCRIT)XI=1.+(XI-1.)*EXP(-AKPAR*(GAV/GCRIT-1.))
    2 CONTINUE
      RMIX=AKTP*XI*U*DAV*DZ
      RMIX=RMIX*EXP(-PARK*VEX*(1.-VPZ(I,KI)))*15.
  101 CONTINUE
      SRMIX(I,JJ)=RMIX
      RETURN
  100 ALFDD=0.
      RMIX=0.
      GO TO 101
C     DIVERTED FLOW SLIP FACTOR
      ENTRY SLIPF(I,JJ)
      ALFI=VFI(I)
      ALCZ=.2
   11 SLIP(I)=1./AK
      IF(ALFI.LE.ALCZ)SLIP(I)=SLIP(I)*ALFI/ALCZ
      RETURN
      ENTRY REYSE(I,JJ)
      TURMT=0.
      KS=JOIN(I)
      DO 20 K=1,KS
      JJ=NJOIN(I,K)
      GST=GT(JJ)-GT(I)
```

```
      AAV=A(I)+A(JJ)
      DAV=4.*AAV/(WP(I)+WP(JJ))
      U=(AJT(I)*A(I)+AJT(JJ)*A(JJ))/AAV
      SAVE=DZ*AKTP*U*DAV*GST
   20 TURMT=TURMT+SAVE
      RETURN
      END
```

2.6.8 Listing of Subroutine SPLITD

```
      SUBROUTINE SPLITD(J)
C     SPLITS THE DIVERTED FLOW INTO VAPOUR AND LIQUID FLOW                00001436
      LOGICAL IBCH,IB(45)
      COMMON/UNI/DZ,   DT,   VZERO,   AN,   ANI,   ZE,   R,   FI,
     1FV,   CPAR,   ZURER,   P
      COMMON/LOG/IB,IBCH                                                  00001439
      COMMON/SCVFC/AJT(45),   AJVAP(45),   FIHLIN(45),   QT(45),
     1QVT(45),   QLT(45),   FXCHM(45),   HLIN(45),   HDIV(45),
     2TDH(45),   GFL(45),   VFI(45),   AJN(45),   AJVN(45),   AJLN(45),
     3DPFR(45),   VFN(45),   HLN(45),   GN(45),   GFN(45),   GT(45),
     4SAVN(45),   ENSAVE(45),   FAC(45),   DPS(45),   EDP(45),
     5EDPO(45),   QTO(45),   AJLI(45),   XTR(45)
      COMMON/GEN/NAROD(45),   KROD(4,45),   HF(50,36),   VINLET(45),
     1GINLET(45),   HINLET,   GTOT,   POWER,   CHANN(45),   A(45),
     2FFLC(10,45),   NRODS,   GTFAC,   GTUR,   AVHYD,   VIZERO,   TFIN,
     3PZERO,   HZERO,   POWO,   IBLOC,   LBLOC,   T1BL,   T2BL,   FBL1,
     4FBL2,   PRIN,   MDPR,   HYD(45),   LOC(10),   HPER(4,45),
     5PFDAC,   DFRP,   NCHAN,   JMAX
      COMMON/PROP/RO,   ROVAP,   HVAP,   HSAT,   ALAM,   DLAM,   DHSAT,
     1GAMMA,   GAMLA,   ROVRA,   HCO,   GRAD,   IDOWN,   TSAT,   PRAND,
     2HB,   RROUGH,   AFRIC,   BFRIC,   ANM,   AK,   AMU,   WCON,
     3SIGMA,   VDRIFT,   ROGRAV,   DZUMG,   CP,   RERGH(45)
      DIMENSION QTK(45,4),   QVK(45,4),   QLK(45,4)
      COMMON/GEOM/JOIN(45),   NJOIN(45,4),   MCIRC(45),   SL(4,45),
     1NOCIR,   RODN(36),   AREA,   IDOP
      COMMON/MAT/MATDIM,   NEQ,   NTW(45,4),   TMATI(80,80),
     1TMAT(80,80),   XLU(80,80),   SRMIX(80,80),   SALDD(80,80)
      COMMON/MIX/ALFDD,   RMIX,   SLIP(45),   TURMT,   VEX,
     1VPZ(45,4)
      J1=J                                                                00001459
      JM1=J-1                                                             00001460
C     FIND CROSS-FLOWS                                                    00001461
      CALL SOLMAT(QTK,QT)                                                 00001462
C     FIND QVT(I)VAPOUR INLET CROSSFLOWS                                  00001463
      DO 1 I=1,NCHAN                                                      00001464
      QVMIX=0.                                                            00001465
      QVDIV=0.                                                            00001466
      KS=JOIN(I)                                                          00001467
      DO 2 K=1,KS                                                         00001468
      JJ=NJOIN(I,K)                                                       00001469
```

```
      SAVE=SRMIX(JJ,I)*VFI(JJ)-SRMIX(I,JJ)*VFI(I)
      QVMIX=QVMIX+SAVE
      QVK(I,K)=SAVE
      IF(QTK(I,K)) 4,2,3
    3 SAVE=SLIP(JJ)*VFI(JJ)*QTK(I,K)
      GO TO 100
    4 SAVE=SLIP(I)*VFI(I)*QTK(I,K)
  100 QVDIV=QVDIV+SAVE
      QVK(I,K)=QVK(I,K)+SAVE
    2 QLK(I,K)=QTK(I,K)-QVK(I,K)
      QVT(I)=QVMIX+QVDIV
    1 QLT(I)=QT(I)-QVT(I)
      RETURN
      ENTRY HEXC(J)
C       CALCULATES ENTHALPY EXCHANGE
      IF(IBCH)RETURN
      DO 5 I=1,NCHAN
      IF(IB(I))GO TO 5
      GO TO 7
    5 CONTINUE
      IBCH=.TRUE.
      DO 6 I=1,NCHAN
    6 HDIV(I)=0.
      RETURN
    7 CONTINUE
C       DIVERIED FLOW ENTHALPY
      DO 10 I=1,NCHAN
      SAVE=0.
      KS=JOIN(I)
      DO 11 K=1,KS
      JJ=NJOIN(I,K)
      IF(QLK(I,K))13,11,12
   12 SAVE=SAVE+HLIN(JJ)*QLK(I,K)
      GO TO 11
   13 SAVE=SAVE+HLIN(I)*QLK(I,K)
   11 COUTINUE
   10 HDIV(I)=SAVE
C       TURBULENT DIFFUSION ENTHALPY
      IF(IBCH)GO TO 200
      DO 20 I=1,NCHAN
      SAVE=0.
```

```
      KS=JOIN(I)
      DO 21 K=1,KS
      JJ=NJOIN(I,K)
      SAVE=SAVE+HLIN(JJ)-HLIN(I)
   21 CONTINUE
   20 TDH(I)=GTURB*DZ*SAVE
      RETURN
  200 DO 201 I=1,NCHAN
  201 TDH(I)=0.
      RETURN
      ENTRY MEXC(J)
C     CALCULATES MOMENTUM TRANSER
C     DIVERTED FLOW MOMENTUM
      DO 30 I=1,NCHAN
      SAVE=0.
      KS=JOIN(I)
      DO 31 K=1,KS
      JJ=NJOIN(I,K)
      IF(OLK(I,K))33,34,32
   32 SAVE=SAVE+OLK(I,K)*AJLI(JJ)/(1.-VFI(JJ))
      GO TO 34
   33 SAVE=SAVE+OLK(I,K)*AJLI(I)/(1.-VFI(I))
   34 IF(OVK(I,K))36,31,35
   35 IF(VFI(JJ).LE.0.)GO TO 31
      SAVE=SAVE+GAMMA*OVK(I,K)*AJVAP(JJ)/VFI(JJ)
      GO TO 31
   36 IF(VFI(I).LE.0.)GO TO 31
      SAVE=SAVE+GAMMA*OVK(I,K)*AJVAP(I)/VFI(I)
   31 CONTINUE
   30 EXCHM(I)=RO/A(I)*SAVE
      IF(IDOP.EQ.1)RETURN
      DO 40 I=1,NCHAN
      CALL HEYSF(I,J)
   40 EXCHM(I)=EXCHM(I)+DZ*TURMT/A(I)
      RETURN
      END
```

2.6.9 Listings of Subroutines WATER and HYDP

```
      SUBROUTINE WATER(P)
      COMMON/PROP/RO,    ROVAP,    HVAP,    HSAT,    ALAM,    DLAM,    DHSAT,
     1GAMMA,    GAMLA,    ROVRA,    HCO,    GRAD,    IDOWN,    TSAT,    PRAND,
     2HB,    RROUGH,    AFRIC,    BFRIC,    ANM,    AK,    AMU,    WCON,
     3SIGMA,    VDRIFT,    ROGRAV,    DZUMG,    CP,    RERGH(45)
      COMMON/UNI/DZ,    DT,    VZERO,    AN,    AN1,    ZE,    R,    FL,
     1FV,    CPAR,    ZUBER,    PR
      EQUIVALENCE(VISC,AMU),(HLAT,ALAM),(SURT,SIGMA)
C     WATER PROPERTIES FITTINGS
      PP=1.01972*P
      TSAT=285.8+(P-70.)-0.00555*(P-70.)*(P-70.)
      HSAT=787.428*(1.+9.366E-3*PP-1.279E-5*PP*PP)
      HVAP=2793.36*(1.+2.717E-4*PP-5.3E-6*PP*PP)
      ROVAP=0.03664+0.59E-3*(P-70.)+1.2E-6*(P-70.)*(P-70.)
      WCON=0.006963*(1.-3.042E-3*PP+5.672E-6*PP*PP)
      VISC=0.15088E-2*(1.-8.6437E-3*PP+4.61E-5*PP*PP)
      CP=4.64+0.014*(P-30.)+0.00004*(P-30.)*(P-30.)
      GAMMA=ROVAP/RO
      HLAT=HVAP-HSAT
      TT=315.55-TSAT
      SURT=11.7+0.235*TT-0.5E-06*TT**3
      GAMLA=GAMMA*HLAT
C     OTHER PRESSURE DEPENDENT PARAMETERS
      DATA PPC/221.9/
      DATA BANK /0.815/
      AFRIC=155.044*(1.-1.4517E-2*PP+5.021E-5*PP*PP)
      BFRIC=-132.322*(1.-1.135E-2*PP+4.3716E-5*PP*PP)
      AK=BANK+(1.-BANK)*P/PPC
      VDRIFT=ZUBER*(GRAD*SURT*(1.-GAMMA)/RO)**0.25
      IF(IDOWN.GT.0)VDRIFT=-VDRIFT
      HB=2.54E-04*EXP(0.0632*PP)
      PRAND=CP*VISC/WCON
      HCO=0.023*WCON*PRAND**0.4
      RETURN
      END
```

```
      SUBROUTINE HYDP(REY,DIAH,GG)
      LOGICAL IBB,IREV,IFREV,ITRA,ILOC                                  00001720
      COMMON/UNI/DZ,    DT,    VZERO,    AN,    AN1,    ZE,    R,    FI,
     1EV,    CPAR,    ZUBER,    P
      COMMON/CONT/FI(4),    IBB,    IREV,    IFREV,    ITRA,    ILOC,
     1TETA,    APAR,    TIN,    H,    HP,    TW,    PSI,    HOLD,    VFOLD,
     2VFIN,    HBAR,    TD,    AA,    AJIN,    AJVIN,    HLINJ,    HIN,
     3GFLIN,    GOLD,    Q,    QV,    QL,    FFAC,    FFLOC,    AJ,    AJV,
     4AJL,    VF,    HL,    G,    DPF,    DP,    DPEXC,    SAVEN,    QP,
     5PH(4),    XT,    KR,    GFLUX
      COMMON/PROP/RO,    ROVAP,    HVAP,    HSAT,    ALAM,    DLAM,    DHSAT,
     1GAMMA,    GAMLA,    ROVRA,    HCO,    GRAD,    IDOWN,    TSAT,    PRAND,
     2HB,    RROUGH,    AFRIC,    BFRIC,    ANM,    AK,    AMU,    WCON,
     3SIGMA,    VDRIFT,    ROGRAV,    DZUMG,    CP,    RERGH(45)
      HP=HB                                                             00001729
      HC=HCO*REY**0.8                                                   00001730
      H=HC                                                              00001731
      TETA=(HC/HB/AN)**ANM                                              00001732
      FSAVE=FFACT(REY,RROUGH)                                           00001733
      FFAC=0.5*FSAVE/DIAH                                               00001734
      RETURN                                                            00001735
      END                                                               00001736
```

2.6.10 Listings of Functions TIMEF, FFACT, TPFM and TFLM

```
      FUNCTION TIMEFF(T,I,A,X,TAB)
      DIMENSION A(5),TAB(100)
      GO TO (1,2,3),I
    1 K=1
    4 K=K+1
      L=K+50
      IF(TAB(K).LE.0..OR.K.EQ.51) GO TO 10
      IF(T-TAB(K)) 6,5,4
    5 TIMEFF=X*TAB(L)
      RETURN
    6 TIMEFF=X*(TAB(L-1)+(TAB(L)-TAB(L-1))*(T-TAB(K-1))/(TAB(K)-TAB(K-1))
     1)
      RETURN
   10 TIMEFF=X*TAB(L-1)
      RETURN
    2 TIMEFF=X*(1.+A(1)*SIN(A(2)*T))
      RETURN
    3 TIMEFF=X*(1.+A(1)*T+A(2)*T**2+A(3)*T**3+A(4)*T**4+A(5)*T**5)
      RETURN
      END
```

```
      FUNCTION FFACT(REY,ROUGH)
C     FRICTION FACTOR
      FFACT=0.0055*(1.+(20000.*ROUGH+1.E06/REY)**0.33333)
      RETURN
      END
      FUNCTION TPFM(XT,AFRIC,BFRIC)
C     TWO PHASE FLOW MULTIPLIER
      TPFM=1.
      IF(XT.LE.0.)RETURN
      TPFM=1.+XT*(AFRIC+XT*BFRIC)
      RETURN
      END
      FUNCTION TFLM(Q,VF,GAM)
C     LOCAL TWO PHASE FLOW MULTIPLIER
      TFLM=1.
      IF(VF.LE.0.)RETURN
      TFLM=(1.-Q)*(1.-Q)/(1.-VF)+Q*Q/VF/VF/GAM
      RETURN
      END
```

2.6.11 Listing of Subroutine CONTI

```
      SUBROUTINE CONTI
      LOGICAL IBB,IREV,IFREV,ITRA,ILOC                                  00001614
      COMMON/UNI/DZ,   DT,   VZERO,   AN,   AN1,   ZE,   R,   FL,
     1EV,   CPAR,   ZUBER,   P
      COMMON/CONT/FI(4),   IBB,   IREV,   IFREV,   ITRA,   ILOC,
     1TETA,   APAR,   TIN,   H,   HP,   TW,   PSI,   HOLD,   VFOLD,
     2VFIN,   HBAR,   TD,   AA,   AJIN,   AJVIN,   HLINJ,   HIN,
     3GFLIN,   GOLD,   Q,   QV,   QL,   FFAC,   FFLOC,   AJ,   AJV,
     4AJL,   VF,   HL,   G,   DPF,   DP,   DPEXC,   SAVFN,   QP,
     5PH(4),   XT,   KR,   GFLUX
      COMMON/PROP/RO,   ROVAP,   HVAP,   HSAT,   ALAM,   DLAM,   DHSAT,
     1GAMMA,   GAMLA,   ROVRA,   HCO,   GRAD,   IDOWN,   TSAT,   PRAND,
     2HB,   RROUGH,   AFRIC,   BFRIC,   ANM,   AK,   AMU,   WCON,
     3SIGMA,   VDRIFT,   ROGRAV,   DZUMG,   CP,   RERGH(45)
C     SOLVES CONTINUITY EQUATIONS FOR SUBCHANNEL I                      00001623
C     VAPOUR SOURCE EQUATION                                            00001624
C     HEAT FLUX SPLIT AND WALL TEMPERATURE                              00001625
      PSIS=0.                                                           00001626
      TC=TETA*(1.-TIN/TETA)**AN1                                        00001627
      TC=TETA*((TC-TIN)/TETA)**AN1                                      00001628
      DO 1 K=1,KR                                                       00001629
      TW=TIN+FI(K)/H                                                    00001630
      IF(TW-TC)1,1,2                                                    00001631
    2 FIC=H*(TC-TIN)-HP*TC**AN                                          00001632
      FIB=FI(K)-FIC                                                     00001633
      TW=(FIB/HP)**AN1                                                  00001634
      PSIS=PSIS+PH(K)/AA   *FIB/RO/(GAMLA-CPAR*HIN)                     00001635
    1 CONTINUE                                                          00001636
C     TOTAL VAPOUR SOURCE                                               00001637
      IF(IBB)GO TO 3                                                    00001638
      PSIB=0.                                                           00001639
      IF(R.LE.0.)GO TO 40                                               00001640
      C1=AK*(AJVIN+QV/AA+DZ*PSIS)+ZE*PSIS                               00001641
      IF(ITRA)C1=C1+VZERO*ROVRA*VFOLD*AK                                00001642
      IF(C1.LE.0.)GO TO 40                                              00001643
      C1=-R*TIN*C1                                                      00001644
      B1=AJIN+Q/AA+DZUMG*PSIS+AK*VDRIFT-R*TIN*AK*DZ                     00001645
      IF(ITRA)B1=B1+AK*VZERO-VZERO*VFOLD*(1.-ROVRA)                     00001646
      SAVE=B1*B1-4.*C1*DZUMG                                            00001647
      IF(SAVE)41,42,42                                                  00001648
```

```
   41 PSIR=-PSIS
      GO TO 40
   42 PSIR=.5*(SQRT(SAVE)-B1)/2/UMG
   40 PSI=PSIS+PSIR
      GO TO 4
    3 SAVE=D//RO*QP+HLINJ     +HBAR/AA      +TD/(RO*AA)
      IF(ITRA)SAVE=SAVE-VZERO*(DLAM*ROVRA*VFOLD+DHSAT*(1.-VFOLD*(1.-ROVR
     1A))-HOLD*(1.-VFOLD))
   31 PSI=SAVE/GAMLA/DZ
      SAVEH=0.
C     TOTAL CONTINUITY EQUATION
    4 AJ=AJIN+DZUMG*PSI+Q/AA
      IF(ITRA)AJ=AJ-VZERO*(1.-ROVRA)*VFOLD
C     VAPOUR CONTINUITY
      SAVE=AJVIN+DZ*PSI+QV/AA
      SAVJ=AJ+AK*VDRIFT
      IF(.NOT.ITRA)GO TO 5
      SAVE=SAVE+VZERO*ROVRA*VFOLD
      SAVE=SAVJ*SAVE-VZERO*ZE*PSIS
      SAVE=SAVE/(SAVJ+AK*VZERO)
    5 AJV=SAVE
C     VOID FRACTION CALCULATION
      VF=(AK*AJV+ZE*PSIS)/SAVJ
      IF(VF-0.00001)43,43,44
   43 VF=0.
      AJV=0.
      Q=AJVIN+QV/AA
      IF(ITRA)Q=Q+VZERO*ROVRA*VFOLD
      PSI=-Q/DZ
      AJ=AJIN+DZUMG*PSI+Q/AA
      IF(ITRA)AJ=AJ-VZERO*(1.-ROVRA)*VFOLD
   44 CONTINUE
C     LIQUID CONTINUITY
      AJL=AJ-AJV
C     TEST FLOW REVERSAL
      IF(AJL.LE.0.)IREV=.TRUE.
C     ENERGY CONTINUITY
      HL=0.
      IF(IRO)GO TO 6
      SAVE =HLINJ+DZ/RO*QP+HBAR/AA    +TD/(RO*AA)-DZ*GAMLA*PSI
```

```
      IF(ITRA)SAVE =SAVE -VZERO*(DLAM*ROVRA*VFOLD+DHSAT*(1.-VFOLD*(1.-RO00001689
     1VRA))-HOLD*(1.-VFOLD))                                            00001690
      IF(IREV)GO TO 7                                                   00001691
      DEN=AJL                                                           00001692
      IF(ITRA)DEN=DEN+VZERO*(1.-VFOLD)                                  00001693
      HL=SAVE /DEN                                                      00001694
      IF(HL)6,7,7                                                       00001695
    7 HL=0.                                                             00001696
      IBB =.TRUE.                                                       00001697
      SAVE=SAVE+DZ*GAMLA*PSI                                            00001698
      GO TO 31                                                          00001699
    6 CONTINUE                                                          00001700
C     PRESSURE DROP CALCULATION                                         00001701
      DPG=ROGRAV*(1.-VF+GAMMA*VF)*DZ                                    00001702
      GSAVE=AJL+GAMMA*AJV                                               00001703
      G=RO*GSAVE                                                        00001704
      G2=G*ABS(GSAVE)                                                   00001705
      XT=ROVAP*AJV/G                                                    00001706
      FFM=TPFM(XT,AFRIC,BFRIC)                                          00001707
      DPF=DZ*FFAC*G2*FFM                                                00001708
      IF(.NOT.ILOC)GO TO 8                                              00001709
      FFML=TFLM(XT,VF,GAMMA)                                            00001710
      DPF=DPF+FFML*FFLOC*G2                                             00001711
    8 GFLUX=RO*FL*AJL*ABS(AJL)/(1.-VF)                                  00001712
      IF(VF.GT.0.)GFLUX=GFLUX+ROVAP*FV*AJV*ABS(AJV)/VF                  00001713
      DPACC=GFLUX-GFLIN                                                 00001714
      DP=DPG+DPF+DPACC-DPEXC                                            00001715
      IF(ITRA)DP=DP+VZERO*(G-GOLD)
      RETURN                                                            00001717
      END                                                               00001718
```

2.6.12 Listing of Subroutine SWEEP

```
      SUBROUTINE SWEEP
      LOGICAL IBCH                                                      00001075
      LOGICAL ITIND                                                     00001076
      LOGICAL IBR,IREV,IFREV,ILOC,ITRA,ICONV
      LOGICAL IR(45),IRF(45),IFRE(45),IBN(45),IREN(45)
      COMMON/UNIT/DZ,   DT,    VZERO,   AN,   AN1,   ZE,   R,   FL,
     1FV,   CPAR,   ZUBER,   P
      COMMON/LOG/IB,IBCH                                                00001078
      COMMON/CONT/FI(4),    IBR,   IREV,    IFREV,   ITRA,   ILOC,
     1TETA,   APAR,   TIN,   H,   HP,   TW,   PSI,   HOLD,   VFOLD,
     2VFIN,   HBAR,   TD,   AA,   AJIN,   AJVIN,   HLINJ,   HIN,
     3GFLIN,   GOLD,   Q,   QV,   QL,   FFAC,   FFLOC,   AJ,   AJV,
     4AJL,   VF,   HL,   G,   DPF,   DP,   DPEXC,   SAVFN,   QP,
     5PH(4),   XT,   K2,   GFLUX
      COMMON/PROP/RO,   ROVAP,   HVAP,   HSAT,   ALAM,   DLAM,   DHSAT,
     1GAMMA,   GAMLA,   ROVPA,   HCO,   GRAD,   IDOWN,   TSAT,   PRAND,
     2HB,   RROUGH,   AFRIC,   BFRIC,   ANM,   AK,   AMU,   WCON,
     3SIGMA,   VDRIFT,   ROGRAV,   DZUMG,   CP,   RERGH(45)
      COMMON/SCVEC/AJIT(45),   AJVAP(45),   FIHLIN(45),   QT(45),
     1OVT(45),   DLT(45),   EXCHM(45),   HLIN(45),   HDIV(45),
     2TDH(45),   GFL(45),   VFI(45),   AJIN(45),   AJVN(45),   AJLN(45),
     3DPFR(45),   VFN(45),   HLN(45),   GN(45),   GFN(45),   GT(45),
     4SAVN(45),   FNSAVE(45),   FAC(45),   DPS(45),   EDP(45),
     5EDPO(45),   DTO(45),   AJLI(45),   XTR(45)
      COMMON/RESVE/VFAV(45),   GOUT(45),   GOUTV(45),   GOUTL(45),
     1XOUT(45),   FOUT(45),   BAL(45)
      COMMON/RES/ITER(50),   PDROP(50),   IEOUT,   FMOUT,   PACC,
     1TBAL,   AVX,   DPTOT
      COMMON/ARR/DTR(50,45),   ALF(50,45),   HEL(50,45),
     1GR(50,45),   TQUAL(50,45),   XQUAL(50,45)
      COMMON/GEN/NAROD(45),   KROD(4,45),   HF(50,36),   VINLET(45),
     1GINLET(45),   HINLET,   STOT,   POWER,   CHANN(45),   A(45),
     2FFLC(10,45),   NRODS,   SIFAC,   GTUR,   AVHYD,   VIZERO,   TFIN,
     3PZERO,   HZERO,   POWO,   IBLOC,   LBLOC,   T1BL,   T2BL,   FBL1,
     4FBL2,   PRIN,   MDPR,   HYD(45),   LOC(10),   HPER(4,45),
     5PFDAC,   DFRP,   NCHAN,   JMAX
      COMMON/RELAX/REL1,   REL2,   RESTG
      TEST=.001                                                         00001102
      ITMAX=10                                                          00001103
      REL=REL1                                                          00001104
```

```
      J=1
      ITIND=.FALSE.
 2233 CONTINUE
      IRCH=.FALSE.
      IL=1
      IT=0
C     SET BOUNDARY CONDITIONS FOR FIRST NODE
      DO 50 I=1,NCHAN
      AJT(I)=VINLET(I)
      AJLT(I)=AJT(I)
      AJVAP(I)=0.
      FIHLIN(I)=HINLET*VINLET(I)
      QT(I)=0.
      QVT(I)=0.
      QLT(I)=0.
      EXCHM(I)=0.
      HLIN(I)=HINLET
      HDIV(I)=0.
      TDH(I)=0.
      GEL(I)=RO*VINLET(I)**2*FL
      VFI(I)=0.
      GT(I)=RO*VINLET(I)
      IR(I)=.FALSE.
      IRF(I)=.FALSE.
      IFRF(I)=.TRUE.
      ENSAVE(I)=FIHLIN(I)
   50 CONTINUE
      CALL VMIX
  100 ILOC=LOC(IL).EQ.1
    1 DPAV=0.
      SAVG=0.
      ICONV=.TRUE.
      DO 10 I=1,NCHAN
      AA=A(I)
      AJIN=AJT(I)
      AJVIN=AJVAP(I)
      HLINJ=FIHLIN(I)
      Q=QT(I)
      QV=QVT(I)
      QL=QLT(I)
```

```
      HIN=HLIN(I)
      HBAR=HDIV(I)
      ID=IDH(I)
      IBR=IB(I)
      IREV=IRF(I)
      IFREV=IFRF(I)
      GFLIN=GFL(I)
      IF(J.GT.1)GO TO 9
      GFLIN=RO*FL*(AJIN+Q/AA)**2
      DPEXC=0.
    9 CONTINUE
      GIN=GI(I)
      VFIN=VFI(I)
      TIN=HIN/CP
      HOLD=HFL(J,I)
      VFOLD=ALF(J,I)
      GOLD=GR(J,I)
      SAVE=ENSAVE(I)
      IF(ILOC)FFLOC=0.5*FFLC(IL,I)
C     HEAT FLUXES AND ENERGY ADDITION
      KR=NAROD(I)
      QP=0.
      DO 11  K=1,KR
      KRO=KROD(K,I)
      FI(K)=HF(J,KRO)
      PH(K)=HPER(K,I)
   11 QP=QP+PH(K)*FI(K)*PFDAC
      QP=QP/AA
      IF(ITRA)QP=QP+DERP
      GLO=GIN+RO*(QL+GAMMA*QV)/A(I)
      DIAH=HYD(I)
      REY=ABS(GLO)*DIAH/AMU
      RROUGH=RERGH(I)
      CALL HYDP(REY,DIAH,GLO)
      CALL CONTI
      DPS(I)=DP
      SAVE=A(I)*ABS(GIN)
      DPAV=DPAV+SAVE*DP
      SAVG=SAVG+SAVE
      AJN(I)=AJ
```

```
      AJVN(I)=AJV
      AJLN(I)=AJL
      DPER(I)=DPE
      VEN(I)=VE
      HEN(I)=HL
      GN(I)=G
      GFN(I)=GFLUX
      SAVN(I)=SAVEN
      XTR(I)=XT
      IBN(I)=IBR
      IREN(I)=IREV
   10 CONTINUE
      DPAV =DPAV/SAVG
C     ITERATION SCHEME
      DO 12I=1,NCHAN
      EDP(I)=DPS(I)-DPAV
      IF(ABS(EDP(I)).GT.TEST*ABS(DPAV))ICONV=.FALSE.
   12 CONTINUE
      IF(IT.EQ.ITMAX)GO TO 200
      IF(ICONV)GO TO 201
      IF(IT.GT.0)GO TO 101
C     SECOND GUESS FOR DIVERTED FLOWS
      QTOT=0.
      FACS=0.
      DO 2 I=1,NCHAN
      SAVE=AJT(I)/DPS(I)
      QTT=QT(I)-.5*A(I)*SAVE*EDP(I)*RESTG
      QTO(I)=QT(I)
      QT(I)=QTT
      QTOT=QTOT+QTT*CHANN(I)
      FAC(I)=A(I)
    2 FACS=FACS+FAC(I)*CHANN(I)
      RENO=QTOT/FACS
      DO 3 I=1,NCHAN
      QT(I)=QT(I)-FAC(I)*RENO
    3 EDPO(I)=EDP(I)
      GO TO 5
C     ITERATION
  101 QTOT=0.
      DO 6 I=1,NCHAN
```

```
      QTT=QT(I)
      SAVE=EDP(I)-EDPO(I)
      IF(ABS(SAVE).LT.0.1)GO TO 4
      QTT=QTT-REL*EDP(I)*(QTT-QTO(I))/SAVE
    4 CONTINUE
      QTO(I)=QT(I)
      QT(I)=QTT
    6 QTOT=QTOT+QTT*CHANN(I)
      RFNO=QTOT/FACS
      DO 7 I=1,NCHAN
      QT(I)=QT(I)-FAC(I)*RFNO
    7 EDPO(I)=EDP(I)
    5 CALL SPLITD(J)
      CALL HEXC(J)
      CALL MEXC (J)
      IT=IT+1
      GO TO 1
C     SAVING RESULTS AND SETTING INITIAL CONDITIONS FOR NEXT NODE
 1000 ITER(J)=IT
      PDPOP(J)=DPAV
      DO 20 I=1,NCHAN
      QTR(J,I)=QT(I)
      ALF(J,I)=VFN(I)
      HFL(J,I)=HLN(I)
      TQUAL(J,I)=XTR(I)
      XQUAL(J,I)=PO*(HLN(I)*AJLN(I)+GAMLA*AJVN(I))/GN(I)/ALAM
      HLIN(I)=HLN(I)
      GR(J,I)=GN(I)
      VFI(I)=VFN(I)
      AJT(I)=AJN(I)
      AJVAP(I)=AJVN(I)
      AJLI(I)=AJLN(I)
      FIHLIN(I)=HLIN(I)*AJLN(I)
      GFL(I)=GFN(I)
      GT(I)=GN(I)
      IR(I)=IRN(I)
      IRF(I)=IRFN(I)
      IFRF(I)=.TRUE.
      FNSAVE(I)=FIHLIN(I)
      IF(.NOT.IRF(I))GO TO 20
```

```
      IFRF(I)=.FALSE.
      FNSAVE(I)=SAVN(I)
   20 CONTINUE
      IF(J.EQ.JMAX)GO TO 2000
      IT=0
    2 J=J+1
      CALL VMIX
  202 CONTINUE
      DO 22 I=1,NCHAN
      QT(I)=0.
      IF(ITPA)QT(I)=QTR(J,I)
   22 CONTINUE
      CALL SPLITD(J)
      CALL HEXC(J)
      CALL MEXC(J)
      IF(ILOC)IL=IL+1
      IF(J.EQ.1) GO TO 2233
      GO TO 100
 2000 CONTINUE
C     CORRECT INLET VELOCITY OF FIRST NODE
      DO 1001 I=1,NCHAN
      VINLET(I)=VINLET(I)+QTR(1,I)/A(I)
      GINLET(I)=RO*VINLET(I)
 1001 QTR(1,I)=0.
C     CALCULATE EXIT VARIABLES AND BALANCES
      DO 1002 I=1,NCHAN
      VFAV(I)=0.
      DO 1003 J=1,JMAX
 1003 VFAV(I)=VFAV(I)+ALF(J,I)
      VFAV(I)=VFAV(I)/FLOAT(JMAX)
      GOUT(I)=GN(I)
      GOUTV(I)=ROVAP*AJVN(I)
      GOUTL(I)=GOUT(I)-GOUTV(I)
      EOUT(I)=HLN(I)*GOUTL(I)+ALAM*GOUTV(I)
      XOUT(I)=EOUT(I)/(GOUT(I)*ALAM)
 1002 BAL(I)=A(I)*(EOUT(I)-HINLET*GINLET(I))
      TEOUT=0.
      DO 1004 I=1,NCHAN
      TEOUT=TEOUT+EOUT(I)*A(I)*CHANN(I)
 1004 CONTINUE
      TBAL=TEOUT-GTOT*HINLET
      RACC=POWER-TBAL
```

```
      FMOUT=0.
      DO 1005 I=1,NCHAN
 1005 FMOUT=FMOUT+A(I)*GOUT(I)*CHANN(I)
      AVX=TFOUT/FMOUT/ALAM
      DPTOT=0.
      DO 1006 J=1,JMAX
 1006 DPTOT=DPTOT+PDROP(J)
      RETURN
  200 IF(ITIND)GO TO 201
      ITIND=.TRUE.
      REL=REL2
      ITMAX=20
      IT=0
      GO TO 202
  201 IF(.NOT.ITIND)GO TO 1000
      ITIND=.FALSE.
      REL=REL1
      ITMAX=10
      GO TO 1000
      END
```

2.6.13 Listing of Subroutine SOLMAT

```
      SUBROUTINE SOLMAT
      DIMENSION TW3(45,4),   W(45),     RHS(45),     VEC(80),
      COMMON/GEOM/JOIN(45),  NJOIN(45,4),   MCIRC(45),   SL(4,45),
     1NOCIR,   RODN(36),   AREA,   IOOP
      COMMON/MAT/MATDIM,   NEQ,   NTW(45,4),   TMATI(80,80),
     1TMAT(80,80),   XLU(80,80)
      COMMON/GEN/NAROD(45),   KROD(4,45),   HF(50,36),   VINLET(45),
     1GINLET(45),   HINLET,   GTOT,   POWER,   CHANN(45),   A(45),
     2FFLC(10,45),   NRODS,   GTFAC,   GTUR,   AVHYD,   VIZERO,   TFIN,
     3PZERO,   HZERO,   POWO,   IBLOC,   LBLOC,   T1BL,   T2BL,   FBL1,
     4FBL2,   PRIN,   MDPR,   HYD(45),   LOC(10),   HPER(4,45),
     5PEDAC,   DERP,   NCHAN,   JMAX
      EQUIVALENCE(NSUB,NCHAN)                                    00001559
      DO 823 I=1,MATDIM
  823 RHS(I)=0.
      DO 8 I=1,NSUB
      RHS(I)=W(I)
    8 CONTINUE
      IF(NOCIR .LE.0)    GO TO 9                                 00001562
      RHS(NEQ) = 0.                                              00001563
    9 DO 10 I = 1,MATDIM                                         00001564
      VEC(I) =   TMATI(I,1)*RHS(1)                               00001565
      DO 10 J = 2,MATDIM                                         00001566
      VEC(I)=VEC(I)+TMATI(I,J)*RHS(J)
   10 CONTINUE
      DO 12 I = 1,NSUB                                           00001568
      JJ = JOIN(I)                                               00001569
      DO 12 J = 1,JJ                                             00001570
      K = NTW(I,J)                                               00001571
      NNN = NJOIN(I,J)                                           00001572
      IF(NNN .LT. I)    GO TO 11                                 00001573
      TW3(I,J) = VEC(K)                                          00001574
      GO TO 12                                                   00001575
   11 TW3(I,J) = -VEC(K)                                         00001576
   12 CONTINUE                                                   00001577
      RETURN
      END                                                        00001579
```

2.6.14 Listing of Subroutine MATSET

```
      SUBROUTINE MATSET
      COMMON/GEN/NAROD(45),    KROD(4,45),   HF(50,36),   VINLET(45),
     1GINLET(45),   HINLET,   GTOT,   POWER,   CHANN(45),   A(45),
     1GINLET(45),   HINLET,   GTOT,   POWER,   CHANN(45),   A(45),
     2FFLC(10,45),   NRODS,   GTFAC,   GTUR,   AVHYD,   VIZERO,   TFIN,
     3PZERO,   HZERO,   POWO,   IBLOC,   LBLOC,   TIBL,   T2BL,  FBL1,
     4FBL2,  PRIN,  MDPR,   HYD(45),   LOC(10),   HPER(4,45),
     5PEDAC,   DFRP,   NCHAN,   JMAX
      COMMON/GEOM/JOIN(45),  NJOIN(45,4),   MCIRC(45),   SL(4,45),
     1NOCIR,   RODN(36),   AREA,   IDOP
      COMMON/MAT/MATDIM,   NEQ,   NTW(45,4),   TMATI(80,80),
     1TMAT(80,80),   XLU(80,80),   SRMIX(80,80),   SALDD(80,80)
      EQUIVALENCE(NSUB,NCHAN)
      DIMENSION IJ(5)
      DO 1 I=1,80
      DO 1 I=1,80
      DO 1 J =1,80
      XLU(I,J)=0.
      TMATI(I,J)=0.
    1 TMAT(I,J)=0.
      MATDIM = NSUB + NOCIR - 1
      IPNTR = 1
      DO 6000 I=1,NSUB
      JJ = JOIN(I)
      DO 6000 J=1,JJ
 6000 NTW(I,J) = 0
      DO 6005 I = 1,NSUB
      JJ = JOIN(I)
      DO 6005 J = 1, JJ
      M = NJOIN(I,J)
      IF(M.LT.I) GO TO 6004
      IF(NTW(I,J).NE.0) GO TO 6003
      NTW(I,J) = IPNTR
      KK = JOIN(M)
      DO 6001 K = 1,KK
      IF(NJOIN(M,K).EQ.I) GO TO 6002
 6001 CONTINUE
 6002 NTW(M,K) = IPNTR
      TMAT(I,IPNTR) = 1.
      IPNTR = IPNTR + 1
```

```
      GO TO 6005                                              00000826
 6003 M = NTW(I,1)                                            00000827
      TMAT(I,M) = 1.                                          00000828
      GO TO 6005                                              00000829
 6004 M = NTW(I,1)                                            00000830
      TMAT(I,M) = -1.                                         00000831
 6005 CONTINUE                                                00000832
      IF(NOCIR.LE.0) GO TO 6021                               00000833
      DO 500 NN = 1,4                                         00000834
  500 IJ(NN) = MOD(MCIRC( 1),10**(2*NN))/ 10**(2*NN-2)        00000835
      IF(IJ(4).EQ.0) GO TO 6006                               00000836
      IJ(5) = IJ(1)                                           00000837
      II = 5                                                  00000838
      KK = 4                                                  00000839
      GO TO 6007                                              00000840
 6006 IJ(4) = IJ(1)                                           00000841
      II = 4                                                  00000842
      KK = 3                                                  00000843
      NEQ = IJ(1)                                             00000846
      DO 6050 I = 1,MATDIM                                    00000847
 6050 TMAT(NEQ,I)=0.
      DO 6012 I = 1,KK                                        00000849
      M = IJ(I)                                               00000850
      JJ = JOIN(M)                                            00000851
      DO 6009 J = 1,JJ                                        00000852
      IF(NJOIN(M,J).EQ.IJ(I+1)) GO TO 6010                    00000853
 6009 CONTINUE                                                00000854
 6010 JJ = NTW(M,J)                                           00000855
      IF(IJ(I).GT.IJ(I+1)) GO TO 6011                         00000856
      TMAT(NEQ,JJ) = 1.                                       00000857
      GO TO 6012                                              00000858
 6011 TMAT(NEQ,JJ) = -1.                                      00000859
 6012 CONTINUE                                                00000860
      IF(NOCIR.EQ.1) GO TO 6021                               00000861
      II = NSUB + 1                                           00000862
      IPCTR = 2                                               00000863
      DO 6020 I = II,MATDIM                                   00000864
      DO 600 NN = 1,4                                         00000865
```

```
  600 IJ(NN) = MOD(MCIRC(IPNTR),10**(2*NN))/ 10**(2*NN-2 )
      IF(IJ(4).EQ.0) GO TO 6013
      JJ = 5
      KK = 4
      IJ(5) = IJ(1)
      GO TO 6014
 6013 IJ(4) = IJ(1)
      JJ=4
      KK = 3
      DO 6019 K=1,KK
      M = IJ(K)
      JJ = JOIN(M)
      WRITE(6,654) IJ(K),JJ
  654 FORMAT(1X,'IJ(K) IN LOOP 6019=',I16,10X,'JJ=',I6)
      DO 6016 J = 1,JJ
      IF(NJOIN(M,J).EQ.IJ(K+1)) GO TO 6017
 6016 CONTINUE
 6017 JJ = NTW(M,J)
      IF(IJ(K) .GT. IJ(K+1))   GO TO 6018
      TMAT(I,JJ) = 1.
      GO TO 6019
 6018 TMAT(I,JJ) = -1.
 6019 CONTINUE
 6020 IPNTR = IPNTR + 1
 6021 IF(NSUB .EQ. 2)    GO TO 1701
      CALL INVERT(MATDIM,TMAT,TMATI,XLU,40,NERR)
      DO 7000 I=1,MATDIM
      DO 7000 K=1,MATDIM
      TMATI(I,K)=TMAT(I,K)
 7000 CONTINUE
      GO TO 300
 1701 TMATI(1,1) = 1.
  300 DO 6022 I =1,80
      DO 6022 J =1,80
      XLU(I,J)=0.
 6022 TMAT(I,J)=0.
 6023 RETURN
      END
```

2.6.15 Listing of Subroutine INVERT

```
      SUBROUTINE INVERT(N,TMAT,A,V,KK,NERR)
      DIMENSION TMAT(80,80),A(N,N),V(80,80),V1(80),V2(80)
      DO 1 I=1,N
      DO 1 K=1,N
      A(I,K)=TMAT(I,K)
    1 CONTINUE
      CALL MINV(A,N,D,V1,V2)
      DO 2 I=1,N
      DO 2 K=1,N
      TMAT(I,K)=A(I,K)
    2 CONTINUE
      RETURN
      END
```

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