MANUAL FOR

ENERGY I, II, III COMPUTER PROGRAMS

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1. Introduction

The ENERGY computer programs have been developed[1] for predicting coolant temperature distributions in wire wrapped fuel and blanket assemblies of a Liquid Metal Fast Breeder Reactor. The ENERGY series of codes consist of ENERGY I, ENERGY II and ENERGY III. ENERGY I must be used when the bundle is operating in Forced Convection (Natural Convection effects are small). The ENERGY II and ENERGY III programs may be used either when the bundle is operating in Forced Convection or in Mixed Convection (Forced and Free Convection effects are of the same order of magnitude). However, ENERGY II and III require much large computational time than ENERGY I and hence it is desirable to use the latter when the bundle is operating in forced convection. A criterion,[1,3] has been derived which determines if the bundle is operating in forced or mixed convection.

The major difference between ENERGY II and ENERGY III computer programs is that ENERGY II neglects the convective terms in the axial momentum equation and it also neglects the lateral convection of energy transfer in the energy equation. However the temperature maps found to date by ENERGY II and ENERGY III, for various sets of bundles(Ref.1) are very similar. For this reason it is desirable to use

ENERGY II(less computational time) as compared to ENERGY III. However for cases having both large radial power skews (peak/average > 2) and small Reynolds numbers (Re < 1000) it is recommended ENERGY III be used.

2. ENERGY MODEL

Most existing calculational procedures are based on the subchannel analysis approach, i.e. a lumped parameter approach in which the lumped region is a subchannel. The present model differs from subchannel analysis methods in two distinct ways. First, the rod array in a LMFBR assembly is divided into two predominant regions; the central and wall regions. Second, each of these regions is treated as a continuum by viewing the wire wrapped bundle as a porous body.

The wire-wrapped rods are packed in an array which is enclosed by a flow duct and as a result there is a region of flow next to the duct wall which is quite different in character from the flow in the central region. In the central core the mean flow oscillates around each rod progressing in an axial direction. This oscillation of flow, shown in Fig. 1, may be imagined to contribute an effective eddy diffusivity superimposed on the normal eddy diffusivity associated with turbulence. Thus a basis of our model is the existence of a uniform lateral effective enhanced eddy diffusivity, ε, for heat transfer, in the inner region of the bundle. The eddy diffusivity in the axial direction is not significantly enhanced by the presence of wire wraps. In the outer region near the wall the flow is quite different.since the wire wrap is spiralled around each rod in the same direction, the flow progresses with both an axial component and a tangential component parallel to the wall (Fig. 2).

The proposed model treats the rod assembly as a continuous porous media and energy generation by the rods is modelled by a continuous volumetric heat source distribution. The energy transfer in the transverse direction is modelled by the effective eddy diffusivity which includes the fluid oscillations due to the presence of wire wraps and also by any other means of energy transport, like natural turbulence.

The model described above is applicable to any wire-wrapped assembly irrespective of whether it is operating under conditions of forced convection or in the mixed convection regime. However the formulation for assemblies operating in forced convection is much simpler than those operating in mixed convection. In forced convection a flow split between regions I and II is calculated based on methods developed in Ref. 3 (or from experimental data available). It is assumed that the slug velocity profiles in region I and II do not change axially. The energy equation for regions I and II are solved to determine the temperature field[1]. The two unknowns $\varepsilon^*(=\frac{\varepsilon}{\bar{U}d_e})$ and $C(=\frac{Us}{\bar{U}})$ are empirically determined as functions of geometry (p/d,h/d) and Reynolds number. Here $\bar{U}$ is the bundle average superficial velocity and de is the hydraulic diameter of an interior channel in the actual assembly.

In the mixed convection rēgion the buoyancy effects become important and the assumption of an axially constant slug velocity profiles in each of the two regions no longer holds good. The momentum, energy and continuity equations must now be solved simultaneously. The number of unknowns that must be empirically determined is still two - ε^* and C.

Given the bundle geometry and operating characteristics one can determine ε^* and C as well as the flow split by the correlations summarized in Ref. 3 and originally obtained in Ref. 1. In addition to the above Ref. 3 also presents a criterion for determining when buoyancy effects are important.

3. Mesh Size In ENERGY

The ENERGY computer programs are all based on the same basic model described in the previous section. Since a discreet set of rods in an assembly is modelled as a continuum the node spacing can be chosen as desired and it need not be taken equal to the centroid distance between subchannels (as is done in subchannel analysis) but may be so taken, if desired. The maximum size of the node spacing is not totally arbitrary. Since the temperature distributions must be independent of mesh spacing, the temperature distributions must be found for two different node sizes. If the effect of a large change in the node size on the temperature distribution is not significant the mesh size need not be reduced. Our results have shown that, for a large bundle, one can use node spacing greater than the centroid distance between subchannels without significant differences in temperature distribution at the exit of the bundle.

4a Various Versions of the ENERGY Code

The ENERGY I code must be used for predicting temperature distributions in bundles in forced convection. The ENERGY I and II codes can be used for bundles in forced or mixed convection. Since the subchannel analysis methods are being currently used in nuclear industry each of the ENERGY codes (I, II, III) are provided with an additional capability to run as subchannel analysis codes. This option is provided in ENERGY I, II and III. The subchannel analysis versions of ENERGY are called ENERGY I S, II S and III S respectively for future reference. Recommended values of input data for ENERGY I S, II S and III S is also described in Ref. 3.

4b <u>Limitation of ENERGY codes</u>

The present versions of the ENERGY codes have the following limitations.

(a) The two empirical constants ε^* and C were determined from available data. The computer program should not be used outside the range of data used to determine ε^* and C. The range of data (p/d, h/d, Reynolds No.) within which these constants ε^* and C are known is quite extensive and is summarized in Ref. 3.

(b) The computer programs at present are applicable to bundles containing one wire wrap on each rod of the same size and the same starting position. Additionally the bundle duct should bound the array of wire pins in a manner which does not allow bypass flow space beyond that normally required for bundle fabrication.

(c) The power skews for which the codes have been successfully tested are given below.

1. Flat to 400% power skew across a bundle (of 1.4 in. flat to flat distance). As the bundle size increases the confidence in predictions would be better for the same power skew.

2. Single rod heated at center of the bundle.

3. Two rods - one at the center of the bundle and one at the wall.

4. The present versions of the ENERGY codes do not include interassembly heat transfer. However this boundary condition is not fundamental to the model and can be easily incorporated. Work in this direction is being done presently at Massachusetts Institute of Technology.

5. Data Input For ENERGY Codes

5.1 ENERGY I and ENERGY I S (Subchannel)

5.1.1 Card Group 1, Saturated Fluid Property Table

First Card - Number of cards in Table (maximum of 50). (Format I 5)

Each card of Table - Pressure(psi2), Temperature (^oF), density of liquid (lbm/ft^3), density of vapor (lbm/ft^3), enthalpy of liquid (Btu/lbm), enthalpy of vapor (Btu/lbm), liquid viscosity (lbm/ft. hr), liquid thermal conductivity $\left[\frac{BM}{hr\ ^oF\ ft}\right]$, liquid surface tension (lb/ft). Cards must be in order of increasing pressure (Format 9E8.4) (in the present version ENERGY enthalpy of vapor, viscosity, thermal conductivity and surface tension are not used and a value of 1.0 may be specified for them).

5.1.2 Card Group 2

One Card - Number of Values in Axial Heat Flux Distribution Table (Max. of 50), Number of runs desired,. Number of runs desired (Last two optional) (FORMAT 3I5)

5.1.3 Card Group 3

Each card of Table - Relative distance from inlet ($\frac{X}{L}$), Relative Power (Local/avg.) up to 4 pairs of values per card (FORMAT 8E10.4)

5.1.4 Card Group 4

Number of Type 1 nodes (or channels of ENERGY I S, Number of (Type 1 + Type 2) nodes (or channels), Number of (Type 1 + Type 2 + Type 3) nodes (or channels), Number of (Type 1 + Type 2 + Type 3 + Type 4) nodes (or channels), Number of rods, total number of nodes (or channels) FORMAT (6I5). (For various types of nodes or channels see end of Data Input).

5.1.5 Card Group 5, Channel Layout Table

Each Card of Table - node number (channel number for ENERGY I S),Number of an adjacent node (up to 3 adjacent nodes), number of rods in channel (up to 3 rods/ channel, needs to be specified only for ENERGY I S), Fraction of channel (for ENERGY I S only, otherwise put this = 1.0), FORMAT (I 5, 6 I 10, E 10.4).

5.1.6 Card Group 6

Relative Rod Power (Local/avg) in ascending rod numbers up to 8 per card, FORMAT (8E 10.4). If CHOICE = 2 (see below) put 1.0 for relative rod power of each rod.

5.1.7 Card Group 7

Nodal spacing between Type 1 nodes (or Type 1 channels), nodal spacing between Type 2 and Type 3 nodes, spacing between Type 3 nodes, spacing between Type 3 and Type 4 nodes, choice of using porous body model (= 2.0) or subchannel analysis (= 1.0), shape-factor on the conduction term, FORMAT (6E 11.4)

5.1.8 Card Group 8

Effective cross-flow area per unit axial length between nodes (or channels), in^2/in, wire wrap lead divided by rod diameter, diameter of wire (in.), thickness of region II in ENERGY (in.), axial step size (in.) (only specified if CHOICE = 2), gap between rod and wall (in)., FORMAT (6E 11.4). If CHOICE = 1, put thickness of region II equal to gap between rod and wall (in).

5.1.9 Card Group 9

Diameter of rod (in.), total length (in.), (pitch/diameter), number of rings of rods from center, FORMAT (3E11.4, I 5)

Operating-Conditions

If several operating conditions must be investigated insert the following card prior to Read 12 --- card in the source deck.

Do 160 LNL = 1, NRUN1.

5.1.10 Card Group 10

Mass velocity (lbm/hr ft^2), inlet enthalpy ($\frac{Btu}{lbm}$), reference pressure (psia), average heat flux ($\frac{Btu}{hr\ ft^2}$), inlet density (lbm/ft^3), total flow rate (lbm/hr), FORMAT (6E11.4), if total flow rate > 0 mass velocity need not be supplied but is calculated by the code. If mass velocity is known leave total flow rate blank.

If CHOICE < 2.0 (subchannel analysis version is being used) skip the following cards Group 11, 12, 13.

5.1.11 Card Group 11

Area associated with typical interior rods (in^2) (node Type 1 and 2), area associated with typical wall node (Type 3) (in^2), area associated with typical corner node (in^2), hydraulic diameter of subchannels in region I, flow area in the presence of rods in^2, ratio of bundle avg. inlet axial velocity to avg. inlet velocity in region I, ratio of bundle avg. inlet axial velocity to avg. inlet axial velocity in region II, same ratio for corner nodes (sub-region II), FORMAT (8E10.4).

5.1.12 Card Group 12

Avg. axial porosity in region I, in region II, in subregion II (corners), hydraulic diameter to be used in region II, hydraulic diameter to be used in subregion II (corners). (5E10.4)

In case subregion II is not to be considered separately but as an integral part of region II specify CHOICE = 3 in card group 7. In that case flow split is automatically taken to be uniform in region 2 and also porosity of region 2 is taken to be uniform and equal to avg. axial porosity in region II specified in card group 12. If CHOICE = 3 the method of calculating flow split between the two regions is described at end of data input.

5.1.13 Card Group 13

Volumetric heat generation rate for each node (Btu/hr ft^3) in ascending order of nodes (FORMAT 8E10.4)

5.1.14 Card Group 14

Axial increment for printout (if CHOICE = 1) (in.), a number which controls axial calculational step size (recommended value = 10), enhanced effective eddy diffusivity in region I, between region I and II, in region II, between region II and subregion II (corners), swirl flow ratio FORMAT (7E11.4)

A uniform enhanced effective eddy diffusivity in the entire bundle is recommended.

Input Parameters

If several input parameters are to be run consecutively insert the following card prior to statement Read 11 card in the source deck.

Do 160 NRNL = 1, NO RUNS

5.2 Data Input for ENERGY II and ENERGY II(S).

This input data is the same as ENERGY-I & II(S) except for the following differences.

5.2.1 Card Group 2

Same as before except for one additional entry - No. of iterations in an internal loop which calculates velocity distribution to be used in the energy equations FORMAT (4I5). Recommended Value is 5.

5.2.2 Card Group 4

One Card - first five entries same as ENERGY I - sixth and seventh entries are as follows.

Values of A and B in the equation $f = \frac{A}{Re^B}$

FORMAT (5I5, 2E10.4)

5.3 Data Input For ENERGY III and ENERGY III(S)

Data Input for ENERGY III and IIIS is same as for ENERGY I and I(S) except for the following cards.

5.3.1 Card Group 8

In between axial step size (in.) and gap between rod and wall (in.) read in the convergence criterion for cross flow ($\sum_N W_c = 0^{(1,2)}$). A suggested value for this parameter is 1.0E-6. FORMAT (7E11.4)

5.3.2 Card Group 9

Diameter of rod, total length, p/d, number of rings, number of axial steps. FORMAT (3E11.4, 2I5)

5.3.3 Card Group 15

0.0, multiplication factor on axial drag, axial step above which debug printout is in operation in buoyancy subroutine, FORMAT (2E10.4, I5)

5.4 General Information

The following additional information is provided to complete this section.

5.4.1 Node Numbering Scheme (see Appendix 1 also)

Figures 3, 4 and 5 show the subchannel numbering scheme for a 19, 61 and 217 rod array. This could also be the node numbering scheme if in the porous body option the mesh size was made equal to the centroidal distance between subchannels. However the node size for the porous body option can be selected as desired. In addition any numbering scheme for nodes, channels and rods may be used provided the following caution is observed.

(a) Type 1 nodes or channels are those with connections with nodes or channels in region I.

(b) Type 2 nodes or channels are those connecting nodes or channels between regions I and II.

(c) Type 3 nodes or channels are in region II but are not corner nodes or channels.

(d) Type 4 nodes or channels are corner nodes or channels.

Each channel or node must have three connections. If only two real connections exist the third fictitious node or channel is given the number 500.

Nodes adjacent to Type 3 nodes (or channels) are numbered as follows. First connection is with node (or channel) in region I. Second connection is with node (or channel) from which swirl flow enters. Third connection is with node (or channel) into which swirl flow goes after leaving the node (or channel) under consideration. Nodes adjacent to Type 4 nodes (or channels) are numbered as follows. First connection is with node (or channel) from which swirl flow enters. Second connection is with node (or channel) into which swirl flow goes after leaving the node (or channel) under consideration.

6. Listing of Codes (FORTRAN 4)

ENERGY I

ENERGY II

ENERGY III

```
  COMPUTER  PROGRAM  ENERGY  1
   COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
  1UUF(50),KKF(50),SSIGMA(50)
   COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
  1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
   COMMON  ENTHAL(200),TEMP(200)
   COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
  1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN
   COMMON  FLO(200)
   COMMON  AFT
   DIMENSION  AXIAL(50),FAX(50)
   DIMENSION  LC(200,4),P1(500),FRAC(200)
   DIMENSION   A(200),WP(200),DE(200),HPERIM(200)
   DIMENSION   ASTAR(200),QTPRIM(200),QSTAR(200),HSTAR(500),DHDZST(20
  10)
   DIMENSION  MROD(200,3),SUMM(200)
   DIMENSION   QTPRI(150),BENTH(150),DHDZ(150)
    PROGRAM  ENERGY FOR CALCULATING TEMP. OF FLUID IN WIRE WRAP.RODS
   REAL    LAMBAV,LAMBL1,LAMBL2,LAMBA1,LAMBA2,LAMBA3
   REAL LEADOD,LENGTH,KKF
   READ(5,1) NODATA
 1 FORMAT(I5)
   READ(5,2)(PP(I),TT(I),RHOFF(I),RHOGG(I),HHF(I),HHG(I),UUF(I),
  1KKF(I),SSIGMA(I),I=1,NODATA)
 2 FORMAT(9E8.4)
   READ (5,3) NOOFAX,NORUNS,NRUN1
 3 FORMAT(3I5)
   READ(5,4)(AXIAL(I),FAX(I),I=1,NOOFAX)
 4 FORMAT(8E10.4)
   READ(5,5) N1,N2,N3,N4,NOROD,NCHANL
 5 FORMAT(6I5)
   INDI=0
   DO 6 J=1,NCHANL
   READ 7,I,LC(I,1),LC(I,2),LC(I,3),MROD(I,1),MROD(I,2),MROD(I,3),FRA
  1C(I)
 6 CONTINUE
 7 FORMAT(I5,6I10,E10.4)
   READ(5,201)(P1(I),I=1,NOROD)
201 FORMAT(8E10.4)
   READ  8,ETA1,ETA2,ETA3,ETA4,CHOICE,SHAPEF,DDE
 8 FORMAT(7E11.4)
   READ  9,AIJ,LEADOD,DWIRE,GAP,DELZ,GAP1
 9 FORMAT(6E11.4)
   READ 10,DROD,LENGTH,POD,NORING
10 FORMAT(3E11.4,I5)
   READ 12,GBAR,HIN,PREF,QBAR,RHOIN,FLOWW
12 FORMAT(6E11.4)
   OPTIONS
   IF(CHOICE.LT.2.0)GO  TO  17
   READ  501,AUNIT1,AWALL1,ACORN1,DEUNIT,AFT,VEL1,VEL2,VEL3
501 FORMAT(8E10.4)
   READ  503,LAMBA1,LAMBA2,LAMBA3,DEWALL,DECORN
503 FORMAT(5E10.4)
   READ(5,505)(QTPRIM(I),I=1,NCHANL)
505 FORMAT(8E10.4)
17 CONTINUE
   DO  160 LLL=1,NORUNS
```

```
      READ 11,PRINT1,OPTION,EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
   11 FORMAT(7E11.4)
      EHSTA1=EHSTA1*DDE/DROD
      EHSTA2=EHSTA2*DDE/DROD
      EHSTA3=EHSTA3*DDE/DROD
      EHSTA4=EHSTA4*DDE/DROD
      INPUT CALCULATIONS BEGIN
      IF(CHOICE.GE.2.0)GO  TO  506
      CALL  GEOM
  506 CONTINUE
      IF(CHOICE.LT.3.0)GO  TO  510
      VEL3=VEL2
      LAMBA3=LAMBA2
  510 CONTINUE
      IF(CHOICE.LT.2.0)GO  TO  515
      WPUNIT=1.0
      WPWALL=1.0
      WPCORN=1.0
      HPUNIT=1.0
      HPWALL=1.0
      HPCORN=1.0
      AUNIT=AUNIT1
      AWALL=AWALL1
      ACORN=ACORN1
  515 CONTINUE
      JJ=1
      RHAVG=RHOIN
      NN=N2
      DO 19 I=1,N2
      A(I)=AUNIT*FRAC(I)
      WP(I)=WPUNIT*FRAC(I)
      DE(I)=DEUNIT*FRAC(I)
   19 HPERIM(I)=HPUNIT*FRAC(I)
      IF(N3-NN)140,140,141
  141 CONTINUE
      NK1=NN+1
      DO  21  I=NK1,N3,1
      A(I)=AWALL*FRAC(I)
      WP(I)=WPWALL*FRAC(I)
      DE(I)=DEWALL*FRAC(I)
   21 HPERIM(I)=HPWALL*FRAC(I)
  140 IF(N4-N3)142,142,143
  143 CONTINUE
      NK2=N3+1
      DO 22 I=NK2,N4,1
      A(I)=ACORN*FRAC(I)
      WP(I)=WPCORN*FRAC(I)
      DE(I)=DECORN*FRAC(I)
   22 HPERIM(I)=HPCORN*FRAC(I)
  142 CONTINUE
      ATOTAL=0.0
      HPTOTL=0.0
      DO 25 I=1,NCHANL
      ATOTAL=A(I)+ATOTAL
   25 HPTOTL=HPTOTL+HPERIM(I)
      PRINT2=PRINT1
      LAMBAV=AFT/ATOTAL
      LAMBL1=1.0-1.0/POD
      LAMBL2=GAP1/GAP
```

```
      IF(CHOICE.GT.1.0)GO  TO  520
      LAMBAV=1.0
      LAMBL2=1.0
      LAMBL1=1.0
      LAMBA1=1.0
      LAMBA2=1.0
      LAMBA3=1.0
      GAP=GAP1
  520 CONTINUE
      IF(FLOWW.GT.0.0)GO TO 215
      GO TO 217
  215 GBAR=(FLOWW/ATOTAL)*144.0
  217 DO 170 I=1,N2
  170 FLO(I)=(A(I)/144.0)*(GBAR/VEL1)*(LAMBA1/LAMBAV)
      DO 175 I=NK1,N3,1
  175 FLO(I)=(A(I)/144.0)*(GBAR/VEL2)*(LAMBA2/LAMBAV)
      DO 176 I=NK2,N4,1
  176 FLO(I)=(A(I)/144.0)*(GBAR/VEL3)*(LAMBA3/LAMBAV)
      FLOWW=GBAR*ATOTAL/144.0
C     CALCULATE  AXIAL STEP SIZE
      ZSTART=LENGTH/DROD
      ZSTAR=0.0
      XPRINT=PRINT1/DROD
      ETA1ST=ETA1/DROD
      ETA2ST=ETA2/DROD
      ETA3ST=ETA3/DROD
      ETA4ST=ETA4/DROD
      GAPST=GAP/DROD
      DO 40 I=1,NCHANL
   40 ASTAR(I)=A(I)/(DROD*DROD)
      IF(DELZ.GT.0.0) GO TO 529
      IF(EHSTA1.LE.0.0)EHSTA1=0.000001
      DSTARM=(ASTAR(1))*ETA1ST/(2.0*EHSTA1*OPTION*(POD-1.0))
      NNN=XPRINT/DSTARM
      IF(NNN.LT.1)NNN=1
      DZSTAR=XPRINT/(6.0*FLOAT(NNN))
      GO TO 530
  529 DZSTAR=DELZ/DROD
  530 CONTINUE
C      CALCULATE ALL SAT PROPERTIES
      IPART=1
      CALL PROP(IPART)
C      ALL SAT PROPERTIES ARE OBTAINED
      IF(CHOICE.GT.1.0) GO TO 147
      PROD1=0.0
      P1(500)=0.0
      DO 205 I=1,NCHANL
      DO 206 J=1,3
      M=MROD(I,J)
      PROD=P1(M)
      PROD1=PROD+PROD1
  206 CONTINUE
      SUMM(I)=PROD1
      PROD1=0.0
  205 CONTINUE
C      CALCULATE  QSTAR AND QTP/FAXL
      QTPBAR=(QBAR*HPTOTL/ATOTAL)*12.0
      DO 45 I=1,NN
      QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/3.0)*SUMM(I))
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```
 45 CONTINUE
    IF(N3-NN)145,145,146
146 CONTINUE
    DO 46 I=NK1,N3,1
    QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/2.0)*SUMM(I))
 46 CONTINUE
145 IF(N4-N3)147,147,148
148 CONTINUE
    DO 47 I=NK2,N4,1
    QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/1.0)*SUMM(I))
 47 CONTINUE
147 CONTINUE
C      CALCULATE  QSTAR(I) BY  MULT.QTPRIM*FAXL/QTPBAR
    DO 49 I=1,NCHANL
 49 HSTAR(I)=0.0
    HSTAR(500)=0.0
C      PRINT ALL INPUYT QUANTITIES
    IF(INDI.GT.0)GO TO 97
    PRINT 30
 30 FORMAT(1X,'ENERGY WITH UNIFORM VEL. IN ALL CHAN.')
    PRINT 31
 31 FORMAT(1X,'PP(I)      TT(I)      RHOFF(I)     RHOGG(I)     HHF I    HHG
   1(I)    UUF   I    KKF   I   SIGMA')
    WRITE(6,32) (PP(I),TT(I),RHOFF(I),RHOGG(I),HHF(I),HHG(I),UUF(I),
   1KKF(I),SSIGMA(I),I=1,NODATA)
 32 FORMAT(1X,9F12.6/)
    WRITE(6,33)
 33 FORMAT(1X,'THE AXIAL DIST. AND AXIAL PEAKING RATIOS')
    WRITE(6,34) (AXIAL(I),FAX(I),I=1,NOOFAX)
 34 FORMAT(1X,8E10.4/)
    WRITE(6,110)
110  FORMAT(1X,'N1          N2        N3          N4           NCHANL')
    WRITE(6,111) N1,N2,N3,N4,NCHANL
111 FORMAT(1X,5I5/)
    WRITE (6,112)
112 FORMAT(1X,'CHANNEL NO. NO. OF ADJACENT CHAN IN ASCEND. ORDER PEA
   1KING RATIOOF RODS FRACTION OF CHANN USED')
    DO 113 I=1,NCHANL
    WRITE(6,114) I,LC(I,1),LC(I,2),LC(I,3),MROD(I,1),MROD(I,2),MROD(I,
   13),FRAC(I)
113 CONTINUE
114 FORMAT(1X,7I10,E10.4/)
    WRITE(6,115)
115 FORMAT(1X,'CENTROID SPACE BETWEEN ADJ.TYPES ORF CHANNEL')
    WRITE(6,116)ETA1,ETA2,ETA3,ETA4
116 FORMAT(1X,4E11.4/)
    WRITE(6,117)
117 FORMAT(1X,'WWW       LEAD/DIA    DIA OF WIRE   GAP BETW. ROD -WAL')
    WRITE(6,118) WWW,LEADOD,DWIRE,GAP
118 FORMAT(4E11.4)
    WRITE(6,120)
120 FORMAT(1X,'ROD DIA. 2(" IN. LENGTH  IN.P/D  NO OF RINGS')
    WRITE(6,121) DROD,LENGTH,POD,NORING
121 FORMAT(1X,3F15.6,I5)
    PRINT  127
127 FORMAT(1X,'AREAS(I)   WETTED PERI  EQ. DIA.  HEATED PRERI.')
    DO 128 I=1,NCHANL
    WRITE(6,129) A(I),WP(I),DE(I),HPERIM(I)
128 CONTINUE
```

```
  129 FORMAT(1X,4E11.4/)
      WRITE(6,130)
  130 FORMAT(1X,'ZSTART      ETA1ST   ETA2ST     ETA3ST    ETA4ST   GAPST
     1  DZSTAR   ')
       WRITE(6,131) ZSTART,ETA1ST,ETA2ST,ETA3ST,ETA4ST,GAPST,DZSTAR,
     1QTPBAR
  131 FORMAT(1X,8E11.4/)
      WRITE(6,202)
  202 FORMAT(1X,'ROD NO.   ROD POWER')
      DO 203 I=1,NOROD
  200 WRITE(6,204)I,P1(I)
  203 CONTINUE
  204 FORMAT(1X,I5,6X,E10.4)
      WRITE(6,210)
  210 FORMAT(1X,'VUNIT/VBAR   VWALL/VBAR   VCORNER/VBAR')
      WRITE(6,211)VEL1,VEL2,VEL3
  211 FORMAT(1X,3E10.4)
   97 CONTINUE
      WRITE(6,122)
  122 FORMAT(1X,'AXIAL INCREM. FOR PRINT OPTION>2 EHSTA1      2   3    4
     1 COEFF FOR PERI. VEL.')
      WRITE(6,123) PRINT1,OPTION,EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
  123 FORMAT(1X,7E11.4/)
      WRITE(6,124)
  124 FORMAT(1X,'GBAR   HIN  BTU/LB. REF PRES.  AVG. HEAT FLUX VEL OPT')
      WRITE(6,125) GBAR,HIN,PREF,QBAR,OPVEL,FLOWW,A(1),A(115),DE(1),
     1ATOTAL
  125 FORMAT(1X,10E11.4/)
      WRITE(6,132)
  132 FORMAT(1X,'CHANNEL NO.  ASTAR   HEAT GEN. PER UNIT VOL/FAX')
      INDI=INDI+1
      IF(OPVEL)70,70,71
   71 CALL HYDRO(V1,V2,V3)
   70  PREF=PREF
      HIN=HIN
      IPART=2
      SUM1=0.0
      DO  101 I=1,NCHANL
      ENTHAL(I)=HIN
      SUM1=SUM1+ENTHAL(I)*FLO(I)
  101 CONTINUE
      SUM4=0.0
      SUM3=0.0
      CALL PROP(IPART)
C      ENTERING  MAIN LOOP
C      CALL AXIAL  PEAKING  FACTOR
   26 ZBAR=DZSTAR/2.0+ZSTAR
      ZBAR=ZBAR*DROD/LENGTH
      CALL CURVE(FAXL,ZBAR,FAX,AXIAL,NOOFAX,IERROE,1)
      ALPSTA=12.0*CONAVG/(GBAR*CPAVG*DROD)*SHAPEF
      ALPSTA=ALPSTA*LAMBL1
      IF(CHOICE.LE.1.0) GO TO 545
      DO 550 I=1,NCHANL
  550 QTPRI(I)=QTPRIM(I)*FAXL
      CALL  ENT1(LC,FLO,A,DE,ENTHAL,QTPRI,GBAR,AIJ,N1,N2,N3,NCHANL,RHOIN
     1,HIN,DROD,POD,JJ,EHSTA1,EHSTA2,EHSTA3,EHSTA4,ALPSTA,ETA1,ETA2,
     2ETA3,ETA4,C1,DELZ,GAP,DHDZ)
      GO TO 560
  545 CONTINUE
```

```
      DO   76   I=1,NCHANL
   76 QSTAR(I)=QTPRIM(I)*FAXL/QTPBAR
       DO 80  I=1,N1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=QSTAR(I)+(1.0/ASTAR(I))*(EHSTA1+ALPSTA)*((POD-1.0)/ETA1S
     1T)*(HSTAR(MM1)+HSTAR(MM2)+HSTAR(MM3)-3.0*HSTAR(I))
      DHDZST(I)=DHDZST(I)*VEL1
   80 CONTINUE
       IF(N2-N1)150,150,151
  151 CONTINUE
      NK3=N1+1
      DO 81  I=NK3,N2,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=QSTAR(I)+(1.0/ASTAR(I))*((POD-1.0)*((EHSTA1+ALPSTA)/ETA1
     1ST)*(HSTAR(MM1)+HSTAR(MM2)-2.0*HSTAR(I))+((EHSTA2+ALPSTA)/ETA2ST)
     2 *(HSTAR(MM3)-HSTAR(I))*(POD-1.0))
      DHDZST(I)=DHDZST(I)*VEL1
   81 CONTINUE
  150 CONTINUE
      IF(N3-N2)155,155,156
  156 CONTINUE
      DO   85  I=NK1,N3,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      IF(MM2.GT.N3)GO TO 888
       ETASTR=ETA3ST
      GO TO 889
  888 ETASTR=ETA4ST
  889 CONTINUE
      IF(MM3.GT.N3)GO TO 890
      ETASTS=ETA3ST
      GO TO 891
  890 ETASTS=ETA4ST
  891 CONTINUE
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=(1.0/ASTAR(I))*((GAPST)*((EHSTA3+ALPSTA)*(((HSTAR(MM2)-
     1HSTAR(I))/ETASTR)+((HSTAR(MM3)-HSTAR(I))/ETASTS))+C1*(HSTAR(MM2)-
     2HSTAR(I)))+(POD-1.0)*(((EHSTA2+ALPSTA)/ETA2ST)*(HSTAR(MM1)-HSTAR(I
     3))))+QSTAR(I)
      DHDZST(I)=DHDZST(I)*VEL2
   85 CONTINUE
  155 CONTINUE
      IF(N4-N3)157,157,158
  158 CONTINUE
      DO 88 I=NK2,N4,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=(1.0/ASTAR(I))*((GAPST)*(((EHSTA4+ALPSTA)/ETA4ST)*(HST
     1AR(MM1)+HSTAR(MM2)-2.0*HSTAR(I))+C1*(HSTAR(MM1)-HSTAR(I))))+QSTAR
     2(I)
```

```
      DHDZST(I)=DHDZST(I)*VEL3
   88 CONTINUE
  157 CONTINUE
      DO  90  I=1,NCHANL
   90 HSTAR(I)=HSTAR(I)+DHDZST(I)*DZSTAR
      DO  91 I=1,NCHANL
      ENTHAL(I)=(HSTAR(I)*DROD*QTPBAR/(GBAR*12.0))+HIN
   91 CONTINUE
  560 CONTINUE
      SUM2=0.0
      DO 570 I=1,NCHANL
      SUM2=SUM2+ENTHAL(I)*FLO(I)
  570 CONTINUE
      SUM5=SUM2-SUM1
      SUM4=SUM4+SUM2
      IPART=2
      CALL PROP(IPART)
      ZSTAR=ZSTAR+DZSTAR
      IF(CHOICE.GT.1.0) GO TO 600
      DIFF=ABS(ZSTAR-XPRINT)
      IF(DIFF-0.1)92,92,26
   92 XPRINT=XPRINT+PRINT1/DROD
      ZZSTAR=ZSTAR*DROD
      PRINT 171,SUM2,SUM3,SUM4,SUM5,SUM1,FLO(1),FLO(27),FLO(41)
  171 FORMAT(1X,8F13.5/)
      PRINT 93
   93 FORMAT(1X,'AXIAL DIST. IN.      ZSTAR   AVERAGE TEMP.')
      WRITE(6,94)ZZSTAR,ZSTAR,TAVGZ
   94 FORMAT(1X,3E11.4/)
      WRITE(6,95)(TEMP(I),I=1,NCHANL)
   95 FORMAT(1X,10F12.4/)
      ZCZ=ABS(ZSTAR-ZSTART)
      IF(ZCZ.LT.0.1) GO TO 100
      IF(CHOICE.LE.1.0) GO TO 26
  600 CONTINUE
      ZZSTAR=ZSTAR*DROD
      DIFF=ABS(ZZSTAR-PRINT2)
      IF(DIFF-0.1)601,601,26
  601 PRINT2=PRINT2+PRINT1
      PRINT 625,SUM2,SUM5,SUM1
  625 FORMAT(1X,3F13.6)
      PRINT 626
  626 FORMAT(1X,'AXIAL DIST IN.   ZSTAR   AVG.TEMP')
      PRINT 627,ZZSTAR,ZSTAR,TAVGZ
  627 FORMAT(1X,3E11.4//)
      WRITE(6,509)(TEMP(I),I=1,NCHANL)
  509 FORMAT(8F10.4)
      ZCZ=ABS(ZSTAR-ZSTART)
      IF(ZCZ.LT.0.1) GO TO 100
      GO TO 26
  100 CONTINUE
      IF(CHOICE.LT.2.0) GO TO 160
      DO 508 I=1,NCHANL
      A(I)=A(I)*144.0
      DE(I)=DE(I)*12.0
  508 CONTINUE
      AIJ=AIJ*12.0
      DELZ=DELZ*12.0
      ETA1=ETA1*12.0
      ETA2=ETA2*12.0
```

```
      ETA3=ETA3*12.0
      ETA4=ETA4*12.0
      GAP=GAP1*12.0
  160 CONTINUE
      STOP
        END
      SUBROUTINE  GEOM
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON  ENTHAL(200),TEMP(200)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN
      COMMON  FLO(200)
      COMMON  AFT
C      SUBROUTINE  CALCULATES  GEOMETRY FOR  3 TYPES  OF CHANNELS
      REAL  LEADOD
      N11=N2
      N22=N3-N11
      N33=N4-N3
      SPACE=GAP
      DR=DROD
      DW=DWIRE
      P=DR*POD
      PPP=FLOAT(NORING)*P*1.732/2.0
      DFLAT=2.0*(PPP+DR/2.0+GAP)
      DFACE=DFLAT/1.732
      PI=3.14159
      AUNIT=1.732/4.0*P*P-PI/8.0*DR*DR-PI/8.0*DW*DW
      AWALL=P*(DR/2.0+SPACE)-PI*DR*DR/8.0-PI*DW*DW/8.0
      ACORN=2.0*(0.5*(DR/2.0+SPACE)*(DFACE-P*NORING)*0.5-PI*DR*DR/48.0
     1)-PI*DW*DW/24.0
      WPUNIT=(PI/2.0)*DR+0.5*PI*DW
      WPWALL=P+WPUNIT
      WPCORN=(PI/6.0)*DR+(PI/6.0)*DW+2.0*(DFACE-P*NORING)*0.5
      DEUNIT=4.0*AUNIT/WPUNIT
      DEWALL=4.0*AWALL/WPWALL
      DECORN=4.0*ACORN/WPCORN
      HPUNIT=(PI/2.0)*DR
      HPWALL=(PI/2.0)*DR
      HPCORN=(PI/6.0)*DR
      AFT=N11*AUNIT+N22*AWALL+N33*ACORN
      XX1=AFT/(N11*AUNIT+N22*AWALL*((DEWALL/DEUNIT)**0.714)+N33*ACORN*
     1((DECORN/DEUNIT)**0.714))
      XX2=AFT/(N11*AUNIT*((DEUNIT/DEWALL)**0.714)+N22*AWALL+N33*ACORN*
     1((DECORN/DEWALL)**0.714))
      XX3=AFT/(N11*AUNIT*((DEUNIT/DECORN)**0.714)+N22*AWALL*((DEWALL/
     1DECORN)**0.714)+N33*ACORN)
      VEL1=1.0/XX1
      VEL2=1.0/XX2
      VEL3=1.0/XX3
      RETURN
      END
      SUBROUTINE  CURVE(FX,X,F,Y,N,J,ISAVE)
      DIMENSION  F(60),Y(60)
      GO TO(10,50),ISAVE
   10 DO 20 KK=1,N
      IF(X-Y(KK))30,15,20
```

```
   15 IF(KK.EQ.N) GO TO 40
   20 CONTINUE
      GO TO 60
   30 IF(KK.EQ.1) GO TO 60
   40 B=(X-Y(KK-1))/(Y(KK)-Y(KK-1))
   50 FX=F(KK-1)+B*(F(KK)-F(KK-1))
      RETURN
   60 PRINT 61
   61 FORMAT(1X,'PROG.STOPPED IN CURVE')
      J=2
      RETURN
      END
         SUBROUTINE  PROP(IPART)
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON  ENTHAL(200),TEMP(200)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN
      COMMON  FLO(200)
      COMMON  AFT
      REAL  KKF
      GO TO (10,100),IPART
C     PART 1  CALCUL. OF SATURATED PROPERTIES
   10 DO 11 I=1,NODATA
      IF(PREF .LT. PP(I)) GO TO 20
   11 CONTINUE
      GO TO 300
   20 IF(I.GT.1) GO TO 40
      GO TO 300
   40 VALUE=(PREF-PP(I-1))/(PP(I)-PP(I-1))
      HSAT=HHF(I-1)+VALUE*(HHF(I)-HHF(I-1))
      HVSAT=HHG(I-1)+VALUE*(HHG(I)-HHG(I-1))
      RHSAT=RHOFF(I-1)+VALUE*(RHOFF(I)-RHOFF(I-1))
      RHVSAT=RHOGG(I-1)+VALUE*(RHOGG(I)-RHOGG(I-1))
      VISSAT=UUF(I-1)+VALUE*(UUF(I)-UUF(I-1))
      TSAT=TT(I-1)+VALUE*(TT(I)-TT(I-1))
      CONSAT=KKF(I-1)+VALUE*(KKF(I)-KKF(I-1))
      SIGSAT=SSIGMA(I-1)+VALUE*(SSIGMA(I)-SSIGMA(I-1))
      RETURN
C      PART2  CALCULATE PROPERTIES AT LOCAL CONDIT.
  100 CONTINUE
      DO 110 I=1,NCHANL
      TEMP(I)=TSAT
      IF(ENTHAL(I).GT.HSAT)GO TO 300
      CALL CURVE(TEMP(I),ENTHAL(I),TT,HHF,NODATA,IERROR,1)
  110 CONTINUE
       SUMM1=0.0
      DO  111 I=1,NCHANL
       SUMM1=SUMM1+FLO(I)*TEMP(I)/RHAVG
  111 CONTINUE
       SUMM2=0.0
       DO  112 I=1,NCHANL
       SUMM2=SUMM2+FLO(I)/RHAVG
      TAVGZ=SUMM1/SUMM2
  112 CONTINUE
C     NOW CALCULCATE  CONDUCTIVITY CP  DENSITY
      CONAVG=54.306-(1.878E-2)*TAVGZ+(2.0914E-6)*TAVGZ*TAVGZ
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      CPAVG=0.344021-(7.03539E-5)*TAVGZ+(2.68131E-8)*TAVGZ*TAVGZ
      RHAVG=59.566-(7.9504E-3)*TAVGZ-(0.2872E-6)*TAVGZ*TAVGZ+(0.06035E-
     19)*TAVGZ**3
      RETURN
  300 PRINT 301
  301 FORMAT(1X,'STOPPED IN PROP')
      STOP
      END
      SUBROUTINE  HYDRO(V1,V2,V3)
      V1=1.0
      V2=1.0
      V3=1.0
      RETURN
      END
      SUBROUTINE   ENT1(LC,FLO,A,DE,ENTHAL,QTPRI,GBAR,AIJ,N1,N2,N3,
     1       NCHANL,RHOIN,HIN,DROD,POD,JJ,EHSTA1,EHSTA2,EHSTA3,EHSTA4,
     2  ALPSTA,ETA1,ETA2,ETA3,ETA4,C1,DELZ,GAP,DHDZ)
      DIMENSION  FLO(200),A(200),DE(200),ENTHAL(200),LC(200,4),
     1QTPRI(150),Q(200),FLR(200),DHDZ(150),ETP(200)
      IF(JJ.GT.1)GO  TO  10
      DO  5  I=1,NCHANL
       A(I)=A(I)/144.0
       DE(I)=DE(I)/12.0
      ENTHAL(I)=HIN
      FLR(I)=FLO(I)/3600.0
    5 CONTINUE
      AIJ=AIJ/12.0
      DROD1=DROD/12.0
      GBAR1=GBAR/3600.0
      DELZ=DELZ/12.0
      ETA1=ETA1/12.0
      ETA2=ETA2/12.0
      ETA3=ETA3/12.0
      ETA4=ETA4/12.0
      GAP=GAP/12.0
   10 CONTINUE
      JJ=JJ+1
      DO  12  I=1,NCHANL
      ETP(I)=ENTHAL(I)
      Q(I)=QTPRI(I)*A(I)/3600.0
   12 CONTINUE
      DO  400  I=1,NCHANL
      QT=Q(I)
      AJ=A(I)
      AM=FLR(I)
      IF(I.GT.N1)  GO  TO  35
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      EX1=      AIJ*GBAR1*(EHSTA1+ALPSTA)*(DROD1/ETA1)*(ETP(MM1)+ETP(MM2)
     1+ETP(MM3)-3.0*ETP(I))
      DHDZ(I)=(EX1+QT)/AM
      GO  TO  400
   35 CONTINUE
      IF(I.GT.N2)GO  TO  55
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      EX1=      AIJ*DROD1*GBAR1*((EHSTA1+ALPSTA)*(1.0/ETA1)*(ETP(MM1)
     1+ETP(MM2)-2.0*ETP(I))+(EHSTA2+ALPSTA)*(1.0/ETA2)*(ETP(MM3)-ETP(I))
```

```
     2)
      DHDZ(I)=(EX1+QT)/AM
      GO  TO  400
   55 CONTINUE
      IF(I.GT.N3)GO  TO  130
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      IF(MM2.GT.N3)GO TO 100
      ETASTR=ETA3
      GO  TO  101
  100 ETASTR=ETA4
  101 CONTINUE
      IF(MM3.GT.N3)GO  TO  105
      ETASTS=ETA3
      GO  TO  104
  105 ETASTS=ETA4
  104 CONTINUE
      EX1=         (GAP*(DROD1*GBAR1*(EHSTA3+ALPSTA)*(((ETP(MM2)-ETP(I))
     2/ETASTR)+((ETP(MM3)-ETP(I))/ETASTS))+C1*GBAR1*(ETP(MM2)-ETP(I)))
     3+((GBAR1*DROD1/ETA2)*(EHSTA2+ALPSTA)*AIJ*(ETP(MM1)-ETP(I))))
      DHDZ(I)=(EX1+QT)/AM
      GO  TO  400
  130 CONTINUE
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      EX1=     GBAR1*((DROD1/ETA4)*(EHSTA4+ALPSTA)*(ETP(MM1)+ETP(MM2)
     1-2.0*ETP(I))+C1*(ETP(MM1)-ETP(I)))*GAP
      DHDZ(I)=(EX1+QT)/AM
  400 CONTINUE
      DO  153  I=1,NCHANL
      ENTHAL(I)=ENTHAL(I)+DHDZ(I)*DELZ
  153 CONTINUE
      RETURN
      END
```

```
/ DATASET DDNAME=DD1
C     COMPUTER  PROGRAM  ENERGY  2


C        COMMON  MAIN PROG.
       COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
      1UUF(50),KKF(50),SSIGMA(50)
       COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
      1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
       COMMON ENTHAL(150),TEMP(150)
       COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
      1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN,VBAR
       COMMON RHO(150),VISCOS(150),U(150),V(150),AFRIC,BFRIC,FLOWW
       COMMON A(150),WP(150),DE(150),HPERIM(150)
       COMMON  PDOP(150)
       COMMON  KRK
       COMMON INDEX
       COMMON  LAMBAV,LAMBA1,LAMBA2,LAMBA3,LAMBL1,LAMBL2
       COMMON  AFT
       DIMENSION BHSTAR(150)
       DIMENSION  AXIAL(50),FAX(50)
       DIMENSION LC(150,3),P1(500),FRAC(150),RNUM(150)
        DIMENSION  ASTAR(150),QTPRIM(150),QSTAR(150),HSTAR(500),DHDZST(15
      10)
       DIMENSION  PRESSU(150)
       DIMENSION  FLO(150),MROD(150,3),SUMM(150)
       DIMENSION   QTPRI(150),BENTH(150),DHDZ(150)
C        PROGRAM  ENERGY FOR CALCULATING TEMP. OF FLUID IN WIRE WRAP.RODS
       REAL LEADOD,LENGTH,KKF
       REAL   LAMBAV,LAMBL1,LAMBL2,LAMBA1,LAMBA2,LAMBA3
       READ(5,1) NODATA
     1 FORMAT(I5)
       READ(5,2)(PP(I),TT(I),RHOFF(I),RHOGG(I),HHF(I),HHG(I),UUF(I),
      1KKF(I),SSIGMA(I),I=1,NODATA)
     2 FORMAT(9E8.4)
       READ(5,3) NOOFAX,NORUNS,NRUN1,NOITER
     3 FORMAT(4I5)
       READ(5,4)(AXIAL(I),FAX(I),I=1,NOOFAX)
     4 FORMAT(8E10.4)
       READ(5,5)N1,N2,N3,N4,NOROD,AFRIC,BFRIC
     5 FORMAT(5I5,2E10.4)
       INDI=0
       NCHANL=N4
       DO 6  I=1,NCHANL
       READ 7,I,LC(I,1),LC(I,2),LC(I,3),MROD(I,1),MROD(I,2),MROD(I,3),FRA
      1C(I)
     6 CONTINUE
     7 FORMAT(I5,6I10,E10.4)
       READ(5,201)(P1(I),I=1,NOROD)
   201 FORMAT(8E10.4)
       READ  8,ETA1,ETA2,ETA3,ETA4,CHOICE,SHAPEF,DDE
     8 FORMAT(7E11.4)
       READ  9,AIJ,LEADOD,DWIRE,GAP,DELZ,GAP1
     9 FORMAT(6E11.4)
       READ 10,DROD,LENGTH,POD,NORING
    10 FORMAT(3E11.4,I5)
       READ 12,GBAR,HIN,PREF,QBAR,RHOIN,FLOWW
    12 FORMAT(6E11.4)
C      OPTIONS
       IF(CHOICE.LT.2.0)GO  TO  17
       READ  501,AUNIT1,AWALL1,ACORN1,DEUNIT,AF1,VEL1,VEL2,VEL3
   501 FORMAT(8E10.4)
       READ  503,LAMBA1,LAMBA2,LAMBA3,DEWALL,DECORN
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503 FORMAT(5E10.4)
    READ(5,505)(QTPRIM(I),I=1,NCHANL)
505 FORMAT(8E10.4)
 17 CONTINUE
    READ 11,PRINT1,OPTION,EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
 11 FORMAT(7E11.4)
    EHSTA1=EHSTA1*DDE/DROD
    EHSTA2=EHSTA2*DDE/DROD
    EHSTA3=EHSTA3*DDE/DROD
    EHSTA4=EHSTA4*DDE/DROD
C      INPUT CALCULATIONS BEGIN
    DO 326 I=1,NCHANL
326 PRESSU(I)=PREF*144.0
    PRINT 327,(PRESSU(I),I=1,NCHANL)
327 FORMAT(1X,11F11.4)
    IF(CHOICE.GE.2.0)GO  TO  506
    CALL  GEOM
506 CONTINUE
    OPVEL=0
    IF(CHOICE.LT.3.0)GO  TO  510
    VEL3=VEL2
    LAMBA3=LAMBA2
510 CONTINUE
    IF(CHOICE.LT.2.0)GO  TO  515
    WPUNIT=1.0
    WPWALL=1.0
    WPCORN=1.0
    HPUNIT=1.0
    HPWALL=1.0
    HPCORN=1.0
    AUNIT=AUNIT1
    AWALL=AWALL1
    ACORN=ACORN1
515 CONTINUE
    JJ=1
    RHAVG=RHOIN
    PRINT2=PRINT1
    NN=N2
    DO 19 I=1,N2
    A(I)=AUNIT*FRAC(I)
    WP(I)=WPUNIT*FRAC(I)
    DE(I)=DEUNIT*FRAC(I)
 19 HPERIM(I)=HPUNIT*FRAC(I)
    IF(N3-NN)140,140,141
141 CONTINUE
    NK1=NN+1
    DO  21  I=NK1,N3,1
    A(I)=AWALL*FRAC(I)
    WP(I)=WPWALL*FRAC(I)
    DE(I)=DEWALL*FRAC(I)
 21 HPERIM(I)=HPWALL*FRAC(I)
140 IF(N4-N3)142,142,143
143 CONTINUE
    NK2=N3+1
    DO 22 I=NK2,NCHANL,1
    A(I)=ACORN*FRAC(I)
    WP(I)=WPCORN*FRAC(I)
    DE(I)=DECORN*FRAC(I)
 22 HPERIM(I)=HPCORN*FRAC(I)
```

```
  142 CONTINUE
      ATOTAL=0.0
      HPTOTL=0.0
      DO 25 I=1,NCHANL
      ATOTAL=A(I)+ATOTAL
   25 HPTOTL=HPTOTL+HPERIM(I)
      LAMBAV=AFT/ATOTAL
      LAMBL1=1.0-1.0/POD
      LAMBL2=GAP1/GAP
      IF(CHOICE.GT.1.0)GO  TO  520
      LAMBAV=1.0
      LAMBL2=1.0
      LAMBL1=1.0
      LAMBA1=1.0
      LAMBA2=1.0
      LAMBA3=1.0
      GAP=GAP1
  520 CONTINUE
      IF(FLOWW.GT.0.0)GO TO 215
      FLOWW=GBAR*ATOTAL/144.0
      GO TO 217
  215 GBAR=(FLOWW/ATOTAL)*144.0
  217 DO 170 I=1,N2
  170 FLO(I)=(A(I)/144.0)*(GBAR/VEL1)*(LAMBA1/LAMBAV)
      DO 175 I=NK1,N3,1
  175 FLO(I)=(A(I)/144.0)*(GBAR/VEL2)*(LAMBA2/LAMBAV)
      DO 176 I=NK2,NCHANL,1
  176 FLO(I)=(A(I)/144.0)*(GBAR/VEL3)*(LAMBA3/LAMBAV)
      FLOWW=GBAR*ATOTAL/144.0
      PRINT   999
  999 FORMAT(1X,'PASSED  FLAG')
C     CALCULATE  AXIAL STEP SIZE
      ZSTART=LENGTH/DROD
      ZSTAR=0.0
      XPRINT=PRINT1/DROD
      ETA1ST=ETA1/DROD
      ETA2ST=ETA2/DROD
      ETA3ST=ETA3/DROD
      ETA4ST=ETA4/DROD
      GAPST=GAP/DROD
      DO 40 I=1,NCHANL
   40 ASTAR(I)=A(I)/(DROD*DROD)
      IF(DELZ.GT.0.0) GO TO 529
      DSTARM=(ASTAR(1))*ETA1ST/(2.0*EHSTA1*OPTION*(POD-1.0))
      NNN=XPRINT/DSTARM
      IF(NNN.LT.1)NNN=1
      DZSTAR=XPRINT/(2.0*FLOAT(NNN))
      GO TO 530
  529 DZSTAR=DELZ/DROD
  530 CONTINUE
C      CALCULATE ALL SAT PROPERTIES
      IPART=1
      CALL PROP(IPART)
C      ALL SAT PROPERTIES ARE OBTAINED
      IF(CHOICE.GT.1.0) GO TO 147
      PROD1=0.0
      P1(500)=0.0
      DO 205 I=1,NCHANL
      DO 206 J=1,3
```

```
      M=MROD(I,J)
      PROD=P1(M)
      PROD1=PROD+PROD1
  206 CONTINUE
      SUMM(I)=PROD1
      PROD1=0.0
  205 CONTINUE
C       CALCULATE  QSTAR AND QTP/FAXL
      QTPBAR=(QBAR*HPTOTL/ATOTAL)*12.0
      DO 45 I=1,NN
      QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/3.0)*SUMM(I))
   45 CONTINUE
      IF(N3-NN)145,145,146
  146 CONTINUE
      DO 46 I=NK1,N3,1
      QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/2.0)*SUMM(I))
   46 CONTINUE
  145 IF(N4-N3)147,147,148
  148 CONTINUE
      DO 47 I=NK2,N4,1
      QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/1.0)*SUMM(I))
   47 CONTINUE
  147 CONTINUE
C       CALCULATE  QSTAR(I) BY  MULT.QTPRIM*FAXL/QTPBAR
      DO 49 I=1,NCHANL
   49 HSTAR(I)=0.0
      HSTAR(500)=0.0
C       PRINT ALL INPUYT QUANTITIES
      IF(INDI.GT.0)GO TO 97
      PRINT 30
   30 FORMAT(1X,'ENERGY WITH UNIFORM VEL. IN ALL CHAN.')
      PRINT 31
   31 FORMAT(1X,'PP(I)      TT(I)      RHOFF(I)     RHOGG(I)     HHF I    HHG
     1(I)    UUF  I    KKF  I  SIGMA')
      WRITE(6,32) (PP(I),TT(I),RHOFF(I),RHOGG(I),HHF(I),HHG(I),UUF(I),
     1KKF(I),SSIGMA(I),I=1,NODATA)
   32 FORMAT(1X,9F12.6/)
      WRITE(6,33)
   33 FORMAT(1X,'THE AXIAL DIST. AND AXIAL PEAKING RATIOS')
      WRITE(6,34) (AXIAL(I),FAX(I),I=1,NOOFAX)
   34 FORMAT(1X,8E10.4/)
      WRITE(6,110)
  110  FORMAT(1X,'N1          N2        N3          N4          NCHANL')
      WRITE(6,111) N1,N2,N3,N4,NCHANL
  111 FORMAT(1X,5I5/)
      WRITE (6,112)
  112 FORMAT(1X,'CHANNEL NO. NO. OF ADJACENT CHAN IN ASCEND. ORDER PEA
     1KING RATIOOF RODS FRACTION OF CHANN USED')
      DO 113 I=1,NCHANL
      WRITE(6,114) I,LC(I,1),LC(I,2),LC(I,3),MROD(I,1),MROD(I,2),MROD(I,
     13),FRAC(I)
  113 CONTINUE
  114 FORMAT(1X,7I10,E10.4/)
      WRITE(6,115)
  115 FORMAT(1X,'CENTROID SPACE BETWEEN ADJ.TYPES ORF CHANNEL')
      WRITE(6,116)ETA1,ETA2,ETA3,ETA4
  116 FORMAT(1X,4E11.4/)
      WRITE(6,117)
  117 FORMAT(1X,'WWW       LEAD/DIA     DIA OF WIRE    GAP BETW. ROD -WAL')
      WRITE(6,118) WWW,LEADOD,DWIRE,GAP
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118 FORMAT(4E11.4)
    WRITE(6,120)
120 FORMAT(1X,'ROD DIA. 2(" IN. LENGTH  IN.P/D  NO OF RINGS')
    WRITE(6,121) DROD,LENGTH,POD,NORING
121 FORMAT(1X,3F15.6,I5)
    PRINT  127
127 FORMAT(1X,'AREAS(I)   WETTED PERI  EQ. DIA.  HEATED PRERI.')
    DO 128 I=1,NCHANL
    WRITE(6,129) A(I),WP(I),DE(I),HPERIM(I)
128 CONTINUE
129 FORMAT(1X,4E11.4/)
    WRITE(6,130)
130 FORMAT(1X,'ZSTART     ETA1ST   ETA2ST    ETA3ST    ETA4ST    GAPST
   1  DZSTAR   ')
    WRITE(6,131) ZSTART,ETA1ST,ETA2ST,ETA3ST,ETA4ST,GAPST,DZSTAR,
   1QTPBAR
131 FORMAT(1X,8E11.4/)
    WRITE(6,202)
202 FORMAT(1X,'ROD NO.   ROD POWER')
    DO 203 I=1,NOROD
200 WRITE(6,204)I,P1(I)
203 CONTINUE
204 FORMAT(1X,I5,6X,E10.4)
    WRITE(6,210)
210 FORMAT(1X,'VUNIT/VBAR   VWALL/VBAR   VCORNER/VBAR')
    WRITE(6,211)VEL1,VEL2,VEL3
211 FORMAT(1X,3E10.4)
 97 CONTINUE
    WRITE(6,122)
122 FORMAT(1X,'AXIAL INCREM. FOR PRINT OPTION>2 EHSTA1      2    3     4
   1 COEFF FOR PERI. VEL.')
    WRITE(6,123) PRINT1,OPTION,EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
123 FORMAT(1X,7E11.4/)
    WRITE(6,124)
124 FORMAT(1X,'  GBAR     HIN  BTU/LB   REF   PRES.  AVG HEAT FLUX  VEL
   1OPT   FLOWW      ATOTAL')
    WRITE(6,125) GBAR,HIN,PREF,QBAR,OPVEL,FLOWW,ATOTAL
125 FORMAT(1X,7E11.4/)
    WRITE(6,132)
132 FORMAT(1X,'CHANNEL NO.   ASTAR   HEAT GEN. PER UNIT VOL/FAX')
    INDI=INDI+1
 70  PREF=PREF
    HIN=HIN
    IPART=2
    SUM1=0.0
    DO  101 I=1,NCHANL
    ENTHAL(I)=HIN
    SUM1=SUM1+ENTHAL(I)*FLO(I)
101 CONTINUE
    SUM4=0.0
    SUM3=0.0
    VBAR=GBAR/RHOIN
C    ENTERING  MAIN LOOP
    DO 301 I=1,NN
301 U(I)=(VBAR/VEL1)*(LAMBA1/LAMBAV)
    DO 302 I=NK1,N3,1
302 U(I)=VBAR/VEL2*(LAMBA2/LAMBAV)
    DO 303 I=NK2,NCHANL,1
303 U(I)=VBAR/VEL3*(LAMBA3/LAMBAV)
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      DO 304 I=1,NCHANL
  304 V(I)=U(I)
      CALL PROP(IPART)
C      CALL AXIAL  PEAKING  FACTOR
   26 ZBAR=DZSTAR/2.0+ZSTAR
      ZBAR=ZBAR*DROD/LENGTH
      CALL CURVE(FAXL,ZBAR,FAX,AXIAL,NOOFAX,IERROE,1)
      ALPSTA=12.0*CONAVG/(GBAR*CPAVG*DROD)*SHAPEF
      ALPSTA=ALPSTA*LAMBL1
      IF(CHOICE.LE.1.0) GO TO 545
      DO 550 I=1,NCHANL
      BENTH(I)=ENTHAL(I)
  550 QTPRI(I)=QTPRIM(I)*FAXL
      CALL  ENT1(LC,FLO,A,DE,ENTHAL,QTPRI,GBAR,AIJ,N1,N2,N3,NCHANL,RHOIN
     1,HIN,DROD,POD,JJ,EHSTA1,EHSTA2,EHSTA3,EHSTA4,ALPSTA,ETA1,ETA2,
     2ETA3,ETA4,C1,DELZ,GAP,DHDZ)
      GO TO 560
  545 CONTINUE
      DO  76  I=1,NCHANL
   76 QSTAR(I)=QTPRIM(I)*FAXL/QTPBAR
      DO  80  I=1,N1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=QSTAR(I)+(1.0/ASTAR(I))*(EHSTA1+ALPSTA)*((POD-1.0)/ETA1S
     1T)*(HSTAR(MM1)+HSTAR(MM2)+HSTAR(MM3)-3.0*HSTAR(I))
      DHDZST(I)=DHDZST(I)*VBAR/U(I)
   80 CONTINUE
       IF(N2-N1)150,150,151
  151 CONTINUE
      NK3=N1+1
      DO 81 I=NK3,N2,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=QSTAR(I)+(1.0/ASTAR(I))*((POD-1.0)*((EHSTA1+ALPSTA)/ETA1
     1ST)*(HSTAR(MM1)+HSTAR(MM2)-2.0*HSTAR(I))+((EHSTA2+ALPSTA)/ETA2ST)
     2 *(HSTAR(MM3)-HSTAR(I))*(POD-1.0))
      DHDZST(I)=DHDZST(I)*VBAR/U(I)
   81 CONTINUE
  150 CONTINUE
      IF(N3-N2)155,155,156
  156 CONTINUE
      DO  85 I=NK1,N3,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      IF(MM2.GT.N3)GO TO 888
       ETASTR=ETA3ST
      GO TO 889
  888 ETASTR=ETA4ST
  889 CONTINUE
      IF(MM3.GT.N3)GO TO 890
      ETASTS=ETA3ST
      GO TO 891
  890 ETASTS=ETA4ST
  891 CONTINUE
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      HSTAR(500)=HSTAR(I)
      DHDZST(I)=(1.0/ASTAR(I))*((GAPST)*((EHSTA3+ALPSTA)*(((HSTAR(MM2)-
     1HSTAR(I))/ETASTR)+((HSTAR(MM3)-HSTAR(I))/ETASTS))+C1*(HSTAR(MM2)-
     2HSTAR(I)))+(POD-1.0)*(((EHSTA2+ALPSTA)/ETA2ST)*(HSTAR(MM1)-HSTAR(I
     3))))+QSTAR(I)
      DHDZST(I)=DHDZST(I)*VBAR/U(I)
   85 CONTINUE
  155 CONTINUE
      IF(N4-N3)157,157,158
  158 CONTINUE
      DO 88 I=NK2,N4,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=(1.0/ASTAR(I))*((GAPST)*(((EHSTA4+ALPSTA)/ETA4ST)*(HST
     1AR(MM1)+HSTAR(MM2)-2.0*HSTAR(I))+C1*(HSTAR(MM1)-HSTAR(I))))+QSTAR
     2(I)
       DHDZST(I)=DHDZST(I)*VBAR/U(I)
   88 CONTINUE
  157 CONTINUE
      DO  90  I=1,NCHANL
   90 BHSTAR(I)=HSTAR(I)+DHDZST(I)*DZSTAR
      DO  91 I=1,NCHANL
      ENTHAL(I)=(BHSTAR(I)*DROD*QTPBAR/(GBAR*12.0))+HIN
   91 CONTINUE
      IPART=2
      FLOSUM=0.0
      CALL PROP(IPART)
      CALL  RUMBA
      DO 310 IJ=1,NOITER
      CALL HYDRO
      DO 315 I=1,NCHANL
  315 DHDZST(I)=DHDZST(I)*U(I)/VBAR
      VBAR=GBAR/RHAVG
      DO 316 I=1,NCHANL
      DHDZST(I)=DHDZST(I)*VBAR/V(I)
      BHSTAR(I)=DHDZST(I)*DZSTAR+HSTAR(I)
  316 ENTHAL(I)=(BHSTAR(I)*DROD*QTPBAR/(GBAR*12.0))+HIN
      CALL PROP(IPART)
      DO 320 I=1,NCHANL
      U(I)=V(I)
      FLO(I)=RHO(I)*U(I)*A(I)/144.0
  320 CONTINUE
  310 CONTINUE
      DO  1001  I=1,NCHANL
      FLOSUM=FLOSUM+FLO(I)
 1001 CONTINUE
      DO  325 I=1,NCHANL
  325 HSTAR(I)=BHSTAR(I)
      GO TO 700
  560 CONTINUE
      IPART=2
      CALL PROP(IPART)
      FLOSUM=0.0
      CALL RUMBA
      DO 710 IJ=1,NOITER
      CALL HYDRO1
      DO 715 I=1,NCHANL
  715 DHDZ(I)=DHDZ(I)*U(I)/V(I)
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      DO 716 I=1,NCHANL
  716 ENTHAL(I)=DHDZ(I)*DELZ+BENTH(I)
      CALL PROP(IPART)
      DO 720 I=1,NCHANL
      U(I)=V(I)
      FLO(I)=RHO(I)*U(I)*A(I)
  720 CONTINUE
  710 CONTINUE
      DO 730 I=1,NCHANL
      FLOSUM=FLOSUM+FLO(I)
  730 CONTINUE
  700 CONTINUE
      PRINT 321
  321 FORMAT(1X,'OUT OF ITER.LOOP FOR TEMP AT Z+DZ')
      DO 328 I=1,NCHANL
  328 PRESSU(I)=PRESSU(I)-PDOP(I)*DZSTAR*DROD/12.0
      SUM2=0.0
      DO 322 I=1,NCHANL
  322 SUM2=SUM2+ENTHAL(I)*FLO(I)
      SUM5=SUM2-SUM1
      PRINT   171,SUM2,SUM4,SUM5,SUM1,FLO(1),FLO(97),FLO(121),FLOSUM,
     1INDEX
  171 FORMAT(1X,8F13.5,I5/)
      ZSTAR=ZSTAR+DZSTAR
      IF(CHOICE.GT.1.0) GO TO 600
      DIFF=ABS(ZSTAR-XPRINT)
      IF(DIFF-0.1)92,92,26
   92 XPRINT=XPRINT+PRINT1/DROD
      ZZSTAR=ZSTAR*DROD
      PRINT 93
   93 FORMAT(1X,'AXIAL DIST. IN.      ZSTAR    AVERAGE TEMP.')
      WRITE(6,94)ZZSTAR,ZSTAR,TAVGZ
   94 FORMAT(1X,3E11.4/)
      WRITE(6,95)
   95 FORMAT(1X,'    TEMP(2)     TEMP(5)     TEMP(19)     TEMP(20)     TEMP(4
     17)     TEMP(48)     TEMP(69)     TEMP(92)    TEMP(117)')
      WRITE(6,96) TEMP(2),TEMP(5),TEMP(19),TEMP(20),TEMP(47),TEMP(48),
     1TEMP(69),TEMP(92),TEMP(117)
   96 FORMAT(1X,9F12.4/)
      PRINT 329
  329 FORMAT(1X,'FOLLOWING ARE THE CHANNEL PRESSURES IN PSF')
      PRINT 330,(PRESSU(I),I=1,NCHANL)
  330 FORMAT(1X,11F11.4)
      PRINT 311
  311 FORMAT(1X,'FOLLOWING ARE CHANNEL VELOCITIES IN FT./HR.')
      PRINT 312,(V(I),I=1,NCHANL)
  312 FORMAT(1X,11F11.4)
      PRINT 317
  317 FORMAT(1X,'FOLLOWING ARE NEW TEMPERATURES IN ITER. LOOP AT Z+DZ')
      PRINT 318,(TEMP(I),I=1,NCHANL)
  318 FORMAT(1X,10F11.4)
      ZCZ=ABS(ZSTAR-ZSTART)
      IF(ZCZ.LT.0.1) GO TO 100
      IF(CHOICE.LE.1.0) GO TO 26
  600 CONTINUE
      ZZSTAR=ZSTAR*DROD
      DIFF=ABS(ZZSTAR-PRINT2)
      IF(DIFF-0.1)601,601,26
  601 PRINT2=PRINT2+PRINT1
      PRINT 625,SUM2,SUM5,SUM1
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  625 FORMAT(1X,3F13.6)
      PRINT 626
  626 FORMAT(1X,'AXIAL DIST IN.    ZSTAR    AVG.TEMP')
      PRINT 627,ZZSTAR,ZSTAR,TAVGZ
  627 FORMAT(1X,3E11.4//)
      WRITE (6,509)(TEMP(I),I=1,NCHANL)
  509 FORMAT(8E10.4)
      ZCZ=ABS(ZSTAR-ZSTART)
      IF(ZCZ.LT.0.1) GO TO 100
      GO TO 26
  100 CONTINUE
      IF(CHOICE.LT.2.0) GO TO 160
      DO 508 I=1,NCHANL
      A(I)=A(I)*144.0
      DE(I)=DE(I)*12.0
  508 CONTINUE
      AIJ=AIJ*12.0
      DELZ=DELZ*12.0
      ETA1=ETA1*12.0
      ETA2=ETA2*12.0
      ETA3=ETA3*12.0
      ETA4=ETA4*12.0
      GAP=GAP1*12.0
  160 CONTINUE
      STOP
        END
      SUBROUTINE  GEOM
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON ENTHAL(150),TEMP(150)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN,VBAR
      COMMON RHO(150),VISCOS(150),U(150),V(150),AFRIC,BFRIC,FLOWW
      COMMON A(150),WP(150),DE(150),HPERIM(150)
      COMMON  PDOP(150)
      COMMON  KRK
      COMMON INDEX
      COMMON  LAMBAV,LAMBA1,LAMBA2,LAMBA3,LAMBL1,LAMBL2
      COMMON  AFT
C      SUBROUTINE  CALCULATES  GEOMETRY FOR  3 TYPES  OF CHANNELS
      REAL  LEADOD
      N11=N2
      N22=N3-N11
      N33=N4-N3
      SPACE=GAP
      DR=DROD
      DW=DWIRE
      P=DR*POD
      AAAA=(1.0+BFRIC)/(2.0-BFRIC)
      PPP=FLOAT(NORING)*P*1.732/2.0
      DFLAT=2.0*(PPP+DR/2.0+GAP)
      DFACE=DFLAT/1.732
      PI=3.14159
      AUNIT=1.732/4.0*P*P-PI/8.0*DR*DR-PI/8.0*DW*DW
      AWALL=P*(DR/2.0+SPACE)-PI*DR*DR/8.0-PI*DW*DW/8.0
      ACORN=2.0*(0.5*(DR/2.0+SPACE)*(DFACE-P*NORING)*0.5-PI*DR*DR/48.0
     1)-PI*DW*DW/24.0
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      WPUNIT=(PI/2.0)*DR+0.5*PI*DW
      WPWALL=P+WPUNIT
      WPCORN=(PI/6.0)*DR+(PI/6.0)*DW+2.0*(DFACE-P*NORING)*0.5
      DEUNIT=4.0*AUNIT/WPUNIT
      DEWALL=4.0*AWALL/WPWALL
      DECORN=4.0*ACORN/WPCORN
      HPUNIT=(PI/2.0)*DR
      HPWALL=(PI/2.0)*DR
      HPCORN=(PI/6.0)*DR
      AFT=N11*AUNIT+N22*AWALL+N33*ACORN
      XX1=AFT/(N11*AUNIT+N22*AWALL*((DEWALL/DEUNIT)**AAAA )+N33*ACORN*
     1((DECORN/DEUNIT)**AAAA ))
      XX2=AFT/(N11*AUNIT*((DEUNIT/DEWALL)**AAAA )+N22*AWALL+N33*ACORN*
     1((DECORN/DEWALL)**AAAA ))
      XX3=AFT/(N11*AUNIT*((DEUNIT/DECORN)**AAAA )+N22*AWALL*((DEWALL/
     1DECORN)**AAAA )+N33*ACORN)
      VEL1=1.0/XX1
      VEL2=1.0/XX2
      VEL3=1.0/XX3
      RETURN
      END
      SUBROUTINE  CURVE(FX,X,F,Y,N,J,ISAVE)
      DIMENSION  F(60),Y(60)
      GO TO(10,50),ISAVE
   10 DO 20 KK=1,N
      IF(X-Y(KK))30,15,20
   15 IF(KK.EQ.N) GO TO 40
   20 CONTINUE
      GO TO 60
   30 IF(KK.EQ.1) GO TO 60
   40 B=(X-Y(KK-1))/(Y(KK)-Y(KK-1))
   50 FX=F(KK-1)+B*(F(KK)-F(KK-1))
      RETURN
   60 PRINT 61
   61 FORMAT(1X,'PROG.STOPPED IN CURVE')
      J=2
      RETURN
      END
         SUBROUTINE  PROP(IPART)
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON ENTHAL(150),TEMP(150)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN,VBAR
      COMMON RHO(150),VISCOS(150),U(150),V(150),AFRIC,BFRIC,FLOWW
      COMMON A(150),WP(150),DE(150),HPERIM(150)
      COMMON  PDOP(150)
      COMMON  KRK
      COMMON INDEX
      COMMON  LAMBAV,LAMBA1,LAMBA2,LAMBA3,LAMBL1,LAMBL2
      COMMON  AFT
      REAL  KKF
      GO TO (10,100),IPART
C     PART 1  CALCUL. OF SATURATED PROPERTIES
   10 DO 11 I=1,NODATA
      IF(PREF .LT. PP(I)) GO TO 20
   11 CONTINUE
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      GO TO 300
   20 IF(I.GT.1) GO TO 40
      GO TO 300
   40 VALUE=(PREF-PP(I-1))/(PP(I)-PP(I-1))
      HSAT=HHF(I-1)+VALUE*(HHF(I)-HHF(I-1))
      HVSAT=HHG(I-1)+VALUE*(HHG(I)-HHG(I-1))
      RHSAT=RHOFF(I-1)+VALUE*(RHOFF(I)-RHOFF(I-1))
      RHVSAT=RHOGG(I-1)+VALUE*(RHOGG(I)-RHOGG(I-1))
      VISSAT=UUF(I-1)+VALUE*(UUF(I)-UUF(I-1))
      TSAT=TT(I-1)+VALUE*(TT(I)-TT(I-1))
      CONSAT=KKF(I-1)+VALUE*(KKF(I)-KKF(I-1))
      SIGSAT=SSIGMA(I-1)+VALUE*(SSIGMA(I)-SSIGMA(I-1))
      RETURN
C      PART2  CAL3ULATE PROPERTIES AT LOCAL CONDIT.
  100 CONTINUE
      DO 110 I=1,NCHANL
      TEMP(I)=TSAT
      IF(ENTHAL(I).GT.HSAT)GO TO 300
      CALL CURVE(TEMP(I),ENTHAL(I),TT,HHF,NODATA,IERROR,1)
  110 CONTINUE
      SUMM1=0.0
      DO 111 I=1,NCHANL
      SUMM1=SUMM1+V(I)*TEMP(I)*A(I)/144.0
  111 CONTINUE
      SUMM2=0
      DO 112 I=1,NCHANL
      SUMM2=SUMM2+V(I)*A(I)/144.0
  112 CONTINUE
      TAVGZ=SUMM1/SUMM2
C     NOW CALCULCATE  CONDUCTIVITY CP  DENSITY
      CPAVG=0.344021-(7.03539E-5)*TAVGZ+(2.68131E-8)*TAVGZ*TAVGZ
      CONAVG=54.306-(1.878E-2)*TAVGZ+(2.0914E-6)*TAVGZ*TAVGZ
      RHAVG=59.566-(7.9504E-3)*TAVGZ-(0.2872E-6)*TAVGZ*TAVGZ+(0.06035E-
     19)*TAVGZ**3
      DO 140 I=1,NCHANL
      RHO(I)=59.566  -(7.9504E-3)*(TEMP(I))-(0.2872E-6)*TEMP(I)*TEMP(I)+
     1(0.06035E-9)*TEMP(I)**3.0
      VISCOS(I)=  2.87728-(7.59499E-3)*TEMP(I)+(9.97288E-6)*TEMP(I)*TEMP
     1(I)-(6.03425E-9)*TEMP(I)*TEMP(I)*TEMP(I)+(1.34854E-12)*TEMP(I)
     2*TEMP(I)*TEMP(I)*TEMP(I)
  140 CONTINUE
      RETURN
  300 PRINT 301
  301 FORMAT(1X,'STOPPED IN PROP')
      STOP
      END
       SUBROUTINE  RUMBA
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON ENTHAL(150),TEMP(150)
      COMMON DROD,DWIRE,LEADUD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN,VBAR
      COMMON RHO(150),VISCOS(150),U(150),V(150),AFRIC,BFRIC,FLOWW
      COMMON A(150),WP(150),DE(150),HPERIM(150)
      COMMON  PDOP(150)
      COMMON  KRK
      COMMON INDEX
      COMMON  LAMBAV,LAMBA1,LAMBA2,LAMBA3,LAMBL1,LAMBL2
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```
      COMMON   AFT
      J=1
      DO 10 KK=2,NCHANL,1
      IF(TEMP(KK).GT.TEMP(J))GO TO 10
      J=KK
   10 CONTINUE
      KRK=J
      RETURN
      END
      SUBROUTINE   HYDRO1
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON ENTHAL(150),TEMP(150)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN,VBAR
      COMMON RHO(150),VISCOS(150),U(150),V(150),AFRIC,BFRIC,FLOWW
      COMMON A(150),WP(150),DE(150),HPERIM(150)
      COMMON  PDOP(150)
      COMMON  KRK
      COMMON INDEX
      COMMON  LAMBAV,LAMBA1,LAMBA2,LAMBA3,LAMBL1,LAMBL2
      COMMON  AFT
      REAL LAMBA,LAMBAV,LAMBA1,LAMBA2,LAMBA3,LAMBL1,LAMBL2
      REAL LEADOD
      DO  300 I=1,NCHANL
      IF(I.GT.N2) GO TO 310
      LAMBA=LAMBA1
      GO TO 303
  310 IF(I.GT.N3) GO TO 311
      LAMBA=LAMBA2
      GO TO 303
  311 LAMBA=LAMBA3
  303 CONTINUE
      A(I)=A(I)*LAMBA
      U(I)=U(I)/LAMBA
  300 CONTINUE
      B=BFRIC
      M=KRK
      KRK1=M-1
      KRK2=M+1
      RNO=(RHO(1)*U(1)*DE(1)/12.0)/VISCOS(1)
      INDEX=0
      RMULT1=1.034/(POD**0.124)
      RMULT2=(29.7*(POD**6.94)*(RNO**0.086))/(LEADOD**2.239)
      RMULT=(RMULT1+RMULT2)**0.885
      VH=U(M)/3600.0
      DO 10 I=1,NCHANL
      VISCOS(I)=VISCOS(I)/3600.0
   10 CONTINUE
      FLOW =FLOWW/3600.0
  110 ALPHA1=AFRIC*RMULT*(VISCOS(M)**B)*(RHO(M)**(1.0-B))*(VH**(2.0-B))
     1(64.4*(DE(M)**(1.0+B)))
      SUMM=0.0
      SUMF=0.0
      IF(KRK1.LT.1)GO TO 21
      DO 20 I=1,KRK1,1
      SUMM=SUMM+RHO(I)*A(I)*((ALPHA1+(RHO(M)-RHO(I)))**(1.0/(2.0-B)))*
```

```
  1(DE(I)**(1.0+B)*64.4/(RMULT*AFRIC*(VISCOS(I)**B)*(RHO(I)**(1.0-B))
  2))**(1.0/(2.0-B))
   SUMF=SUMF+((RHO(I)*A(I)/(2.0-B))*(ALPHA1+(RHO(M)-RHO(I)))**((B-1.
  10)/(2.0-B))*
  2((2.0-B)*(VH**(1.0-B))*ALPHA1/(VH**(2.0-B))))*
  3(DE(I)**(1.0+B)*64.4/(RMULT*AFRIC*(VISCOS(I)**B)*(RHO(I)**(1.0-B))
  4))**(1.0/(2.0-B))
20 CONTINUE
21 CONTINUE
   IF(KRK2.GT.NCHANL)GO TO 25
   DO 22 I=KRK2,NCHANL,1
   SUMM=SUMM+RHO(I)*A(I)*((ALPHA1+(RHO(M)-RHO(I)))**(1.0/(2.0-B)))*
  1(DE(I)**(1.0+B)*64.4/(RMULT*AFRIC*(VISCOS(I)**B)*(RHO(I)**(1.0-B))
  2))**(1.0/(2.0-B))
   SUMF=SUMF+((RHO(I)*A(I)/(2.0-B))*(ALPHA1+(RHO(M)-RHO(I)))**((B-1.
  10)/(2.0-B))*
  2((2.0-B)*(VH**(1.0-B))*ALPHA1/(VH**(2.0-B))))*
  3(DE(I)**(1.0+B)*64.4/(RMULT*AFRIC*(VISCOS(I)**B)*(RHO(I)**(1.0-B))
  4))**(1.0/(2.0-B))
22 CONTINUE
25 CONTINUE
   FUN=RHO(M)*A(M)*VH+SUMM-FLOH
   FUNP=RHO(M)*A(M)+SUMF
   VHNEW=VH-FUN/FUNP
   EPSIL=(VHNEW-VH)/VH
   EPSIL=ABS(EPSIL)
   INDEX=INDEX+1
   IF(EPSIL.LE.0.0005)GO TO 100
   IF(INDEX.GE.10)GO TO 90
   VH=VHNEW
   GO TO 110
90 PRINT 91
91 FORMAT(1X,'CONVERGENCE CRITERIA IS NOT SAT. IN HYDRO')
   STOP
100 V(M)=VHNEW
   VH=VHNEW
   ALPHA1=AFRIC*RMULT*(VISCOS(M)**B)*(RHO(M)**(1.0-B))*(VH**(2.0-B))/
  1(64.4*(DE(M)**(1.0+B)))
   IF(KRK1.LT.1)GO TO 150
   DO 151 I=1,KRK1,1
   V(I)=((ALPHA1+(RHO(M)-RHO(I)))*DE(I)**(1.0+B)*64.4/((VISCOS(I)**
  1B)*((RHO(I))**(1.0-B))*RMULT*AFRIC))**(1.0/(2.0-B))
151 CONTINUE
150 IF(KRK2.GT.NCHANL)GO TO 153
   DO 152 I=KRK2,NCHANL,1
   V(I)=((ALPHA1+(RHO(M)-RHO(I)))*DE(I)**(1.0+B)*64.4/((VISCOS(I)**
  1B)*((RHO(I))**(1.0-B))*RMULT*AFRIC))**(1.0/(2.0-B))
152 CONTINUE
153 CONTINUE
   DO 202 I=1,NCHANL
   REYNOL=RHO(I)*V(I)*DE(I)/VISCOS(I)
   PDOP(I)=(RMULT*(AFRIC/(REYNOL**B))*RHO(I)*V(I)*V(I)/64.4)+RHO(I)
202 CONTINUE
   DO 201 I=1,NCHANL
    VISCOS(I)=VISCOS(I)*3600.0
201 V(I)=V(I)*3600.0
   DO 330 I=1,NCHANL
   IF(I.GT.N2) GO TO 335
   LAMBA=LAMBA1
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      GO TO 331
  335 IF(I.GT.N3) GO TO 340
      LAMBA=LAMBA2
      GO TO 331
  340 LAMBA=LAMBA3
  331 CONTINUE
      A(I)=A(I)/LAMBA
      V(I)=V(I)*LAMBA
      U(I)=U(I)*LAMBA
  330 CONTINUE
      RETURN
      END
      SUBROUTINE HYDRO
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON ENTHAL(150),TEMP(150)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN,VBAR
      COMMON RHO(150),VISCOS(150),U(150),V(150),AFRIC,BFRIC,FLOWW
      COMMON A(150),WP(150),DE(150),HPERIM(150)
      COMMON  PDOP(150)
      COMMON  KRK
      COMMON INDEX
      COMMON  LAMBAV,LAMBA1,LAMBA2,LAMBA3,LAMBL1,LAMBL2
      COMMON  AFT
      REAL LEADOD
      B=BFRIC
      M=KRK
      KRK1=M-1
      KRK2=M+1
      RNO=(RHO(1)*U(1)*DE(1)/12.0)/VISCOS(1)
      INDEX=0
      RMULT1=1.034/(POD**0.124)
      RMULT2=(29.7*(POD**6.94)*(RNO**0.086))/(LEADOD**2.239)
      RMULT=(RMULT1+RMULT2)**0.885
      VH=U(M)/3600.0
      DO 10 I=1,NCHANL
      VISCOS(I)=VISCOS(I)/3600.0
      DE(I)=DE(I)/12.0
   10 A(I)=A(I)/144.0
      FLOH =FLOWW/3600.0
  110 ALPHA1=AFRIC*RMULT*(VISCOS(M)**B)*(RHO(M)**(1.0-B))*(VH**(2.0-B))/
     1(64.4*(DE(M)**(1.0+B)))
      SUMM=0.0
      SUMF=0.0
      IF(KRK1.LT.1)GO TO 21
      DO 20 I=1,KRK1,1
      SUMM=SUMM+RHO(I)*A(I)*((ALPHA1+(RHO(M)-RHO(I)))**(1.0/(2.0-B)))*
     1(DE(I)**(1.0+B)*64.4/(RMULT*AFRIC*(VISCOS(I)**B)*(RHO(I)**(1.0-B))
     2))**(1.0/(2.0-B))
      SUMF=SUMF+((RHO(I)*A(I)/(2.0-B))*(ALPHA1+(RHO(M)-RHO(I)))**((B-1.
     10)/(2.0-B))*
     2((2.0-B)*(VH**(1.0-B))*ALPHA1/(VH**(2.0-B))))*
     3(DE(I)**(1.0+B)*64.4/(RMULT*AFRIC*(VISCOS(I)**B)*(RHO(I)**(1.0-B))
     4))**(1.0/(2.0-B))
   20 CONTINUE
   21 CONTINUE
```

```
      IF(KRK2.GT.NCHANL)GO TO 25
      DO 22 I=KRK2,NCHANL,1
      SUMM=SUMM+RHO(I)*A(I)*((ALPHA1+(RHO(M)-RHO(I)))**(1.0/(2.0-B)))*
     1(DE(I)**(1.0+B)*64.4/(RMULT*AFRIC*(VISCOS(I)**B)*(RHO(I)**(1.0-B))
     2))**(1.0/(2.0-B))
      SUMF=SUMF+((RHO(I)*A(I)/(2.0-B))*(ALPHA1+(RHO(M)-RHO(I)))**((B-1.
     10)/(2.0-B))*
     2((2.0-B)*(VH**(1.0-B))*ALPHA1/(VH**(2.0-B))))*
     3(DE(I)**(1.0+B)*64.4/(RMULT*AFRIC*(VISCOS(I)**B)*(RHO(I)**(1.0-B))
     4))**(1.0/(2.0-B))
   22 CONTINUE
   25 CONTINUE
      FUN=RHO(M)*A(M)*VH+SUMM-FLOH
      FUNP=RHO(M)*A(M)+SUMF
      VHNEW=VH-FUN/FUNP
      EPSIL=(VHNEW-VH)/VH
      EPSIL=ABS(EPSIL)
      INDEX=INDEX+1
      IF(EPSIL.LE.0.0005)GO TO 100
      IF(INDEX.GE.10)GO TO 90
      VH=VHNEW
      GO TO 110
   90 PRINT 91
   91 FORMAT(1X,'CONVERGENCE CRITERIA IS NOT SAT. IN HYDRO')
      STOP
  100 V(M)=VHNEW
      VH=VHNEW
      ALPHA1=AFRIC*RMULT*(VISCOS(M)**B)*(RHO(M)**(1.0-B))*(VH**(2.0-B))/
     1(64.4*(DE(M)**(1.0+B)))
      IF(KRK1.LT.1)GO TO 150
      DO 151 I=1,KRK1,1
      V(I)=((ALPHA1+(RHO(M)-RHO(I)))*DE(I)**(1.0+B)*64.4/((VISCOS(I)**
     1B)*((RHO(I))**(1.0-B))*RMULT*AFRIC))**(1.0/(2.0-B))
  151 CONTINUE
  150 IF(KRK2.GT.NCHANL)GO TO 153
      DO 152 I=KRK2,NCHANL,1
      V(I)=((ALPHA1+(RHO(M)-RHO(I)))*DE(I)**(1.0+B)*64.4/((VISCOS(I)**
     1B)*((RHO(I))**(1.0-B))*RMULT*AFRIC))**(1.0/(2.0-B))
  152 CONTINUE
  153 CONTINUE
      DO 202 I=1,NCHANL
      REYNOL=RHO(I)*V(I)*DE(I)/VISCOS(I)
      PDOP(I)=(RMULT*(AFRIC/(REYNOL**B))*RHO(I)*V(I)*V(I)/64.4)+RHO(I)
  202 CONTINUE
      DO 201 I=1,NCHANL
       VISCOS(I)=VISCOS(I)*3600.0
      DE(I)=DE(I)*12.0
      A(I)=A(I)*144.0
  201 V(I)=V(I)*3600.0
       RETURN
      END
      SUBROUTINE   ENT1(LC,FLO,A,DE,ENTHAL,QTPR1,GBAR,AIJ,N1,N2,N3,
     1        NCHANL,RHOIN,HIN,DROD,POD,JJ,EHSTA1,EHSTA2,EHSTA3,EHSTA4,
     2  ALPSTA,ETA1,ETA2,ETA3,ETA4,C1,DELZ,GAP,DHDZ)
      DIMENSION   FLO(150),A(150),DE(150),ENTHAL(150),LC(150,3),
     1QTPRI(150),Q(150),FLR(150),DHDZ(150),ETP(150)
      IF(JJ.GT.1)GO  TO  10
      DO  5  I=1,NCHANL
       A(I)=A(I)/144.0
       DE(I)=DE(I)/12.0
```

```
      ENTHAL(I)=HIN
    5 CONTINUE
      AIJ=AIJ/12.0
      DROD1=DROD/12.0
      GBAR1=GBAR/3600.0
      DELZ=DELZ/12.0
      ETA1=ETA1/12.0
      ETA2=ETA2/12.0
      ETA3=ETA3/12.0
      ETA4=ETA4/12.0
      GAP=GAP/12.0
   10 CONTINUE
      JJ=JJ+1
      DO  12  I=1,NCHANL
      FLR(I)=FLO(I)/3600.0
      ETP(I)=ENTHAL(I)
      Q(I)=QTPRI(I)*A(I)/3600.0
   12 CONTINUE
      DO  400  I=1,NCHANL
      QT=Q(I)
      AJ=A(I)
      AM=FLR(I)
      IF(I.GT.N1)  GO  TO  35
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      EX1=      AIJ*GBAR1*(EHSTA1+ALPSTA)*(DROD1/ETA1)*(ETP(MM1)+ETP(MM2)
     1+ETP(MM3)-3.0*ETP(I))
      DHDZ(I)=(EX1+QT)/AM
      GO  TO  400
   35 CONTINUE
      IF(I.GT.N2)GO  TO  55
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      EX1=      AIJ*DROD1*GBAR1*((EHSTA1+ALPSTA)*(1.0/ETA1)*(ETP(MM1)
     1+ETP(MM2)-2.0*ETP(I))+(EHSTA2+ALPSTA)*(1.0/ETA2)*(ETP(MM3)-ETP(I))
     2)
      DHDZ(I)=(EX1+QT)/AM
      GO  TO  400
   55 CONTINUE
      IF(I.GT.N3)GO  TO  130
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      IF(MM2.GT.N3)GO TO 100
      ETASTR=ETA3
      GO  TO  101
  100 ETASTR=ETA4
  101 CONTINUE
      IF(MM3.GT.N3)GO  TO  105
      ETASTS=ETA3
      GO  TO  104
  105 ETASTS=ETA4
  104 CONTINUE
      EX1=          (GAP*(DROD1*GBAR1*(EHSTA3+ALPSTA)*(((ETP(MM2)-ETP(I))
     2/ETASTR)+((ETP(MM3)-ETP(I))/ETASTS))+C1*GBAR1*(ETP(MM2)-ETP(I)))
     3+((GBAR1*DROD1/ETA2)*(EHSTA2+ALPSTA)*AIJ*(ETP(MM1)-ETP(I))))
      DHDZ(I)=(EX1+QT)/AM
      GO  TO  400
```

```
130 CONTINUE
    MM1=LC(I,1)
    MM2=LC(I,2)
    MM3=LC(I,3)
    EX1=      GBAR1*((DROD1/ETA4)*(EHSTA4+ALPSTA)*(ETP(MM1)+ETP(MM2)
   1-2.0*ETP(I))+C1*(ETP(MM1)-ETP(I)))*GAP
    DHDZ(I)=(EX1+QT)/AM
400 CONTINUE
    DO  153  I=1,NCHANL
    ENTHAL(I)=ENTHAL(I)+DHDZ(I)*DELZ
153 CONTINUE
    RETURN
    END
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```
C     COMPUTER  PROGRAM  ENERGY  3
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON  ENTHAL(130),TEMP(130)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN
      COMMON  FLO(130),VISCOS(130)
      COMMON  CHOICE
      COMMON   AUNIT1,AWALL1,ACORN1
      COMMON   GAP1
      COMMON   AFT
      DIMENSION  AXIAL(50),FAX(50)
      DIMENSION  LC(130,4),P1(500),FRAC(130)
      DIMENSION  A(130),WP(130),DE(130),HPERIM(130)
      DIMENSION  ASTAR(130),QTPRIM(130),QSTAR(130),HSTAR(500),DHD7ST(130
     1)
      DIMENSION   MROD(130,3),SUMM(130)
      DIMENSION  V(130),RHO(130)
      DIMENSION   QTPRI(130)
      DIMENSION   ENP(50,260)
C      PROGRAM  ENERGY FOR CALCULATING TEMP. OF FLUID IN WIRE WRAP.RODS
      REAL LEADOD,LENGTH,KKF
      REAL    LAMBAV,LAMBL1,LAMBL2
      REAL  LAMBA1,LAMBA2,LAMBA3
      READ(5,1) NODATA
    1 FORMAT(I5)
      READ(5,2)(PP(I),TT(I),RHOFF(I),RHOGG(I),HHF(I),HHG(I),UUF(I),
     1KKF(I),SSIGMA(I),I=1,NODATA)
    2 FORMAT(9E8.4)
      READ (5,3) NOOFAX,NORUNS,NRUN1
    3 FORMAT(3I5)
      READ(5,4)(AXIAL(I),FAX(I),I=1,NOOFAX)
    4 FORMAT(8E10.4)
      READ(5,5) N1,N2,N3,N4,NOROD,NCHANL
    5 FORMAT(6I5)
      INDI=0
      DO 6 J=1,NCHANL
      READ 7,I,LC(I,1),LC(I,2),LC(I,3),MROD(I,1),MROD(I,2),MROD(I,3),FRA
     1C(I)
    6 CONTINUE
    7 FORMAT(I5,6I10,E10.4)
      READ(5,201)(P1(I),I=1,NOROD)
  201 FORMAT(8E10.4)
      READ  8,ETA1,ETA2,ETA3,ETA4,CHOICE,SHAPEF,DDE
    8 FORMAT(7E11.4)
      READ  9,AIJ,LEADOD,DWIRE,GAP,DELZ,CONVER,GAP1
    9 FORMAT(7E11.4)
      READ   10,DROD,LENGTH,POD,NORING,NSTEPS
   10 FORMAT(3E11.4,2I5)
      READ  12,GBAR,HIN,PREF,QBAR,RHOIN,FLOWW
   12 FORMAT(6E11.4)
      IF(CHOICE.LT.3.0)GO  TO  17
      READ  510,AUNIT1,AWALL1,ACORN1,DEUNIT,AFT,VEL1,VEL2,VEL3
  510 FORMAT(8E10.4)
      READ  511,LAMBA1,LAMBA2,LAMBA3
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  511 FORMAT(3E10.4)
      READ(5,515)(QTPRIM(I),I=1,NCHANL)
  515 FORMAT(8E10.4)
   17 CONTINUE
      DO  160 LLL=1,NORUNS
      READ 11,PRINT1,OPTION,EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
   11 FORMAT(7E11.4)
      READ   13,EHSTAC,COFRI,JMSTAR
   13 FORMAT(2E10.4,I5)
      EHSTA1=EHSTA1*DDE/DROD
      EHSTA2=EHSTA2*DDE/DROD
      EHSTA3=EHSTA3*DDE/DROD
      EHSTA4=EHSTA4*DDE/DROD
      INDC=1
C     INPUT CALCULATIONS BEGIN
      IF(CHOICE.GE.3.0)GO  TO  520
      CALL  GEOM
  520 CONTINUE
      IF(CHOICE.LT.4.0)GO  TO  999
      VEL3=VEL2
      LAMBA3=LAMBA2
  999 CONTINUE
      IF(CHOICE.LT.3.0)GO TO 16
      DEWALL=DEUNIT
      DECORN=DEUNIT
      WPUNIT=1.0
      WPWALL=1.0
      WPCORN=1.0
      HPUNIT=1.0
      HPWALL=1.0
      HPCORN=1.0
      AUNIT=AUNIT1
      AWALL=AWALL1
      ACORN=ACORN1
   16 CONTINUE
      JJ=1
      NN=N2
      PRESSU=PREF
      JJMAX=NSTEPS+1
      DO 19 I=1,N2
      A(I)=AUNIT*FRAC(I)
      WP(I)=WPUNIT*FRAC(I)
      DE(I)=DEUNIT*FRAC(I)
   19 HPERIM(I)=HPUNIT*FRAC(I)
      IF(N3-NN)140,140,141
  141 CONTINUE
      NK1=NN+1
      DO  21  I=NK1,N3,1
      A(I)=AWALL*FRAC(I)
      WP(I)=WPWALL*FRAC(I)
      DE(I)=DEWALL*FRAC(I)
   21 HPERIM(I)=HPWALL*FRAC(I)
  140 IF(N4-N3)142,142,143
  143 CONTINUE
      NK2=N3+1
      DO 22 I=NK2,N4,1
      A(I)=ACORN*FRAC(I)
      WP(I)=WPCORN*FRAC(I)
      DE(I)=DECORN*FRAC(I)
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```
   22 HPERIM(I)=HPCORN*FRAC(I)
  142 CONTINUE
      ATOTAL=0.0
      HPTOTL=0.0
      DO 25 I=1,NCHANL
      ATOTAL=A(I)+ATOTAL
   25 HPTOTL=HPTOTL+HPERIM(I)
      RHAVG=RHOIN
      LAMBAV=AFT/ATOTAL
      LAMBL1=1.0-1.0/(POD)
      LAMBL2=GAP1/GAP
      IF(CHOICE.GT.2.0)GO  TO  15
      LAMBAV=1.0
      LAMBL2=1.0
      LAMBL1=1.0
      LAMBA1=1.0
      LAMBA2=1.0
      LAMBA3=1.0
      GAP=GAP1
   15 CONTINUE
      PRESSU=PREF
      JJ=1
      IF(FLOWW.GT.0.0)GO TO 215
      GO TO 217
  215 GBAR=(FLOWW/ATOTAL)*144.0
  217 DO 170 I=1,N2
  170 FLO(I)=(A(I)/144.0)*(GBAR/VEL1)*(LAMBA1/LAMBAV)
      DO 175 I=NK1,N3,1
  175 FLO(I)=(A(I)/144.0)*(GBAR/VEL2)*(LAMBA2/LAMBAV)
      DO 176 I=NK2,N4,1
  176 FLO(I)=(A(I)/144.0)*(GBAR/VEL3)*(LAMBA3/LAMBAV)
      FLOWW=GBAR*ATOTAL/144.0
C     CALCULATE  AXIAL STEP SIZE
      ZSTART=LENGTH/DROD
      ZSTAR=0.0
      XPRINT=PRINT1/DROD
      ETA1ST=ETA1/DROD
      ETA2ST=ETA2/DROD
      ETA3ST=ETA3/DROD
      ETA4ST=ETA4/DROD
      GAPST=GAP/DROD
      DO 40 I=1,NCHANL
   40 ASTAR(I)=A(I)/(DROD*DROD)
      IF(DELZ.GT.0.0)GO  TO  315
      IF(EHSTA1.LE.0.0)EHSTA1=0.000001
      DSTARM=(ASTAR(1))*ETA1ST/(2.0*EHSTA1*OPTION*(POD-1.0))
      NNN=XPRINT/DSTARM
      IF(NNN.LT.1)NNN=1
      DZSTAR=XPRINT/(2.0*FLOAT(NNN))
      GO  TO  330
  315 DZSTAR=DELZ/DROD
  330 CONTINUE
C      CALCULATE ALL SAT PROPERTIES
      IPART=1
      CALL PROP(IPART)
C      ALL SAT PROPERTIES ARE OBTAINED
      IF(CHOICE.GE.3.0)GO  TO  147
      PROD1=0.0
      P1(500)=0.0
```

```
      DO 205 I=1,NCHANL
      DO 206 J=1,3
      M=MROD(I,J)
      PROD=P1(M)
      PROD1=PROD+PROD1
  206 CONTINUE
      SUMM(I)=PROD1
      PROD1=0.0
  205 CONTINUE
C      CALCULATE  QSTAR AND QTP/FAXL
      QTPBAR=(QBAR*HPTOTL/ATOTAL)*12.0
      DO 45 I=1,NN
      QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/3.0)*SUMM(I))
   45 CONTINUE
      IF(N3-NN)145,145,146
  146 CONTINUE
      DO 46 I=NK1,N3,1
      QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/2.0)*SUMM(I))
   46 CONTINUE
  145 IF(N4-N3)147,147,148
  148 CONTINUE
      DO 47 I=NK2,N4,1
      QTPRIM(I)=(QTPBAR*ATOTAL/(HPTOTL*A(I)))*((HPERIM(I)/1.0)*SUMM(I))
   47 CONTINUE
  147 CONTINUE
      IF(CHOICE.LT.3.0)GO  TO  550
      DO   525   I=1,NCHANL
  525 QTPRIM(I)=(QTPRIM(I)*144.0*QBAR)/A(I)
  550 CONTINUE
C      CALCULATE  QSTAR(I) BY  MULT.QTPRIM*FAXL/QTPBAR
      DO 49 I=1,NCHANL
   49 HSTAR(I)=0.0
      HSTAR(500)=0.0
C      PRINT ALL INPUYT QUANTITIES
      IF(INDI.GT.0)GO TO 97
      PRINT 30
   30 FORMAT(1X,'ENERGY WITH UNIFORM VEL. IN ALL CHAN.')
      PRINT 31
   31 FORMAT(1X,'PP(I)       TT(I)       RHOFF(I)     RHOGG(I)     HHF I    HHG
     1(I)    UUF   I    KKF   I   SIGMA')
      WRITE(6,32) (PP(I),TT(I),RHOFF(I),RHOGG(I),HHF(I),HHG(I),UUF(I),
     1KKF(I),SSIGMA(I),I=1,NODATA)
   32 FORMAT(1X,9F12.6/)
      WRITE(6,33)
   33 FORMAT(1X,'THE AXIAL DIST. AND AXIAL PEAKING RATIOS')
      WRITE(6,34) (AXIAL(I),FAX(I),I=1,NOOFAX)
   34 FORMAT(1X,8E10.4/)
      WRITE(6,110)
  110  FORMAT(1X,'N1         N2        N3          N4          NCHANL')
      WRITE(6,111) N1,N2,N3,N4,NCHANL
  111 FORMAT(1X,5I5/)
      WRITE (6,112)
  112 FORMAT(1X,'CHANNEL NO. NO. OF ADJACENT CHAN IN ASCEND. ORDER PEA
     1KING RATIOOF RODS FRACTION OF CHANN USED')
      DO 113 I=1,NCHANL
      WRITE(6,114) I,LC(I,1),LC(I,2),LC(I,3),MROD(I,1),MROD(I,2),MROD(I,
     13),FRAC(I)
  113 CONTINUE
  114 FORMAT(1X,7I10,E10.4/)
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      WRITE(6,115)
  115 FORMAT(1X,'CENTROID SPACE BETWEEN ADJ.TYPES ORF CHANNEL')
      WRITE(6,116)ETA1,ETA2,ETA3,ETA4
  116 FORMAT(1X,4E11.4/)
      WRITE(6,117)
  117 FORMAT(1X,'WWW         LEAD/DIA     DIA OF WIRE    GAP BETW. ROD -WAL')
      WRITE(6,118) WWW,LEADOD,DWIRE,GAP
  118 FORMAT(4E11.4)
      WRITE(6,120)
  120 FORMAT(1X,'ROD DIA. 2(" IN. LENGTH  IN.P/D  NO OF RINGS')
      WRITE(6,121) DROD,LENGTH,POD,NORING
  121 FORMAT(1X,3F15.6,I5)
      PRINT  127
  127 FORMAT(1X,'AREAS(I)    WETTED PERI  EQ. DIA.  HEATED PRERI.')
      DO 128 I=1,NCHANL
      WRITE(6,129) A(I),WP(I),DE(I),HPERIM(I)
  128 CONTINUE
  129 FORMAT(1X,4E11.4/)
      WRITE(6,130)
  130 FORMAT(1X,'ZSTART      ETA1ST    ETA2ST      ETA3ST     ETA4ST    GAPST
     1  DZSTAR    ')
      WRITE(6,131) ZSTART,ETA1ST,ETA2ST,ETA3ST,ETA4ST,GAPST,DZSTAR,
     1QTPBAR
  131 FORMAT(1X,8E11.4/)
      WRITE(6,202)
  202 FORMAT(1X,'ROD NO.    ROD POWER')
      DO 203 I=1,NOROD
  200 WRITE(6,204)I,P1(I)
  203 CONTINUE
  204 FORMAT(1X,I5,6X,E10.4)
      WRITE(6,210)
  210 FORMAT(1X,'VUNIT/VBAR    VWALL/VBAR    VCORNER/VBAR')
      WRITE(6,211)VEL1,VEL2,VEL3,LAMBAV,LAMBL1,LAMBL2,LAMBA1,LAMBA2,LAMB
     1A3
  211 FORMAT(1X,9E10.4)
   97 CONTINUE
      WRITE(6,122)
  122 FORMAT(1X,'AXIAL INCREM. FOR PRINT OPTION>2 EHSTA1       2    3     4
     1 COEFF FOR PERI. VEL.')
      WRITE(6,123) PRINT1,OPTION,EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
  123 FORMAT(1X,7E11.4/)
      WRITE(6,124)
  124 FORMAT(1X,'GBAR    HIN  BTU/LB. REF PRES.  AVG. HEAT FLUX VEL OPT')
      WRITE(6,125) GBAR,HIN,PREF,QBAR,OPVEL,FLOWW,A(1),A(115),DE(1),
     1ATOTAL
  125 FORMAT(1X,10E11.4/)
      WRITE(6,132)
  132 FORMAT(1X,'CHANNEL NO.  ASTAR    HEAT GEN. PER UNIT VOL/FAX')
      INDI=INDI+1
      HIN=HIN
      IPART=2
      PRINT2=PRINT1
      NDIM=2*NCHANL+1
      NORDER=NDIM
      SUM1=0.0
      DO  101 I=1,NCHANL
      ENTHAL(I)=HIN
      SUM1=SUM1+ENTHAL(I)*FLO(I)
  101 CONTINUE
```

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      SUM4=0.0
      SUM3=0.0
      CALL PROP(IPART)
C       ENTERING  MAIN LOOP
C       CALL AXIAL  PEAKING  FACTOR
   26 ZBAR=DZSTAR/2.0+ZSTAR
      ZBAR=ZBAR*DROD/LENGTH
      CALL CURVE(FAXL,ZBAR,FAX,AXIAL,NOOFAX,IERROE,1)
      IF(FAXL.GT.4.0)FAXL=4.0
      ALPSTA=12.0*CONAVG/(GBAR*CPAVG*DROD)*SHAPEF
      ALPSTA=ALPSTA*LAMBL1
      PRINT  601,FAXL,ALPSTA
  601 FORMAT(1X,2E10.4)
      IF(CHOICE.LE.1.0)GO TO 300
      DO   410  I=1,NCHANL
  410 QTPRI(I)=QTPRIM(I)*FAXL
                   CALL    BUOYAN(LC,FLO,A,DE,ENTHAL,V,RHO,VISCOS,
     1QTPRI, GBAR,AIJ,N1,N2,N3,NCHANL,RHOIN,HIN,FLOWW,DROD,POD,LEADOD,
     2PRESSU,JJ,NDIM,NORDER,EHSTA1,EHSTA2,EHSTA3,EHSTA4.ALPSTA,ETA1,
     3ETA2,ETA3,ETA4,C1,DELZ,GAP,JJMAX,CONVER,LAMBAV,LAMBL1,LAMBL2,
     4LAMBA1,LAMBA2,LAMBA3,ENP,EHSTAC,INDC,COFRI,JMSTAR)
      GO TO  301
  300 CONTINUE
      DO   76   I=1,NCHANL
   76 QSTAR(I)=QTPRIM(I)*FAXL/QTPBAR
       DO 80 I=1,N1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=QSTAR(I)+(1.0/ASTAR(I))*(EHSTA1+ALPSTA)*((POD-1.0)/ETA1S
     1T)*(HSTAR(MM1)+HSTAR(MM2)+HSTAR(MM3)-3.0*HSTAR(I))
      DHDZST(I)=DHDZST(I)*VEL1
   80 CONTINUE
       IF(N2-N1)150,150,151
  151 CONTINUE
      NK3=N1+1
      DO 81 I=NK3,N2,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=QSTAR(I)+(1.0/ASTAR(I))*((POD-1.0)*((EHSTA1+ALPSTA)/ETA1
     1ST)*(HSTAR(MM1)+HSTAR(MM2)-2.0*HSTAR(I))+((EHSTA2+ALPSTA)/ETA2ST)
     2 *(HSTAR(MM3)-HSTAR(I))*(POD-1.0))
      DHDZST(I)=DHDZST(I)*VEL1
   81 CONTINUE
  150 CONTINUE
      IF(N3-N2)155,155,156
  156 CONTINUE
      DO   85 I=NK1,N3,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      IF(MM2.GT.N3)GO TO 888
       ETASTR=ETA3ST
      GO TO 889
  888 ETASTR=ETA4ST
  889 CONTINUE
      IF(MM3.GT.N3)GO TO 890
```

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      ETASTS=ETA3ST
      GO TO 891
  890 ETASTS=ETA4ST
  891 CONTINUE
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=(1.0/ASTAR(I))*((GAPST)*((EHSTA3+ALPSTA)*(((HSTAR(MM2)-
     1HSTAR(I))/ETASTR)+((HSTAR(MM3)-HSTAR(I))/ETASTS))+C1*(HSTAR(MM2)-
     2HSTAR(I)))+(POD-1.0)*(((EHSTA2+ALPSTA)/ETA2ST)*(HSTAR(MM1)-HSTAR(I
     3))))+QSTAR(I)
      DHDZST(I)=DHDZST(I)*VEL2
   85 CONTINUE
  155 CONTINUE
      IF(N4-N3)157,157,158
  158 CONTINUE
      DO 88 I=NK2,N4,1
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      HSTAR(500)=HSTAR(I)
      DHDZST(I)=(1.0/ASTAR(I))*((GAPST)*(((EHSTA4+ALPSTA)/ETA4ST)*(HST
     1AR(MM1)+HSTAR(MM2)-2.0*HSTAR(I))+C1*(HSTAR(MM1)-HSTAR(I))))+QSTAR
     2(I)
      DHDZST(I)=DHDZST(I)*VEL3
   88 CONTINUE
  157 CONTINUE
      DO  90  I=1,NCHANL
   90 HSTAR(I)=HSTAR(I)+DHDZST(I)*DZSTAR
      DO  91 I=1,NCHANL
      ENTHAL(I)=(HSTAR(I)*DROD*QTPBAR/(GBAR*12.0))+HIN
   91 CONTINUE
  301 CONTINUE
      SUM2=0.0
      DO  320  I=1,NCHANL
      SUM2=SUM2+ENTHAL(I)*FLO(I)
  320 SUM5=SUM2-SUM1
      IPART=2
      CALL PROP(IPART)
      ZSTAR=ZSTAR+DZSTAR
      IF(CHOICE.GT.1.0)GO  TO  400
      DIFF=ABS(ZSTAR-XPRINT)
      IF(DIFF-0.1)92,92,26
   92 XPRINT=XPRINT+PRINT1/DROD
      ZZSTAR=ZSTAR*DROD
      SUM3=0.0
      SUM4=0.0
      PRINT 171,SUM2,SUM3,SUM4,SUM5,SUM1,FLO(1),FLO(27).FLO(41)
  171 FORMAT(1X,8F13.5/)
      PRINT 93
   93 FORMAT(1X,'AXIAL DIST. IN.      ZSTAR    AVERAGE TEMP.')
      WRITE(6,94)ZZSTAR,ZSTAR.TAVGZ
   94 FORMAT(1X,3E11.4/)
      WRITE(6,95)(TEMP(I),I=1,NCHANL)
   95 FORMAT(1X,10F12.4/)
      ZCZ=ABS(ZSTAR-ZSTART)
      IF(ZCZ.LT.0.1)GO  TO  100
      IF(CHOICE.LE.1.0)GO  TO  26
  400 CONTINUE
      ZZSTAR=ZSTAR*DROD
      DIFF=ABS(ZZSTAR-PRINT2)
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      IF(DIFF-0.1)401,401,26
  401 PRINT2=PRINT2+PRINT1
      PRINT  425,SUM2,SUM5,SUM1
  425 FORMAT(1X,3F13.6)
      PRINT  426
  426 FORMAT(1X,'AXIAL  DIST IN.  ZSTAR   AVG.  TEMP.')
      PRINT  427,ZZSTAR,ZSTAR,TAVGZ
  427 FORMAT(1X,3E11.4//)
      PRINT   310
  310 FORMAT(6X,'TEMP,     ENTHALPY   VELOCITY FT./SEC DENSITY  FLOW
     1PRESSURE')
      DO  305 I=1,NCHANL
      PRINT  311,I,TEMP(I),ENTHAL(I),V(I),RHO(I),FLO(I),PRESSU
  311 FORMAT(1X,I5,6F11.4/)
  305 CONTINUE
      ZCZ=ABS(ZSTAR-ZSTART)
      IF(ZCZ.LT.0.1)GO  TO  100
      GO TO 26
  100 CONTINUE
      IF(CHOICE.LT.2.0)GO  TO  160
      DO  261  I=1,NCHANL
      A(I)=A(I)*144.0
      DE(I)=DE(I)*12.0
  261 CONTINUE
      AIJ=AIJ*12.0
      DELZ=DELZ*12.0
      ETA1=ETA1*12.0
      ETA2=ETA2*12.0
      ETA3=ETA3*12.0
      ETA4=ETA4*12.0
      GAP=GAP*12.0
      IF(EHSTAC.LE.0.00001)GO  TO  160
      INDC=INDC+1
      DO  500  I=1,NCHANL
      ENP(I,JJMAX)=ENP(I,NSTEPS)
  500 CONTINUE
      IF(INDC.GT.3)GO  TO  160
      GO  TO  15
  160 CONTINUE
      STOP
        END
      SUBROUTINE  GEOM
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON  ENTHAL(130),TEMP(130)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN
      COMMON  FLO(130),VISCOS(130)
      COMMON  CHOICE
      COMMON   AUNIT1,AWALL1,ACORN1
      COMMON   GAP1
      COMMON   AFT
C      SUBROUTINE  CALCULATES  GEOMETRY FOR  3 TYPES  OF CHANNELS
      REAL  LEADOD
      N11=N2
      N22=N3-N11
      N33=N4-N3
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```
      SPACE=GAP1
      DR=DROD
      DW=DWIRE
      P=DR*POD
      PPP=FLOAT(NORING)*P*1.732/2.0
      DFLAT=2.0*(PPP+DR/2.0+GAP1)
      DFACE=DFLAT/1.732
      PI=3.14159
      AUNIT1=(1.732/4.0)*P*P
      AWALL1=P*GAP
      ACORN1=2.0*(0.5*GAP*(DFACE-P*NORING)*0.5)
      AUNIT=1.732/4.0*P*P-PI/8.0*DR*DR-PI/8.0*DW*DW
      AWALL=P*(DR/2.0+SPACE)-PI*DR*DR/8.0-PI*DW*DW/8.0
      ACORN=2.0*(0.5*(DR/2.0+SPACE)*(DFACE-P*NORING)*0.5-PI*DR*DR/48.0
     1)-PI*DW*DW/24.0
      WPUNIT=(PI/2.0)*DR+0.5*PI*DW
      WPWALL=P+WPUNIT
      WPCORN=(PI/6.0)*DR+(PI/6.0)*DW+2.0*(DFACE-P*NORING)*0.5
      DEUNIT=4.0*AUNIT/WPUNIT
      DEWALL=4.0*AWALL/WPWALL
      DECORN=4.0*ACORN/WPCORN
      HPUNIT=(PI/2.0)*DR
      HPWALL=(PI/2.0)*DR
      HPCORN=(PI/6.0)*DR
      AFT=N11*AUNIT+N22*AWALL+N33*ACORN
      XX1=AFT/(N11*AUNIT+N22*AWALL*((DEWALL/DEUNIT)**0.714)+N33*ACORN*
     1((DECORN/DEUNIT)**0.714))
      XX2=AFT/(N11*AUNIT*((DEUNIT/DEWALL)**0.714)+N22*AWALL+N33*ACORN*
     1((DECORN/DEWALL)**0.714))
      XX3=AFT/(N11*AUNIT*((DEUNIT/DECORN)**0.714)+N22*AWALL*((DEWALL/
     1DECORN)**0.714)+N33*ACORN)
      VEL1=1.0/XX1
      VEL2=1.0/XX2
      VEL3=1.0/XX3
      RETURN
      END
SUBEND

      SUBROUTINE  CURVE(FX,X,F,Y,N,J,ISAVE)
      DIMENSION  F(60),Y(60)
      GO TO(10,50),ISAVE
   10 DO 20 KK=1,N
      IF(X-Y(KK))30,15,20
   15 IF(KK.EQ.N) GO TO 40
   20 CONTINUE
      GO TO 60
   30 IF(KK.EQ.1) GO TO 60
   40 B=(X-Y(KK-1))/(Y(KK)-Y(KK-1))
   50 FX=F(KK-1)+B*(F(KK)-F(KK-1))
      RETURN
   60 PRINT 61
   61 FORMAT(1X,'PROG.STOPPED IN CURVE')
      J=2
      RETURN
      END
         SUBROUTINE  PROP(IPART)
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1UUF(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
```

```
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON  ENTHAL(130),TEMP(130)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN
      COMMON  FLO(130),VISCOS(130)
      COMMON  CHOICE
      COMMON   AUNIT1,AWALL1,ACORN1
      COMMON   GAP1
      COMMON   AFT
      REAL  KKF
      GO TO (10,100),IPART
C     PART 1  CALCUL. OF SATURATED PROPERTIES
   10 DO 11 I=1,NODATA
      IF(PREF .LT. PP(I)) GO TO 20
   11 CONTINUE
      GO TO 300
   20 IF(I.GT.1) GO TO 40
      GO TO 300
   40 VALUE=(PREF-PP(I-1))/(PP(I)-PP(I-1))
      HSAT=HHF(I-1)+VALUE*(HHF(I)-HHF(I-1))
      HVSAT=HHG(I-1)+VALUE*(HHG(I)-HHG(I-1))
      RHSAT=RHOFF(I-1)+VALUE*(RHOFF(I)-RHOFF(I-1))
      RHVSAT=RHOGG(I-1)+VALUE*(RHOGG(I)-RHOGG(I-1))
      VISSAT=UUF(I-1)+VALUE*(UUF(I)-UUF(I-1))
      TSAT=TT(I-1)+VALUE*(TT(I)-TT(I-1))
      CONSAT=KKF(I-1)+VALUE*(KKF(I)-KKF(I-1))
      SIGSAT=SSIGMA(I-1)+VALUE*(SSIGMA(I)-SSIGMA(I-1))
      RETURN
C      PART2  CALCULATE PROPERTIES AT LOCAL CONDIT.
  100 CONTINUE
      DO 110 I=1,NCHANL
      TEMP(I)=TSAT
      IF(ENTHAL(I).GT.HSAT)GO TO 300
      CALL CURVE(TEMP(I),ENTHAL(I),TT,HHF,NODATA,IERROR,1)
  110 CONTINUE
       SUMM1=0.0
      DO   111 I=1,NCHANL
       SUMM1=SUMM1+FLO(I)*TEMP(I)/RHAVG
  111 CONTINUE
       SUMM2=0.0
       DO   112 I=1,NCHANL
       SUMM2=SUMM2+FLO(I)/RHAVG
  112 CONTINUE
      TAVGZ=SUMM1/SUMM2
C     NOW CALCULCATE  CONDUCTIVITY CP  DENSITY
      CPAVG=0.344021-(7.03539E-5)*TAVGZ+(2.68131E-8)*TAVGZ*TAVGZ
      CONAVG=54.306-(1.878E-2)*TAVGZ+(2.0914E-6)*TAVGZ*TAVGZ
      RHAVG=59.566-(7.9504E-3)*TAVGZ-(0.2872E-6)*TAVGZ*TAVGZ+(0.06035E-
     19)*TAVGZ**3
      DO   140  I=1,NCHANL
      VISCOS(I)=2.87728-(7.59499E-3)*TEMP(I)+(9.97288E-6)*TEMP(I)*TEMP
     1(I)-(6.03425E-9)*TEMP(I)**3+(1.34854E-12)*TEMP(I)**4
  140 CONTINUE
      RETURN
  300 PRINT 301
  301 FORMAT(1X,'STOPPED IN PROP')
      STOP
      END
        SUBROUTINE        BUOYAN(LC,FLO,A,DE,ENTHAL,V,RHO,VISCOS,
     1QTPRI, GBAR,AIJ,N1,N2,N3,NCHANL,RHOIN,HIN,FLOWW,DROD,POD,LEADOD,
```

```
     2PRESSU,JJ,NDIM,NORDER,EHSTA1,EHSTA2,EHSTA3,EHSTA4,ALPSTA,ETA1,
     3ETA2,ETA3,ETA4,C1,DELZ,GAP,JJMAX,CONVER,LAMBAV,LAMBL1,LAMBL2,
     4LAMBA1,LAMBA2,LAMBA3,ENP,EHSTAC,INDC,COFRI,JMSTAR)
      REAL     LEADOD,KK,KR
      REAL    LAMBAV,LAMBL1,LAMBL2
      REAL  LAMBA1,LAMBA2,LAMBA3
      REAL  LAMBA
      REAL*8  COEFF,RHS,SCALE
      DIMENSION  COEFF(85,85),RHS(85),FRICFA(130),KK(130),
     1ETP(130),VAVG(130),DELR(130),DELV(130),FLR(130),Q(130),
     2           FLO(130),A(130),DE(130),ENTHAL(130),V(130),LC(130,4),
     3RHO(130),VISCOS(130),QTPRIM(130)
      DIMENSION  REYNO(130)
      DIMENSION  SCALE(130)
      DIMENSION  QTPRI(130)
      DIMENSION   ENP(50,260)
      IDEBUG=0
      IF(JJ.LT.JMSTAR)IDEBUG=2
      IF(IDEBUG.GT.1)GO  TO  7777
      WRITE(6,8888)(FLO(I),A(I),DE(I),ENTHAL(I),V(I),RHO(I),VISCOS(I),
     1QTPRI(I),I=1,NCHANL)
 8888 FORMAT(1X,8F11.4/)
      WRITE(6,8889) HIN,JJ,NDIM,NORDER,NCHANL,EHSTA3,ALPSTA,ETA2,C1,
     1DELZ,JJMAX,GBAR,GBAR1,EHSTA1
 8889 FORMAT(1X,E10.4,I5,3I5,5E10.4,I5,3E10.4)
 7777 CONTINUE
      IF(JJ.GT.1)GO  TO  10
      DO  5  I=1,NCHANL
      A(I)=A(I)/144.0
      V(I)=FLO(I)/(RHOIN*A(I)*3600.0)
      DE(I)=DE(I)/12.0
      ENTHAL(I)=HIN
      RHO(I)=RHOIN
    5 CONTINUE
      FLOH=FLOWW/3600.0
      AIJ=AIJ/12.0
      DROD1=DROD/12.
      GBAR1=GBAR/3600.0
      PRESS=PRESSU*144.0
      DELZ=DELZ/12.0
      ETA1=ETA1/12.0
      ETA2=ETA2/12.0
      ETA3=ETA3/12.0
      ETA4=ETA4/12.0
      GAP=GAP/12.0
      NOMAX=10
   10 CONTINUE
      JJ=JJ+1
      NOITER=0
      CALL  FRICT(FRICFA,V,VISCOS,RHO,DE,POD,LEADOD,REYNO,NCHANL,
     1LAMBAV,LAMBA1,LAMBA2,LAMBA3,N2,N3,COFRI)
      DO  12  I=1,NCHANL
      KK(I)=FRICFA(I)*DELZ/DE(I)
      ETP(I)=ENTHAL(I)
      VAVG(I)=V(I)
      DELR(I)=0.0
      DELV(I)=0.0
      FLR(I)=0.0
      Q(I)=QTPRI(I)*DELZ*A(I)/3600.0
```

```
   12 CONTINUE
      IF(IDEBUG.GT.1)GO  TO  7778
      WRITE(6,8890)(KK(I),ETP(I),Q(I),I=1,NCHANL)
 8890 FORMAT(1X,9E10.4)
 7778 CONTINUE
      DHDRO=-36.33334
  250 CONTINUE
      DO  14  I=1,NDIM
      DO  13  J=1,NORDER
      COEFF(I,J)=0.0D0
   13 CONTINUE
      RHS(I)=0.0D0
   14 CONTINUE
C        ENTERING  LOOP   TO  DET  DR  DV  DP
      NMC=0
      DO  400 I=1,NCHANL
      IF(I.GT.N2)GO  TO  280
      LAMBA=LAMBA1
      GO  TO  286
  280 IF(I.GT.N3)GO  TO  281
      LAMBA=LAMBA2
      GO  TO  286
  281 LAMBA=LAMBA3
  286 CONTINUE
      NMC=NMC+1
      NNMC=2*NMC
      RO=RHO(I)
      VE=V(I)
      EN=ENTHAL(I)
      QT=Q(I)
      DR=DELR(I)
      DV=DELV(I)
      KR=KK(I)
      AJ=A(I)
      IF(NOITER)15,15,16
   15 HSTAR=EN
      VSTAR=VE
   16 CONTINUE
C   CAL.  FOR  V*  ANDH*
      IF(I.GT.N1)GO TO  35
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      ZZJ=0.0
      EX1=DELZ*AIJ*GBAR1*(EHSTA1+ALPSTA)*(DROD1/ETA1)*(ETP(MM1)+ETP(MM2)
     1+ETP(MM3)-3.0*ETP(I))
      IF(INDC.LE.1) GO  TO   301
      EX1=EX1+GBAR1*AJ*DROD1/DELZ*(EHSTAC+ALPSTA)*(ENP(I,JJ)-2.0*ETP(I)+
     1ENP(I,JJ-1))
  301 CONTINUE
      IF(NOITER.LE.0)GO TO  153
      CRSFL1=FLR(I)-FLR(MM1)
      IF(CRSFL1)17,19,21
   17 HSTAR1=ETP(I)
       VSTAR1=VAVG(I)
      GO  TO  19
   21 HSTAR1=ETP(MM1)
      VSTAR1=VAVG(MM1)
   19 CRSFL2=FLR(I)-FLR(MM2)
```

```
      IF(CRSFL2)22,24,26
   22 HSTAR2=ETP(I)
      VSTAR2=VAVG(I)
      GO  TO  24
   26 HSTAR2=ETP(MM2)
      VSTAR2=VAVG(MM2)
   24 CRSFL3=FLR(I)-FLR(MM3)
      IF(CRSFL3)27,29,31
   27 HSTAR3=ETP(I)
      VSTAR3=VAVG(I)
      GO TO  29
   31 HSTAR3=ETP(MM3)
      VSTAR3=VAVG(MM3)
   29 GO  TO  151
   35 CONTINUE
      IF(I.GT.N2)GO  TO  55
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      ZZJ=0.0
      EX1=DELZ*AIJ*DROD1*GBAR1*((EHSTA1+ALPSTA)*(1.0/ETA1)*(ETP(MM1)
     1+ETP(MM2)-2.0*ETP(I))+(EHSTA2+ALPSTA)*(1.0/ETA2)*(ETP(MM3)-ETP(I))
     2)
      IF(INDC.LE.1) GO  TO  305
      EX1=EX1+GBAR1*AJ*DROD1/DELZ*(EHSTAC+ALPSTA)*(ENP(I,JJ)-2.0*ETP(I)+
     1ENP(I,JJ-1))
  305 CONTINUE
      IF(NOITER.LE.0)GO TO  153
      CRSFL1=FLR(I)-FLR(MM1)
      IF(CRSFL1)36,38,40
   36 HSTAR1=ETP(I)
      VSTAR1=VAVG(I)
      GO  TO  38
   40 HSTAR1=ETP(MM1)
      VSTAR1=VAVG(MM1)
   38 CRSFL2=FLR(I)-FLR(MM2)
      IF(CRSFL2)91,92,93
   91 HSTAR2=ETP(I)
      VSTAR2=VAVG(I)
      GO  TO  92
   93 HSTAR2=ETP(MM2)
      VSTAR2=VAVG(MM2)
   92  CRSFL3=FLR(I)-FLR(MM3)
      IF(CRSFL3)95,96,97
   95 HSTAR3=ETP(I)
      VSTAR3=VAVG(I)
      GO  TO  96
   97 HSTAR3=ETP(MM3)
      VSTAR3=VAVG(MM3)
   96 GO  TO 151
   55 CONTINUE
      IF(I.GT.N3)GO  TO  130
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      IF(MM2.GT.N3)GO TO 100
      ETASTR=ETA3
      GO  TO  101
  100 ETASTR=ETA4
  101 CONTINUE
```

```
      IF(MM3.GT.N3)GO  TO  105
      ETASTS=ETA3
      GO  TO  104
  105 ETASTS=ETA4
  104 CONTINUE
      EX1=DELZ    *(GAP*(DROD1*GBAR1*(EHSTA3+ALPSTA)*(((ETP(MM2)-ETP(I))
     2/ETASTR)+((ETP(MM3)-ETP(I))/ETASTS))+C1*GBAR1*(ETP(MM2)-ETP(I)))
     3+((GBAR1*DROD1/ETA2)*(EHSTA2+ALPSTA)*AIJ*(ETP(MM1)-ETP(I))))
      IF(INDC.LE.1) GO  TO   307
      EX1=EX1+GBAR1*AJ*DROD1/DELZ*(EHSTAC+ALPSTA)*(ENP(I,JJ)-2.0*ETP(I)+
     1ENP(I,JJ-1))
  307 CONTINUE
      ZZJ=(-GBAR1*C1*DELZ*GAP*(VAVG(I)-VAVG(MM2))/LAMBA)
      IF(NOITER.LE.0)GO TO  153
      CRSFL1=FLR(I)-FLR(MM1)
      IF(CRSFL1)111,112,113
  111 HSTAR1=ETP(I)
      VSTAR1=VAVG(I)
      GO  TO  112
  113 HSTAR1=ETP(MM1)
      VSTAR1=VAVG(MM1)
  112 CRSFL2=FLR(I)-FLR(MM2)
      IF(CRSFL2)115,116,117
  115 HSTAR2=ETP(I)
      VSTAR2=VAVG(I)
      GO  TO  116
  117 HSTAR2=ETP(MM2)
      VSTAR2=VAVG(MM2)
  116 CRSFL3=FLR(I)-FLR(MM3)
      IF(CRSFL3)120,121,122
  120 HSTAR3=ETP(I)
      VSTAR3=VAVG(I)
      GO  TO  121
  122 HSTAR3=ETP(MM3)
      VSTAR3=VAVG(MM3)
  121 GO TO 151
  130 CONTINUE
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
      EX1=DELZ*GBAR1*((DROD1/ETA4)*(EHSTA4+ALPSTA)*(ETP(MM1)+ETP(MM2)
     1-2.0*ETP(I))+C1*(ETP(MM1)-ETP(I)))*GAP
      IF(INDC.LE.1) GO  TO   310
      EX1=EX1+GBAR1*AJ*DROD1/DELZ*(EHSTAC+ALPSTA)*(ENP(I,JJ)-2.0*ETP(I)+
     1ENP(I,JJ-1))
  310 CONTINUE
      ZZJ=(-GBAR1*C1*DELZ*GAP*(VAVG(I)-VAVG(MM2))/LAMBA)
      IF(NOITER.LE.0)GO  TO  153
      CRSFL1=FLR(I)-FLR(MM1)
      IF(CRSFL1)140,141,142
  140 HSTAR1=ETP(I)
      VSTAR1=VAVG(I)
      GO  TO  141
  142 HSTAR1=ETP(MM1)
      VSTAR1=VAVG(MM1)
  141 CRSFL2=FLR(I)-FLR(MM2)
      IF(CRSFL2)150,151,152
  150 HSTAR2=ETP(I)
      VSTAR2=VAVG(I)
```

```
      GO   TO   151
  152 HSTAR2=ETP(MM2)
      VSTAR2=VAVG(MM2)
  151 CONTINUE
      CRSFL1=ABS(CRSFL1)
      CRSFL2=ABS(CRSFL2)
      CRSFL3=ABS(CRSFL3)
      CRSSUM=CRSFL1+CRSFL2+CRSFL3
      IF(CRSSUM.LE.0.0001)GO   TO   251
      HSTAR=(CRSFL1*HSTAR1+CRSFL2*HSTAR2+CRSFL3*HSTAR3)/
     1CRSSUM
      VSTAR=(CRSFL1*VSTAR1+CRSFL2*VSTAR2+CRSFL3*VSTAR3)/CRSSUM
      GO   TO   153
  251 HSTAR=ETP(I)
      VSTAR=VAVG(I)
  153 CONTINUE
C    SETUP   OF   MATRIX   COEFF
      ZZJ=0.0
      COEFF(NNMC,NNMC-1)=(((VE+DV)*(VE+DV-VSTAR)+(1.0/16.0)*KR*((2.0*VE
     1+DV)**2))/(LAMBA*LAMBA))+32.2*DELZ/2.0
      COEFF(NNMC,NNMC)=(RO*((2.0+KR/2.0)*VE+(1.0+KR/8.0)*DV-VSTAR)/
     1(LAMBA*LAMBA))
      COEFF(NNMC-1,NNMC-1)=AJ*41.0*(VE+DV)*(DHDRO*(RO+DR)+EN-HSTAR)*10.0
      COEFF(NNMC-1,NNMC)=AJ*41.0*RO*(EN-HSTAR)   *10.0
      COEFF(NNMC,NORDER)=32.2
      COEFF(NDIM,NNMC-1)=90.0*AJ*(VE+DV)*2000.0
      COEFF(NDIM,NNMC)=90.0*AJ*RO*2000.0
      RHS(NNMC-1)=41.0*(QT+EX1) *10.0
       RHS(NNMC)=ZZJ-                                      (RO*(32.2*DELZ
     1+0.5*KR*VE*VE/(LAMBA*LAMBA)))
      IF(IDEBUG.GT.1)GO   TO   400
      PRINT   8892
 8892 FORMAT(1X,'RJ             TJ          XJ         YJ            PJ          CONT1
     1    CONT2        QT+EX        RHS737')
      WRITE(6,8893)COEFF(NNMC,NNMC-1),COEFF(NNMC,NNMC),COEFF(NNMC-1,NNMC
     1-1),    COEFF(NNMC-1,NNMC),COEFF(NNMC,NORDER),COEFF(NDIM,NNMC-1),
     2COEFF(NDIM,NNMC),RHS(NNMC-1),RHS(NNMC),QT,EX1
 8893 FORMAT(1X,11E11.4)
  400 CONTINUE
      DO    500 I3=1,NDIM
      SCALE(I3)=COEFF(I3,1)
      DO   500   J3=1,NORDER
      IF(SCALE(I3).GT.DABS(COEFF(I3,J3)))GO   TO   500
      SCALE(I3)=DABS(COEFF(I3,J3))
  500 CONTINUE
      DO   502   I3=1,NDIM
      RHS(I3)=RHS(I3)/SCALE(I3)
      DO   502   J3=1,NORDER
      COEFF(I3,J3)=COEFF(I3,J3)/SCALE(I3)
  502 CONTINUE
      CALL   RSIMQ(NDIM,NORDER,COEFF,RHS,IERR)
      WRITE(6,602)IERR
  602 FORMAT(1X,I5)
      IF(IERR.GT.0)GO TO 270
C   CHECK   FOR   CONVERGENCE
      IF(NOITER.LT.2)GO   TO   206
      NR=0
      CROSUM=0.0
      DO   200 I=1,NCHANL
```

```
      NR=NR+2
      DV=RHS(NR)
      DR=RHS(NR-1)
      IF(IDEBUG.GT.1)GO  TO  525
      PRINT   526,I,DV,DR,V(I),RHO(I),A(I)
  526 FORMAT(I5,5E10.4)
  525 CONTINUE
      CROSUM=CROSUM+A(I)*((V(I)+DV)*DR+RHO(I)*DV)
  200 CONTINUE
      PRINT  9999,CROSUM
 9999 FORMAT(1X,E11.4)
      IF(CROSUM.GT.0.00001)JMSTAR=JJ
      IF(ABS(CROSUM)-CONVER)205,205,206
  206 CONTINUE
C    CALCULATE  AVG  ENTHAL.  ETC
      NR=0
      DO  215  I=1,NCHANL
      NR=NR+2
      DR=RHS(NR-1)
      DV=RHS(NR)
      DELR(I)=DR
      DELV(I)=DV
      DELH=DHDRO*DR
      VUP=V(I)+DV
      RUP=RHO(I)+DR
      HUP=ENTHAL(I)+DELH
      ETP(I)=(HUP+ENTHAL(I))*0.5
      VAVG(I)=(VUP+V(I))*0.5
      FLR(I)=A(I)*(VUP*RUP-V(I)*RHO(I))
  215 CONTINUE
      NOITER=NOITER+1
      IF(NOITER.GE.NOMAX)GO  TO  271
      GO  TO  250
  205 CONTINUE
C    CONVERGED
      NR=0
      DO  260  I=1,NCHANL
      NR=NR+2
      DR=RHS(NR-1)
      DV=RHS(NR)
      DELH=DHDRO*DR
      V(I)=V(I)+DV
      RHO(I)=RHO(I)+DR
      ENTHAL(I)=ENTHAL(I)+DELH
      FLO(I)=RHO(I)*V(I)*A(I)*3600.0
      ENP(I,JJ-1)=ETP(I)
  260 CONTINUE
      PRESS=PRESS+RHS(NORDER)
      PRESSU=PRESS*(1.0/144)
      RETURN
  270  PRINT   272
  272 FORMAT(1X,'MATRIX  SINGULAR')
  271  PRINT  274
  274  FORMAT(1X,'MAX.  NO.  OF.ITER.  EXCEEDED')
      STOP
      END
      SUBROUTINE   FRICT(FRICFA,V,VISCOS,RHO,DE,POD,LEADOD,REYNO,NCHANL,
     1LAMBAV,LAMBA1,LAMBA2,LAMBA3,N2,N3,COFRI)
      DIMENSION  REYNO(130),FRICFA(130),V(130),VISCOS(130),RHO(130),
```

```
  1DE(130)
      REAL   LEADOD
      REAL  LAMBAV,LAMBA1,LAMBA2,LAMBA3
      REAL  LAMBA
      REYNO(1)=RHO(1)*V(1)*3600.0*(DE(1))/VISCOS(1)
    . REYNO(1)=REYNO(1)/LAMBAV
      RMULT1=1.034/(POD**0.124)
      RMULT2=(29.7*(POD**6.94)*(REYNO(1)**0.086))/(LEADOD**2.239)
      RMULT=(RMULT1+RMULT2)**0.885
      RMULT=RMULT*COFRI
      DO  1  I=1,NCHANL
      IF(I.GE.N2)GO  TO  25
      LAMBA=LAMBA1
      GO  TO  30
   25 IF(I.GE.N3)GO  TO  27
      LAMBA=LAMBA2
      GO  TO  30
   27 LAMBA=LAMBA3
   30 CONTINUE
      REYNO(I)=RHO(I)*V(I)*3600.0*(DE(I))/VISCOS(I)
      REYNO(I)=REYNO(I)/LAMBA
      IF(REYNO(I).GT.1500)GO  TO  20
      FRICFA(I)=64.0/REYNO(I)
      GO  TO  5
   20 FRICFA(I)=0.316/(REYNO(I)**0.25)
    5 FRICFA(I)=FRICFA(I)*RMULT
    1 CONTINUE
C    MAKE   CORREC   FOR   HAET   ADD.  ON   F
      RETURN
      END
      SUBROUTINE RSIMQ(NDIM, NORDER, COEFF, RHS, IERR)
C
      REAL*8  COEFF,RHS,BIGC,SAVE,TOL,DABS
      INTEGER NORDER, NDIM, I, J, K, IMAX, JP1, JJ, NM1
C
      DIMENSION COEFF(NDIM, NORDER), RHS(NORDER)
C
C   CHECK FOR ARGUMENT ERRORS.
      IF (NDIM .GE. NORDER .AND. NORDER .GT. 0) GO TO 10
      IERR = 2
      WRITE (6, 1001) NDIM, NORDER
      RETURN
C
   10 TOL=0.0D0
      IERR = 0
C
C   DO FORWARD ELIMINATION, WITH PARTIAL PIVOTING.
      DO 70 J = 1, NORDER
C
C   CHOOSE LARGEST ELEMENT REMAINING IN THIS COLUMN.
      BIGC=0.0D0
         DO 20 I = J, NORDER
      IF(DABS(BIGC) .GE.DABS(COEFF(I,J)))GO TO  20
            BIGC = COEFF(I, J)
            IMAX = I
   20    CONTINUE
C
C   IF ALL ELEMENTS HAVE MAGNITUDES LESS THAN OR EQUAL TO TOL, THEN
C   MATRIX IS SINGULAR.
      IF(DABS(BIGC) .GT. TOL) GO  TO  30
```

```
          IERR = 1                                                          RS
          WRITE (6, 1002)                                                   RS
          RETURN                                                            RS
C                                                                           RS
C   INTERCHANGE ROWS IF NECESSARY, AND DIVIDE NEW CURRENT ROW BY            RS
C   PIVOT ELEMENT.                                                          RS
   30     DO 40 K = J, NORDER                                               RS
             SAVE = COEFF(IMAX, K)                                          RS
             COEFF(IMAX, K) = COEFF(J, K)                                   RS
             COEFF(J, K) = SAVE / BIGC                                      RS
   40     CONTINUE                                                          RS
C                                                                           RS
C   DO THE SAME FOR THE RIGHT-HAND SIDE.                                    RS
          SAVE = RHS(IMAX)                                                  RS
          RHS(IMAX) = RHS(J)                                                RS
          RHS(J) = SAVE / BIGC                                              RS
C                                                                           RS
C   SUBTRACT MULTIPLES OF THIS ROW FROM ANY REMAINING ROWS TO MAKE           RS
C   LEADING COEFFICIENTS VANISH.                                            RS
          IF (J .GE. NORDER) GO TO 80                                       RS
C                                                                           RS
          JP1 = J + 1                                                       RS
          DO 60 I = JP1, NORDER                                             RS
             SAVE = COEFF(I, J)                                             RS
             DO 50 K = JP1, NORDER                                          RS
   50           COEFF(I, K) = COEFF(I, K) - SAVE * COEFF(J, K)              RS
             RHS(I) = RHS(I) - SAVE * RHS(J)                                RS
   60     CONTINUE                                                          RS
   70 CONTINUE                                                              RS
C                                                                           RS
C   NOW FIND ELEMENTS OF SOLUTION VECTOR IN REVERSE ORDER BY DIRECT         RS
C   SUBSTITUTION.                                                           RS
   80 NM1 = NORDER - 1                                                      RS
      NP1 = NORDER + 1                                                      RS
      DO 100 JJ = 1, NM1                                                    RS
         J = NORDER - JJ                                                    RS
         JP1 = J + 1                                                        RS
         DO 90 KK = 1, JJ                                                   RS
            K = NP1 - KK                                                    RS
            RHS(J) = RHS(J) - COEFF(J, K) * RHS(K)                          RS
   90    CONTINUE                                                           RS
  100 CONTINUE                                                              RS
C                                                                           RS
      RETURN                                                                RS
C                                                                           RS
 1001 FORMAT(23H RSIMQ:  ARGUMENT ERROR, 2I11)                              RS
 1002 FORMAT(32H RSIMQ:  EQUATIONS ARE SINGULAR.)                           RS
      END                                                                   RS
/*ENDDATASET
/*
// ' E KHAN    ',CLASS=A,REGION=68K
/*MITID USER=(M7514,10581,,,NECCL)
/*SRI LOW
/*MAIN CARDS=20
/*PROCESS PUNCH
/*FORMAT PU,DDNAME=DD1,COPIES=1
/*PROCESS PRINT
/*DATASET DDNAME=DD1
```

7. SAMPLE CALCULATION

The sample calculation presented is for a typical blanket assembly operating in forced convection. The geometric and operating conditions are shown in Table 1 from Ref. 6. The p/d and h/d ratios are 1.076 and 7.7 respectively. The wire-wrap in the wall channels is almost half the diameter of those in the central channels. The axial peak to average power skew is 2.06. The radial power skew is approx. 3.5:1 across flats and 6:1 across corners.

The ENERGY-I, II and III calculations were made assuming the assembly is a porous body (CHOICE = 2,2 and 3 in ENERGY I, II and III respectively). There are 126 subchannels in the assembly. Here only 42 nodes were used as shown in Fig. 6. The following pages show the results of the exit (64 in. level) temperature distribution using ENERGY I, II and III. The temperatures are identical, as expected, since at the high Reynolds number of operation of the assembly buoyancy effects are not important.

The data input used for ENERGY I, II and III for the above case is shown at the end of the listing of each of these codes. The values of the heat generation per unit volume for node I read in, were multiplied by a factor in the code, as shown below.

$$QTPRIM(I) = [QTPRIM(I)]_{\substack{Read\\In}} * \overbrace{QBAR * 144/A(I)}^{FACTOR}$$

However the user should read in the values of the actual QTPRIM(I) given by the left hand side of the above equation as this multiplication is no longer performed within the code.

One of the difficulties in making ENERGY calculations for the blanket geometry is that both ε^* and C must be determined by extrapolation from fuel geometries. Calibration of ENERGY for blanket geometries has not been made due to lack of any data. For the purpose of this analysis ε^* and C were determined by linearly extrapolating fuel assembly data. The results matched well[1,2] with THI-3D predictions. However, this was fortuitous. It is suggested that where data does not exist ε^* and C must be determined by calibration with the results of codes like COBRA[4] and THI-3D[5].

INPUT FOR ENERGY-I

```
   38
.1526E-3   540.0055.174    .326E-6 106.806 2032.78   1.0      1.0      1.0
.2366E-3   560.0055.007    .498E-6113.0750 2036.     1.0      1.0      1.0
.3606E-3   580.0054.840    .746E-6119.3276 2041.78   1.0      1.0      1.0
.5408E-3   600.0054.673    .109E-5125.5646 2045.     1.0      1.0      1.0
.7988E-3   620.0054.506    .159E-5131.7802 2048.     1.0      1.0      1.0
.1163E-2   640.0054.339    .227E-5137.9930 2052.     1.0      1.0      1.0
.1670E-2   660.0054.172    .321E-5144.1854 2055.     1.0      1.0      1.0
.2368E-2   680.0054.005    .445E-5150.3639 2059.     1.0      1.0      1.0
.3317E-2   700.0   53.839 .6181E-5156.52872063.293   1.0      1.0      1.0
.4593E-2   720.0   53.672 .8420E-5162.66052066.567   1.0      1.0      1.0
.6289E-2   740.0   53.505 .1135E-4168.81952069.716   1.0      1.0      1.0
.8521E-2   760.0   53.338 .1514E-4174.94532072.741   1.0      1.0      1.0
.1143E-1   780.0   53.171 .2001E-4181.06122075.640   1.0      1.0      1.0
.1519E-1   800.0   53.004 .2620E-4187.16472078.413   1.0      1.0      1.0
.2001E-1   820.0   52.837 .3401E-4193.25732081.061   1.0      1.0      1.0
.2612E-1   840.0   52.670 .4375E-4199.33932083.584   1.0      1.0      1.0
.3383E-1   860.0   52.503 .5592E-4205.41122085.987   1.0      1.0      1.0
.4347E-1   880.0   52.336 .7087E-4211.47332088.267   1.0      1.0      1.0
.5543E-1   900.0   52.169 .8919E-4217.52622090.427   1.0      1.0      1.0
.7018E-1   920.0   52.002 .1115E-3223.57032092.447   1.0      1.0      1.0
.8825E-1   940.0   51.835 .1384E-3229.60602094.368   1.0      1.0      1.0
.1102      960.0   51.668 .1707E-3235.63372096.176   1.0      1.0      1.0
.1368      980.0   51.501 .2094E-3241.65382097.873   1.0      1.0      1.0
.1688     1000.0   51.335 .2552E-3247.66582099.463   1.0      1.0      1.0
.2071     1020.0   51.168 .3095E-3253.67322100.948   1.0      1.0      1.0
.2527     1040.0   51.001 .3732E-3259.67322102.332   1.0      1.0      1.0
.3066     1060.0   50.834 .4478E-3265.66752103.619   1.0      1.0      1.0
.3702     1080.0   50.667 .5347E-3271.65632104.814   1.0      1.0      1.0
.4447     1100.0   50.500 .6355E-3277.64022105.919   1.0      1.0      1.0
.5317     1120.0   50.333 .7518E-3283.61952106.941   1.0      1.0      1.0
.6328     1140.0   50.166 .8855E-3289.59472107.883   1.0      1.0      1.0
.7499      1160.0 49.999 .1039E-2295.56622108.7502 1.0      1.0      1.0
.8848      1180.0 49.832 .1213E-2301.53442109.5472 1.0      1.0      1.0


1.040      1200.0 49.665 .1412E-2307.49982110.2802 1.0      1.0      1.0
1.217      1220.0 49.498 .1637E-2313.46232110.9532 1.0      1.0      1.0
1.419      1240.0 49.331 .1891E-2319.42392111.5722 1.0      1.0      1.0
1.649      1260.0 49.164 .2177E-2325.36342112.1422 1.0      1.0      1.0
100.30     2090.0 42.237 .9913E-1576.32772145.0522 1.0      1.0      1.0
   32    1     1     1
  0.0       0.1643     0.0199     0.1776     0.05585   0.2015    0.09178
 0.1222     0.3163     0.1529     0.3958     0.16727   0.5048    0.21998
 0.255      1.1313     0.2402     1.3213     0.3257    1.4945    0.3599
  0.3885    1.8881     0.41898    1.9776     0.45312   2.0417   0.4863
  0.5126    2.0617     0.535      2.0382     0.5682    1.9722    0.6016
  0.6353    1.7319    0.6685      1.2167     0.7022    1.0685    0.7356
  0.7688    0.7521      0.803      0.3890    0.6407     0.2564    0.8772
  0.9132    0.1493     0.948      0.1095     0.963     0.0860    1.0
  12    24    36    42    19    42
   1          2          6          12         1          2          3  1.0
   2          1          3          7          1          2          7  1.0
   3          2          4          8          1          6          7  1.0
   4          3          5          9          1          5          6  1.0
   5    [illegible] [illegible]    10          1          4          5  1.0
   6          1    [illegible]     11          1          3          4  1.0
   7          2          14         15         2          7         19  1.0
   8          5          16         17         5          7         17  1.0
   9    [illegible] [illegible]    19          5          6         15  1.0
   10         5    [illegible]     21          4          5         13  1.0
   11   [illegible]
```

```
12        1       13      24       2       3      9  1.0
13       12       14      36       2       8      91.0
14        7       13      25       2       8      19  1.0
15        7       16      26       7      18      191.0
16        8       15      27       7      17      181.0
17        8       18      28       6      16      171.0
18        9       17      29       6      15      16 1.0
19        9       20      30       5      14      151.0
20       10       19      31       5      13      141.0
21       10       22      32       4      12      131.0
22       11       21      33       4      11      12 1.0
23       11       24      34       3      10      11 1.0
24       12       23      35       3       9      10  1.0
25       14       37      26       8      19      500  1.0
26       15       25      38      18      19      500  1.0
27       16       38      28      17      18      500  1.0
28       17       27      39      16      17      500  1.0
29       18       39      30      15      16      500  1.0
30       19       29      40      14      15      500  1.0
31       20       40      32      13      14      500  1.0
32       21       31      41      12      13      500  1.0
33       22       41      34      11      12      500  1.0
34       23       33      42      10      11      500  1.0
35       24       42      36       9      10      500  1.0
36       13       35      37       8       9      500  1.0
37       36       25     500       8     500      500  1.0
38       26       27     500      18     500      500  1.0
39       28       29     500      16     500      500  1.0
40       30       31     500      14     500      500  1.0
41       32       33     500      12     500      500  1.0
42       34       35     500      10     500      500  1.0
1.4422   1.1322   1.4206   1.81    1.81    1.4206   1.1322
1.1322   1.4206   1.81     2.807   2.807   2.807    1.81
1.1322   1.00     1.0


0.646    0.645    1.12     0.696    2.0     1.0     0.1326
1.12     7.7      0.037    0.28     0.25    0.02
0.52     64.0     1.0757   2  256
1.0      163.9089  29.4    53960.0  53.638  29410.0
0.5431   0.3135   0.0452   0.1326   4.044   1.0     1.0
0.21364  0.3191   0.21409
0.2269   0.273    0.3332   0.334    0.2757  0.2276   0.2572
0.3881   0.26116  0.177    0.17569  0.1616  0.1964   0.298
0.4527   0.454    0.3725   0.3033   0.2006  0.1646   0.136
0.0923   0.1421   0.1952   0.2407   0.2417  0.19798  0.145
0.069    0.0576   0.0570   0.0574   0.01165 0.0282   0.0433
0.012    0.008
1.0      10.0     0-022    0.022    0.022   0.022    0.3
/*EOJ ********
```

INPUT FOR ENERGY-II

```
 38
.1526E-3  540.0055.174   .328E-6 106.806 2032.78  1.0    1.0    1.0
.2366E-3  560.0055.007   .498E-6113.0750 2036.    1.0    1.0    1.0
.3606E-3  580.0054.840   .746E-6119.3276 2041.78  1.0    1.0    1.0
.5408E-3  600.0054.673   .109E-5125.5646 2045.    1.0    1.0    1.0
.7988E-3  620.0054.506   .159E-5131.7862 2048.    1.0    1.0    1.0
.1163E-2  640.0054.339   .227E-5137.9930 2052.    1.0    1.0    1.0
.1670E-2  660.0054.172   .321E-5144.1854 2056.    1.0    1.0    1.0
.2368E-2  680.0054.005   .448E-5150.3639 2059.    1.0    1.0    1.0
.3317E-2  700.0   53.839 .6181E-5156.52872063.293 1.0    1.0    1.0
.4593E-2  720.0   53.672 .8420E-5162.68052066.567 1.0    1.0    1.0
.6289E-2  740.0   53.505 .1135E-4168.81952069.716 1.0    1.0    1.0
.8521E-2  760.0   53.338 .1514E-4174.94632072.741 1.0    1.0    1.0
.1143E-1  780.0   53.171 .2001E-4181.06122075.640 1.0    1.0    1.0
.1519E-1  800.0   53.004 .2620E-4187.16472078.413 1.0    1.0    1.0
.2001E-1  820.0   52.837 .3401E-4193.25732081.061 1.0    1.0    1.0
.2612E-1  840.0   52.670 .4378E-4199.33932083.584 1.0    1.0    1.0
.3383E-1  860.0   52.503 .5592E-4205.41122085.987 1.0    1.0    1.0
.4347E-1  880.0   52.336 .7087E-4211.47332088.267 1.0    1.0    1.0
.5543E-1  900.0   52.169 .8919E-4217.52622090.427 1.0    1.0    1.0
.7018E-1  920.0   52.002 .1115E-3223.57032092.447 1.0    1.0    1.0
.8825E-1  940.0   51.835 .1384E-3229.60602094.368 1.0    1.0    1.0
.1102     960.0   51.668 .1707E-3235.63372096.176 1.0    1.0    1.0
.1368     980.0   51.501 .2094E-3241.65382097.873 1.0    1.0    1.0
.1688    1000.0   51.335 .2552E-3247.66682099.463 1.0    1.0    1.0
.2071    1020.0   51.168 .3095E-3253.67322100.948 1.0    1.0    1.0
.2527    1040.0   51.001 .3732E-3259.67322102.332 1.0    1.0    1.0
.3066    1060.0   50.834 .4478E-3265.66752103.619 1.0    1.0    1.0
.3702    1080.0   50.667 .5347E-3271.65632104.814 1.0    1.0    1.0
.4447    1100.0   50.500 .6355E-3277.64022105.919 1.0    1.0    1.0
.5317    1120.0   50.333 .7518E-3283.61952106.941 1.0    1.0    1.0
.6328    1140.0   50.166 .8855E-3289.59472107.883 1.0    1.0    1.0
.7499     1160.0 49.999 .1039E-2295.56622108.7502 1.0    1.0    1.0
.8848     1180.0 49.832 .1213E-2301.53442109.5472 1.0    1.0    1.0
1.040     1200.0 49.665 .1412E-2307.49982110.2802 1.0    1.0    1.0
1.217     1220.0 49.498 .1637E-2313.46282110.9532 1.0    1.0    1.0
1.419     1240.0 49.331 .1891E-2319.42392111.5722 1.0    1.0    1.0
1.649     1260.0 49.164 .2177E-2325.38342112.1422 1.0    1.0    1.0
100.30    2090.0 42.237 .9913E-1576.82772145.0522 1.0    1.0    1.0
  32    1    1    5
  0.0      0.1643    0.0199    0.1776    0.05585   0.2015    0.09178   0.2538
 0.1222    0.3163    0.1529    0.3958    0.18727   0.5048    0.21998   0.7887
 0.255     1.1313    0.2902    1.3213    0.3257    1.4945    0.3599    1.7117
  0.3885   1.8881    0.41898   1.9776    0.45312   2.0417    0.4863    2.0674
  0.5126   2.0617    0.535     2.0382    0.5682    1.9722    0.6016    1.8692
  0.6353   1.7319    0.6685    1.2167    0.7022    1.0685    0.7356    0.9126
  0.7688   0.7521    0.803     0.3890    0.8407    0.2864    0.5772    0.2071
  0.9132   0.1493    0.943     0.1095    0.963     0.0860    1.0       0.0753
  12   24   36   42   19  0.316   0.25
   1       2       6      12       1       2       3   1.0
   2       1       3       7       1       2       7   1.0
```

```
   3      2      4      8      1      6      7   1.0
   4      3      5      9      1      5      6   1.0
   5      4      6     10      1      4      5   1.0
   6      1      5     11      1      3      4    1.0
   7      2     14     15      2      7     19  1.0
   8      3     16     17      6      7     17  1.0
   9      4     18     19      5      6     15  1.0
  10      5     20     21      4      5     13  1.0
  11      6     22     23      3      4     11 1.0
  12      1     13     24      2      3      9  1.0
  13     12     14     36      2      8     91.0
  14      7     13     25      2      8     19  1.0
  15      7     16     26      7     18     191.0
  16      8     15     27      7     17     181.0
  17      8     18     28      6     16     171.0
  18      9     17     29      6     15     16 1.0
  19      9     20     30      5     14     151.0
  20     10     19     31      5     13     141.0
  21     10     22     32      4     12     131.0

  27     16     38     28     17     18     500  1.0
  28     17     27     39     16     17     500  1.0
  29     18     39     30     15     16     500  1.0
  30     19     29     40     14     15     500  1.0
  31     20     40     32     13     14     500  1.0
  32     21     31     41     12     13     500  1.0
  33     22     41     34     11     12     500  1.0
  34     23     33     42     10     11     500  1.0
  35     24     42     36      9     10     500   1.0
  36     13     35     37      8      9     500  1.0
  37     36     25    500      8    500     500  1.0
  38     26     27    500     18    500     500  1.0
  39     28     29    500     16    500     500  1.0
  40     30     31    500     14    500     500  1.0
  41     32     33    500     12    500     500  1.0
  42     34     35    500     10    500     500  1.0
 1.4422   1.1322   1.4206   1.81   1.81   1.4206   1.1322   1.0
 1.1322   1.4206   1.81   2.807   2.807   2.807   1.81   1.4206
1.1322   1.00   1.0
 0.646   0.646   1.12   0.696   2.0   1.0
 1.12   7.7   0.037   0.28   0.25   0.02
 0.52   64.0   1.0767   2  256
  1.0   163.9089   29.4   53960.0   53.638   29410.0
0.5431   0.3136   0.0452   0.1326   4.044   1.0   1.0   1.0
0.21364   0.3191   0.21409
  0.2269   0.273   0.3332   0.334   0.2757   0.2276   0.2572   0.3865
 0.3881   0.26116   0.177   0.17569   0.1616   0.1964   0.298   0.3677
 0.4527   0.454   0.3725   0.3033   0.2006   0.1646   0.136   0.136
 0.0923   0.1421   0.1952   0.2407   0.2417   0.19798   0.145   0.0947
  0.069   0.0576   0.0570   0.0674   0.01165   0.0282   0.0433   0.0288
  0.012   0.008
  1.0   10.0   0.022   0.022   0.022   0.022   0.3
/*EOJ ********
```

INPUT FOR ENERGY-III

```
   38
.1526E-3   540.0055.174    .328E-6 106.806 2032.78   1.0       1.0       1.0
.2366E-3   560.0055.007    .498E-6113.0750 2036.     1.0       1.0       1.0
.3606E-3   580.0054.840    .746E-6119.3276 2041.78   1.0       1.0       1.0
.5408E-3   600.0054.673    .109E-5125.5646 2045.     1.0       1.0       1.0
.7988E-3   620.0054.506    .159E-5131.7862 2048.     1.0       1.0       1.0
.1163E-2   640.0054.339    .227E-5137.9930 2052.     1.0       1.0       1.0
.1670E-2   660.0054.172    .321E-5144.1854 2056.     1.0       1.0       1.0
.2368E-2   680.0054.005    .448E-5150.3639 2059.     1.0       1.0       1.0
.3317E-2   700.0   53.839 .6181E-5156.52872063.293   1.0       1.0       1.0
.4593E-2   720.0   53.672 .8420E-5162.68052066.567   1.0       1.0       1.0
.6289E-2   740.0   53.505 .1135E-4168.81952069.716   1.0       1.0       1.0
.8521E-2   760.0   53.338 .1514E-4174.94632072.741   1.0       1.0       1.0
.1143E-1   780.0   53.171 .2001E-4181.06122075.640   1.0       1.0       1.0
.1519E-1   800.0   53.004 .2620E-4187.16472078.413   1.0       1.0       1.0
.2001E-1   820.0   52.837 .3401E-4193.25732081.061   1.0       1.0       1.0
.2612E-1   840.0   52.670 .4378E-4199.33932083.584    1.0      1.0      1.0
.3383E-1   860.0   52.503 .5592E-4205.41122085.987    1.0      1.0      1.0
.4347E-1   880.0   52.336 .7087E-4211.47332088.267    1.0      1.0      1.0
.5543E-1   900.0   52.169 .8919E-4217.52622090.427   1.0       1.0      1.0
.7018E-1   920.0   52.002 .1115E-3223.57032092.447   1.0       1.0      1.0
.8825E-1   940.0   51.835 .1384E-3229.60602094.368   1.0       1.0      1.0
.1102      960.0   51.668 .1707E-3235.63372096.176   1.0       1.0      1.0
.1368      980.0   51.501 .2094E-3241.65382097.873   1.0       1.0      1.0
.1688     1000.0   51.335 .2552E-3247.66682099.463   1.0       1.0      1.0
.2071     1020.0   51.168 .3095E-3253.67322100.948   1.0       1.0      1.0
.2527     1040.0   51.001 .3732E-3259.67322102.332   1.0       1.0      1.0
.3066     1060.0   50.834 .4478E-3265.66752103.619   1.0       1.0      1.0
.3702     1080.0   50.667 .5347E-3271.65632104.814   1.0       1.0      1.0
.4447     1100.0   50.500 .6355E-3277.64022105.919   1.0       1.0      1.0
.5317     1120.0   50.333 .7518E-3283.61952106.941   1.0       1.0      1.0
.6328     1140.0   50.166 .8855E-3289.59472107.883   1.0       1.0      1.0
.7499      1160.0 49.999 .1039E-2295.56622108.7502 1.0       1.0      1.0
.8848      1180.0 49.832 .1213E-2301.53442109.5472 1.0       1.0      1.0
1.040      1200.0 49.665 .1412E-2307.49982110.2802 1.0       1.0      1.0
1.217      1220.0 49.498 .1637E-2313.46282110.9532 1.0       1.0      1.0
1.419      1240.0 49.331 .1891E-2319.42392111.5722 1.0       1.0      1.0
1.649      1260.0 49.164 .2177E-2325.38342112.1422 1.0       1.0      1.0
100.30     2090.0 42.237 .9913E-1576.82772145.0522 1.0       1.0      1.0
   32      1      1     5
  0.0         0.1643      0.0199      0.1776      0.05585   0.2015     0.09178    0.2535
 0.1222       0.3163      0.1529      0.3958      0.18727   0.5046     0.21998    0.7887
 0.255        1.1313      0.2902      1.3213      0.3257     1.4445    0.3599      1.7[illegible]
  0.3885       1.8881     0.41898     1.9776      0.45312   2.0417    0.4853      2.667[illegible]
  0.5126       2.0617     0.535       2.0382      0.5682     1.9722    0.6016      [illegible]
  0.6353       1.7319    0.6685       1.2107      0.7022     1.0685    0.7356      0.9126
  0.7588       0.7521      0.803       0.3890      0.9407     0.2864    0.9777      [illegible]71
  0.9132       0.1493     0.948       0.1095      0.963      0.0860     1.0        [illegible]
   12    24    36    42    19  0.316      0.25
    1           2           6           12          1           2          3   1.0
    2         . 1           3           7           1           2          7   1.0
```

```
   3        2        4        8        1        6        7  1.0
   4        3        5        9        1        5        6  1.0
   5        4        6       10        1        4        5  1.0
   6        1        5       11        1        3        4  1.0
   7        2       14       15        2        7       19  1.0
   8        3       16       17        6        7       17  1.0
   9        4       18       19        5        6       15  1.0
  10        5       20       21        4        5       13  1.0
  11        6       22       23        3        4       11 1.0
  12        1       13       24        2        3        9  1.0
  13       12       14       36        2        8       91.0
  14        7       13       25        2        8       19  1.0
  15        7       16       26        7       18       191.0
  16        8       15       27        7       17       181.0
  17        8       18       28        6       16       171.0
  18        9       17       29        6       15       16 1.0
  19        9       20       30        5       14       151.0
  20       10       19       31        5       13       141.0
  21       10       22       32        4       12       131.0

  27       16       38       28       17       18       500  1.0
  28       17       27       39       16       17       500  1.0
  29       18       39       30       15       16       500  1.0
  30       19       29       40       14       15       500  1.0
  31       20       40       32       13       14       500  1.0
  32       21       31       41       12       13       500  1.0
  33       22       41       34       11       12       500  1.0
  34       23       33       42       10       11       500  1.0
  35       24       42       36        9       10       500    1.0
  36       13       35       37        8        9       500  1.0
  37       36       25      500        8      500       500  1.0
  38       26       27      500       18      500       500  1.0
  39       28       29      500       16      500       500  1.0
  40       30       31      500       14      500       500  1.0
  41       32       33      500       12      500       500  1.0
  42       34       35      500       10      500       500  1.0
 1.4422    1.1322   1.4206   1.81     1.81     1.4206   1.1322    1.0
 1.1322    1.4206   1.81     2.807    2.807    2.807    1.81      1.4206
1.1322     1.00     1.0
 0.646    0.646     1.12     0.696      2.0        1.0        0'1326
 1.12       7.7     0.037     0.28      0.25       0.02
 0.52     64.0       1.0767       2  256
  1.0     163.9089    29.4    53960.0     53.638    29410.0
0.5431    0.3136   0.0452   0.1326    4.044    1.0      1.0       1.0
0.21364    0.3191   0.21409
 0.2269   0.273    0.3332   0.334    0.2757   0.2276    0.2572   0.3865
 0.3681   0.26116  0.177    0.17569  0.1616   0.1954   0.298     0.3677
 0.4527    0.454   0.3725   0.3033    0.2006   0.1646   0.136     0.136
 0.0923   0.1421   0.1952   0.2407   0.2417   0.19798  0.145     0.0947
 0.069    0.0576   0.0570   0.0674   0.01165  0.0282   0.0433    0.0283
 0.012    0.008
 1.0      10.0       0.022     0.022     0.022     0.022     0.3
/*EOJ ********
```

ENERGY I OUTPUT AT 50 in.

Temperature Distribution

```
************************************************
AXIAL DIST IN.    ZSTAR    AVG.TEMP
 0.5000E+02 0.9615E+02 0.9785E+03

 963.2635 1034.7729 1073.3245 1079.6575 1017.7659  966.3782  992.8286 1123.9583
1121.3965 1001.9243  913.1843  910.7122  894.9558  922.2805 1011.2732 1067.1682
1143.2715 1152.3523 1089.2524 1038.1648  945.8948  911.9062  879.5961  875.2661
 961.5005  866.4031  865.8765  916.1318  951.0256  971.0945  978.7278  967.6199
 933.5676  919.8469  892.5615  873.3318  871.5374  867.2234  919.3997  972.9275
 965.3670  917.3728
************************************************
```

ENERGY II OUTPUT AT 50.0 in.

Temperature Distribution

```
**************************************
AXIAL DIST IN.    ZSTAR    AVG.TEMP
 0.5000E+02 0.9615E+02 0.9797E+03

.9652E+030.1014E+040.1077E+040.1079E+040.1017E+040.9663E+030.9926E+030.1123E+04
.1127E+040.1002E+040.9143E+030.9109E+030.8952E+030.9224E+030.1011E+040.1066E+04
.1144E+040.1151E+040.1088E+040.1038E+040.9459E+030.9121E+030.8799E+030.8755E+03
.8613E+030.8667E+030.8861E+030.9162E+030.9509E+030.9709E+030.9785E+030.9674E+03
.9454E+030.9198E+030.8927E+030.8736E+030.8718E+030.8675E+030.9195E+030.9728E+03
.[illegible]63E+030.9174E+03
```

ENERGY III OUTPUT AT 50.0 in.

Temperature Distribution

[illegible]	[illegible]	[illegible]	VELOCITY FT./SEC	DENSITY	FLOW	PRESSURE
1	965.3567	237.2461	1.2036	51.6182	843.5461	24.2791
2	1014.6462	252.0654	1.2148	51.2103	844.6414	24.2791
3	1078.0342	271.0676	1.2296	50.6871	846.2354	24.2791
4	1079.3704	271.4678	1.2299	50.6762	846.2612	24.2791
5	1017.6404	252.9646	1.2154	51.1855	844.6987	24.2791
6	966.3774	237.5534	1.2038	51.6098	843.5620	24.2791
7	992.6594	245.4599	1.2099	51.3921	844.2429	24.2791
8	1123.3904	284.6323	1.2411	50.3137	847.8359	24.2791
9	1128.3381	286.1106	1.2422	50.2731	847.9236	24.2791
10	1001.8254	248.2151	1.2118	51.3162	844.3369	24.2791
11	914.4197	221.8839	1.1922	52.0410	842.3630	24.2791
12	911.7019	221.0626	1.1916	52.0635	842.3455	24.2791
13	895.0259	216.0209	1.1878	52.2023	841.8879	24.2791
14	922.1968	224.2333	1.1941	51.9762	842.6641	24.2791
15	1010.9451	250.9538	1.2145	51.2408	844.9495	24.2791
16	1066.6814	267.6682	1.2279	50.7808	846.5989	24.2791
17	1144.5005	290.9385	1.2474	50.1402	849.2170	24.2791
18	1151.5581	293.0457	1.2492	50.0821	849.4111	24.2791
19	1088.7529	274.2751	1.2329	50.5989	846.9858	24.2791
20	1037.8547	259.0295	1.2203	51.0185	845.3188	24.2791
21	945.9238	231.3914	1.1990	51.7793	842.9333	24.2791
22	912.0698	221.1738	1.1913	52.0605	842.0869	24.2791
23	[illegible]	211.7071	1.1843	52.3211	841.3379	24.2791
	[illegible]	[illegible]	1.1185	52.3251	794.6179	24.2791
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24.2791

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	861.1536	205.7609	1.7609	52.4847	724.5818	24.2791
26	866.2153	207.2952	1.7637	52.4426	725.1570	24.2791
27	885.7825	213.2234	1.7718	52.2794	726.2056	24.2791
28	916.0056	222.3632	1.7830	52.0277	727.2786	24.2791
29	950.7703	232.8520	1.7953	51.7392	728.2410	24.2791
30	970.6309	238.8336	1.8014	51.5745	728.3989	24.2791
31	978.0781	241.0753	1.8027	51.5127	728.0352	24.2791
32	966.9436	237.7238	1.7974	51.6049	727.2017	24.2791
33	945.0703	231.1341	1.7887	51.7864	726.2417	24.2791
34	919.7107	223.4829	1.7796	51.9969	725.4612	24.2791
35	893.1001	215.4380	1.7705	52.2184	724.8428	24.2791
36	872.7136	209.2648	1.8671	52.3883	766.8545	24.2791
37	870.9556	208.7319	1.1832	52.4029	70.0608	24.2791
38	867.0752	207.5557	1.1837	52.4354	70.1358	24.2791
39	919.3037	223.3599	1.1972	52.0003	70.3473	24.2791
40	972.4570	239.3833	1.2090	51.5594	70.4415	24.2791
41	965.7935	237.3776	1.2056	51.6146	70.3137	24.2791
42	917.2788	222.7480	1.1934	52.0171	70.1459	24.2791

0.5993E+000.8353E-03
0
0
0
0
0.1525E-09
0.5579E+000.8351E-03
0
0
0
0
0.4275E-10
[illegible]

REFERENCES CITED

1. E.U. Khan, "A Porous Body Model for Predicting Temperature Distributions in Wire Wrapped Fuel and Blanket Assemblies of a Liquid Metal Fast Breeder Reactor," Sc.D thesis, Department of Mechanical Engineering, Massachusetts Institute of Technology, January 1975 - also appears as E.U. Khan et al., "A Porous Body Model for Predicting Temperature Distributions in Wire Wrapped Fuel and Blanket Assemblies of a Liquid Metal Fast Breeder Reactor," Departments of Mechanical and Nuclear Eng., Massachusetts Institute of Technology, COO-2245-15TR Feb. 1975.

2. E.H. Novendstern, "Turbulent Flow Pressure Drop Model for Fuel Rod Assemblies," Nuclear Engineering and Design, Vol. 22, No. 1, ANS. 1972.

3. E. Khan, "Suggested Input to ENERGY Code," Departments of Mechanical and Nuclear Engineering, Massachusetts Institute of Technology, Report COO-2245-TR, Feb. 1975.

4. D.S. Rowe, "COBRA-IIIC - A Digital Computer Program for Steady State and Transient Thermal Hydraulic Analysis in Rod Bundle Nuclear Fuel Element," BNWL-1695, March 1973.

5. W.T. Sha, R.C. Schmitt and P.R. Huebotter, "Temperature Mapping of CRBRB Blanket Assembly Using the THI3D Computer Program," TRANS ANS, Vol. 1974

LIST OF FIGURES

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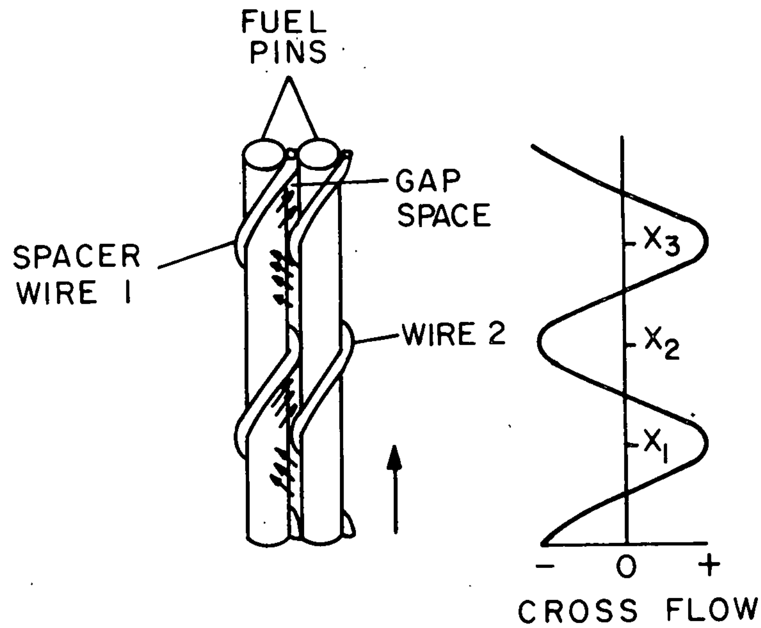

FIG. 1

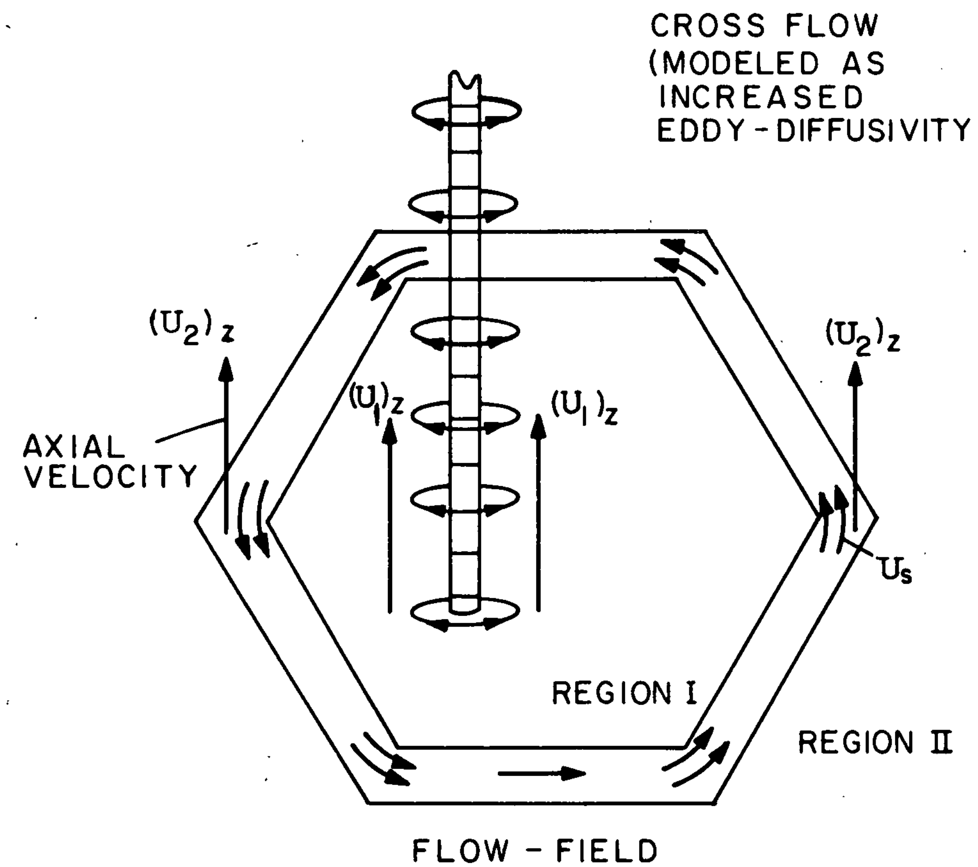
CROSS FLOW
(MODELED AS
INCREASED
EDDY - DIFFUSIVITY)
$(U_2)_z$
$(U_1)_z$
$(U_1)_z$
$(U_2)_z$
AXIAL
VELOCITY
U_s
REGION I
REGION II
FLOW - FIELD

FIG. 2

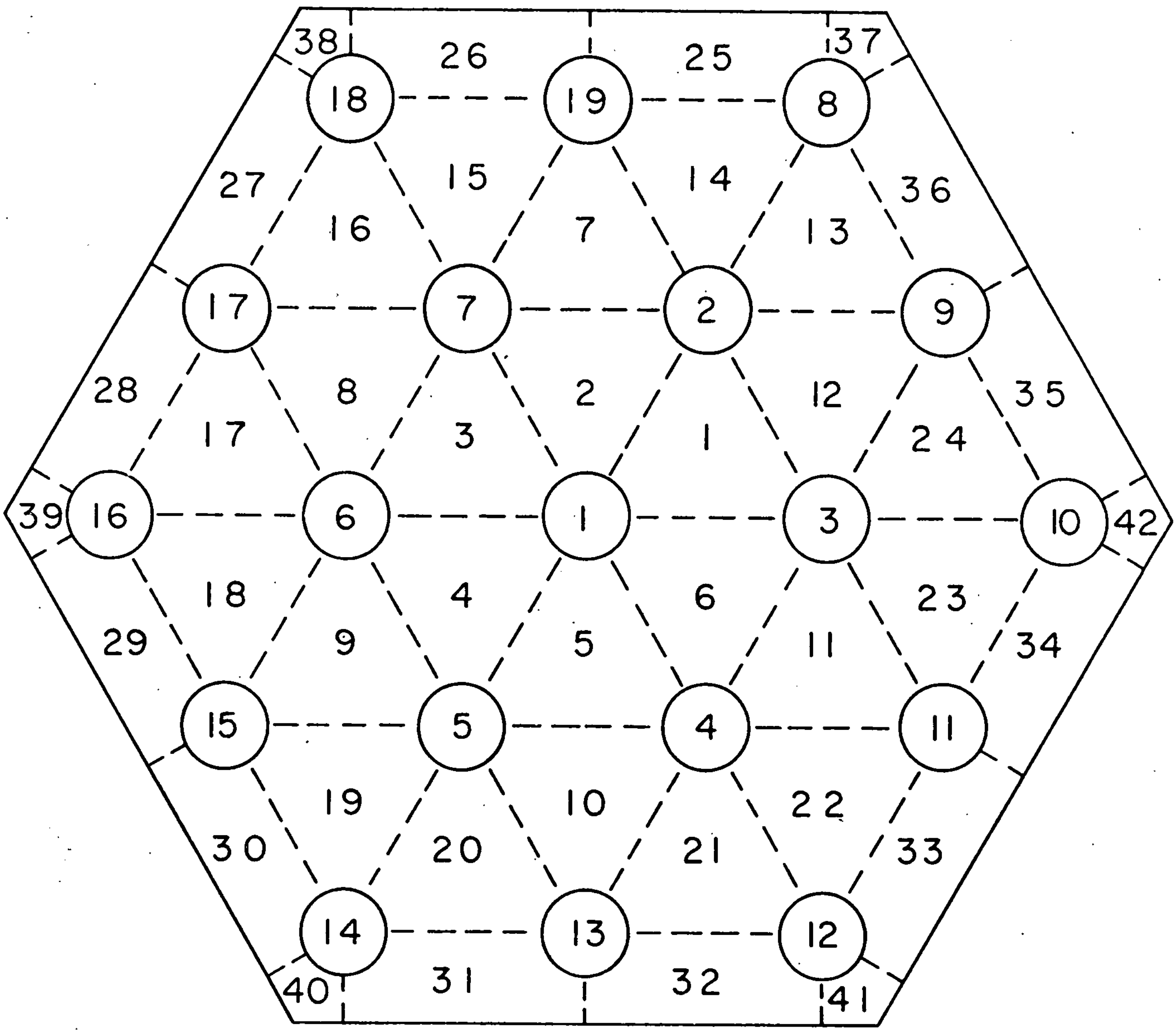

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FIG. 3

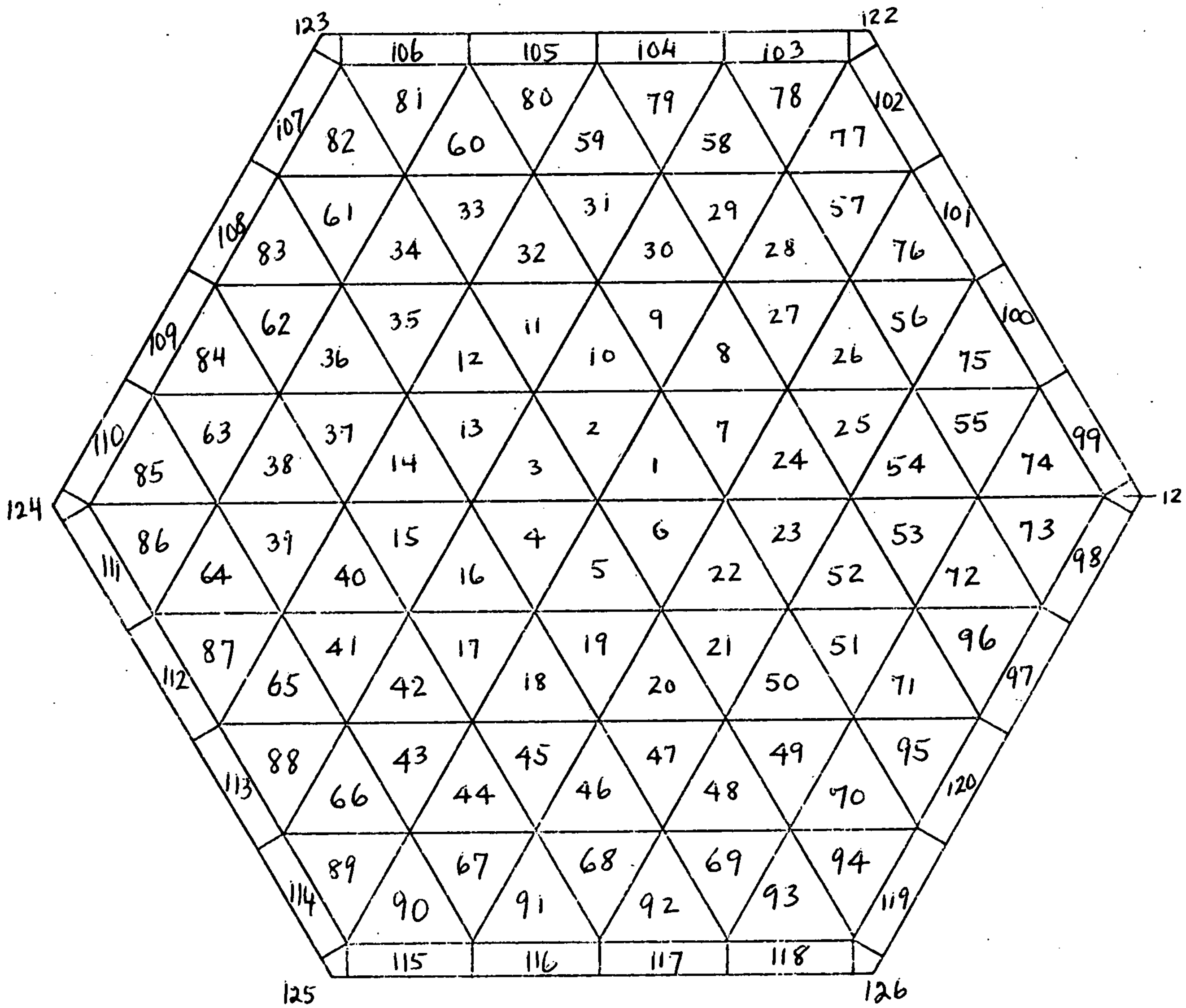
123
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FIG. 4

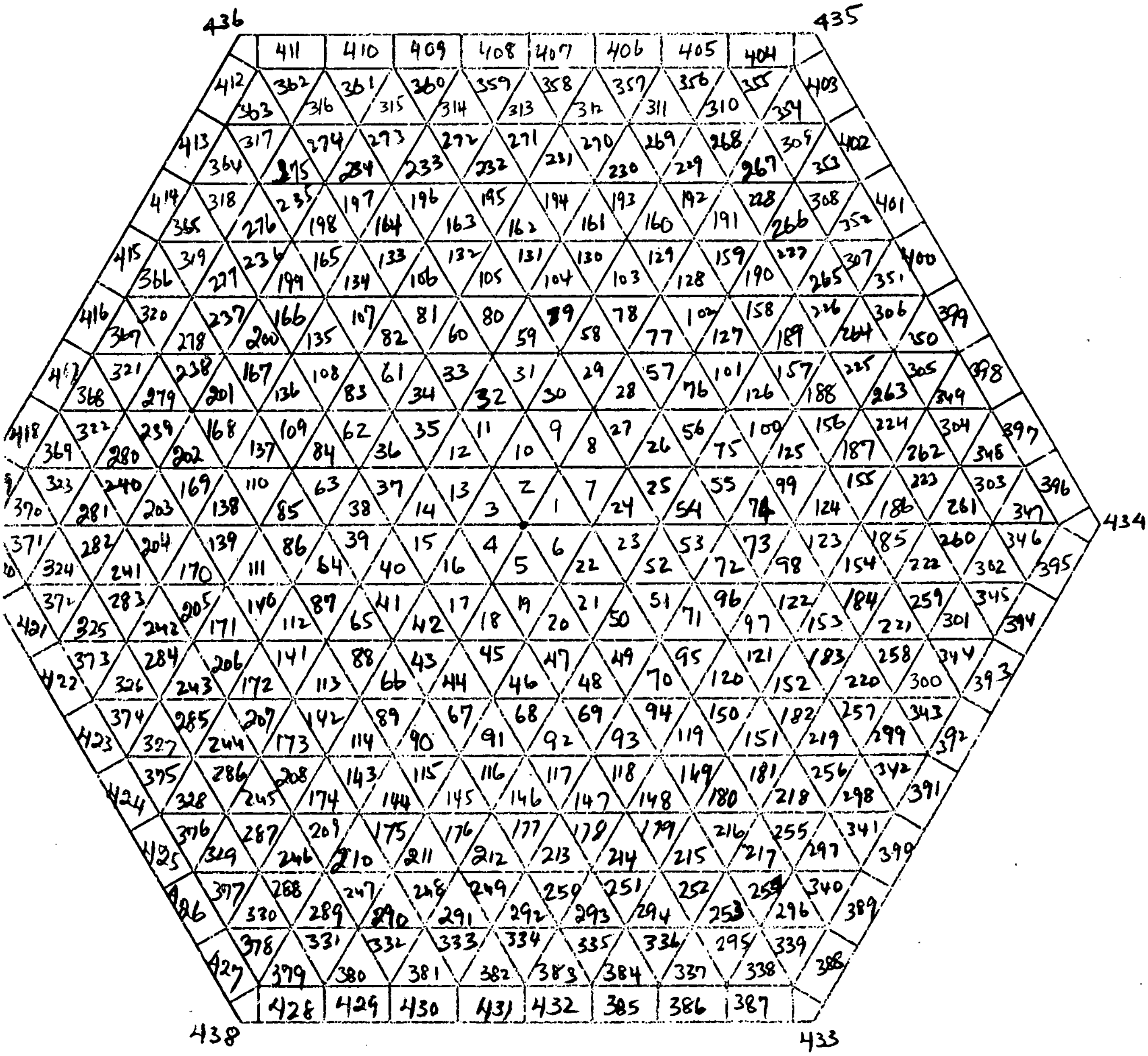

FIG. 5

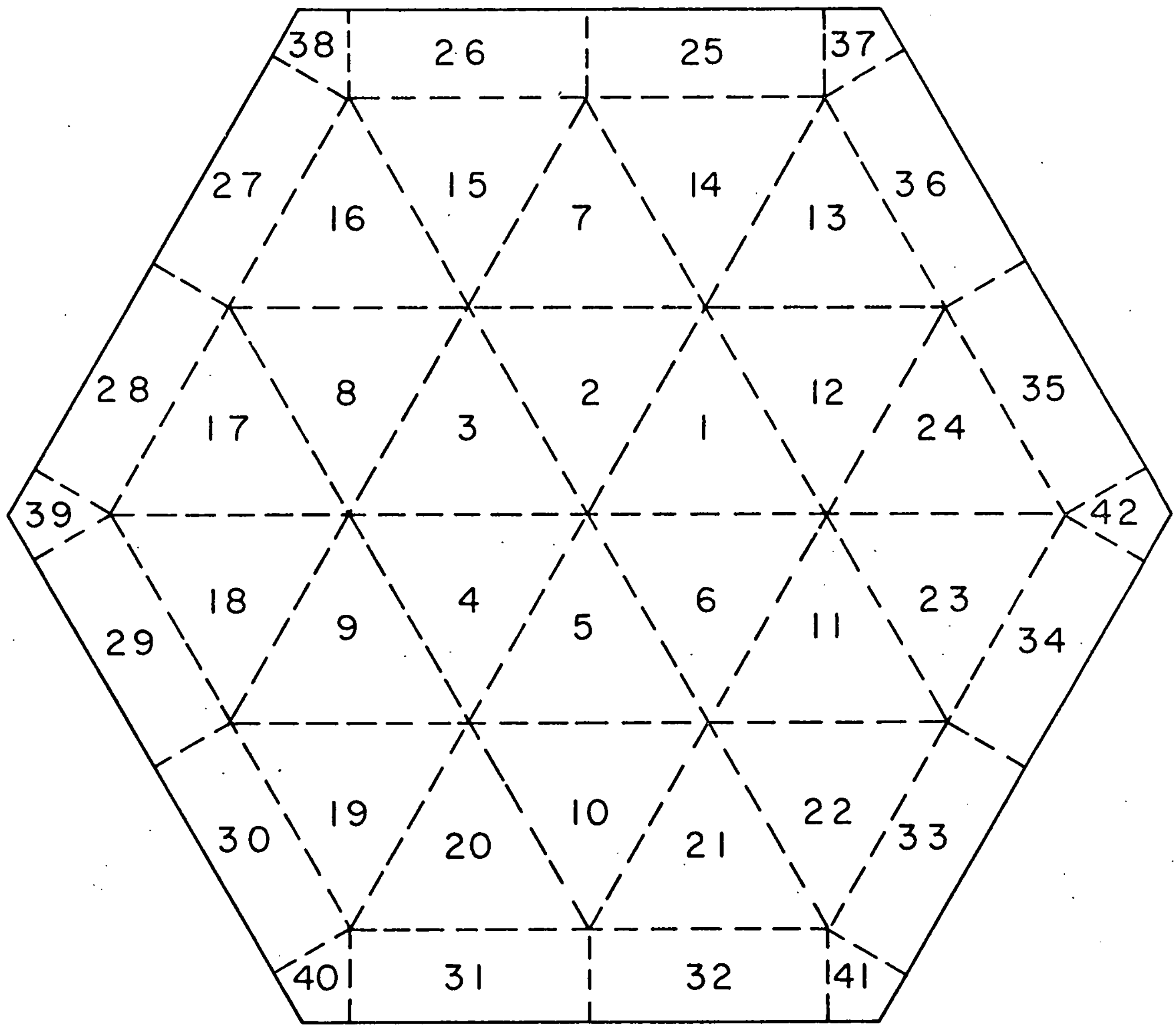
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FIG. 6

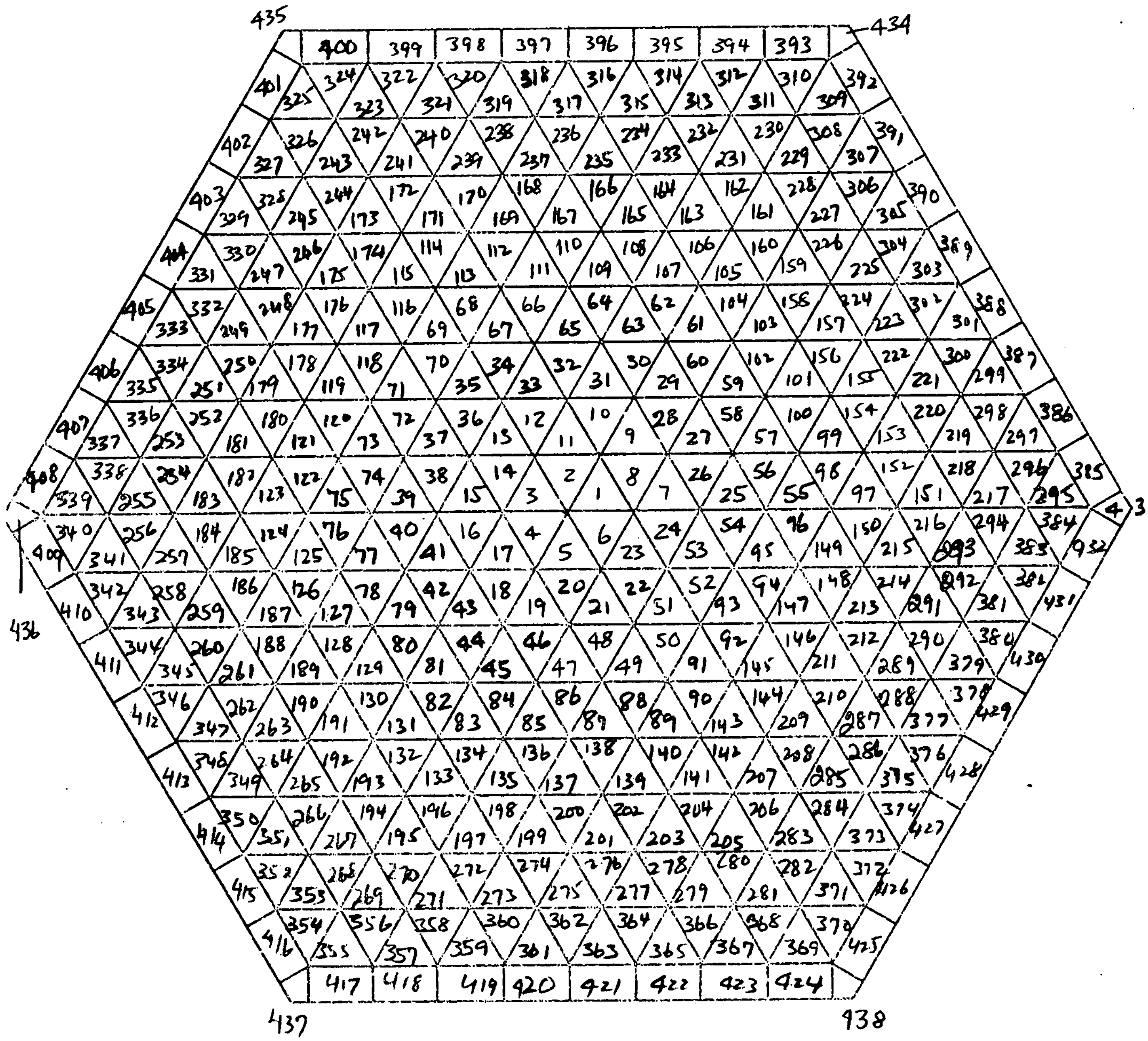


FIG. 7

Table 8[5]

Geometric and Operating Characteristics of a 61-Pin Blanket Assembly

Description	
Cladding o.d. (in.)	0.520
Cladding i.d. (in.)	0.490
Pellet o.d. (in.)	0.485
Pellet density (% of TD)	95.6
Wire-wrap o.d. (in.)	0.037[a]
Wire-wrap pitch (in.)	4.0
Rod pitch (in.)	0.560
Across hex flat (in.)	4.450
Hex corner radius (in.)	0.16
Flow rate (lb/h)	29,412
Total power [kW(th)]	700.3
Heated length (cm)	162.56
Average heat flux [Btu/(h ft^2)]	53,963
Inlet temperature (°F)	724
Outlet temperature (°F)	992
Rod-bundle average velocity (ft/sec)	5.30
Rod-bundle inlet pressure (psia)	29.4

[a]Corner rods have 0.020-in. wires; edge rods have 0.020-in. wires over 120-deg facing duct.

APPENDIX 1

THE METHOD OF NUMBERING CHANNELS FOR ENERGY GIVEN IN THIS APPENDIX WAS DEVELOPED BY B. CHEN AND F. CARRE

The present version of the ENERGY programs requires considerable amount of data input for channel layout. For example, a 217 pin assembly requires 438 cards to be read in for specifying channel layout. The method developed by Chen and Carre considerably simplifies the data input into ENERGY (both for porous body and subchannel analysis versions) and is strongly recommended. Fig. 7 shows the channel numbering scheme suggested by Chen and Carre. The ENERGY program is modified as follows.

(a) A numbering subroutine called Subroutine Numb is added to the program.

(b) As shown in the revised ENERGY-I listing, which follows, statement 41 is added to the main program to call NUMB. The only other changes are made in statements 203 to 227 which replace the corresponding statements in the previous version of ENERGY.

The results obtained by using the channel numbering method of Chen and Carre, described above, have been satisfactorily checked with the previous results for the ENERGY I S code.

CHANGES TO ENERGY I&IS FOR NEW CHANNEL NUMBERING SCHEME (CHANGES ARE MARKED BELOW)

```
C       COMMON  MAIN PROG.
        COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
       1UUF(50),KKF(50),SSIGMA(50)
        COMMCN  NCHANL,PREF,NCDATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
       1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
        COMMCN    ENTHAL(500),TEMP(500)
        COMMON DROD,DWIRE,LEACOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
       1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCURN
        COMMCN    FLO(500)
        COMMCN LC(500,3),MROD(500,3)
        COMMCN ETA1,ETA2,ETA3,ETA4
        DIMENSION   AXIAL(50),FAX(50)
        DIMENSION A(500),WP(500),DE(500),HPERIM(500)
        DIMENSION   ASTAR(500),QTPRIM(500),GSTAR(500),HSTAR(500),DHDZST(500
       1)
        DIMENSION SUMM(500),P1(500),GBARR(500),HINN(500)
C       PROGRAM  ENERGY FOR CALCULATING TEMP. OF FLUID IN WIRE WRAP.RODS
        REAL LEADOD,LENGTH,KKF
        READ(5,1) NODATA
      1 FORMAT(I5)
        READ(5,2)(PP(I),TT(I),RHOFF(I),RHOGG(I),HHF(I),HHG(I),UUF(I),
       1KKF(I),SSIGMA(I),I=1,NODATA)
      2 FORMAT(9E8.4)
        READ(5,3)NORUNS,NCRUN1,NCRUN2
      3 FORMAT(3I5)
        DO 160 LLLLL=1,NORUN2
        READ(5,1)NOOFAX
        READ(5,4)(AXIAL(I),FAX(I),I=1,NCOFAX)
      4 FORMAT(8F10.5)
        READ(5,5) NOROD
      5 FORMAT(I5)
        READ 9,WWW,LEADOD,DWIRE,GAP
      9 FORMAT(4F11.4)
        READ 10,DROD,LENGTH,POD
     10 FORMAT(3F11.4)
        Z=(NCROD-1)/3.
        NORING=SQRT(Z)
        NIMP=6*NORING
        NOTG1=6*(NORING-1)*(NORING-1)
        N1=NOTG1+6*(NORING-1)
        N2=N1+NIMP
        N3=N2+NIMP
        N4=N3+6
        NCHANL=N4
        NCHSC=2*NORING-1
C       INPUT CALCULATIONS BEGIN
        CALL NUMB <------------------------- ADDED
        CALL  GEOM
        DO 160 LLLL=1,NRUN1
        READ(5,201)(P1(I),I=1,NOROD)
    201 FORMAT(8F10.4)
        READ 12,GBAR,HIN,PREF,QBAR,FLOWW
     12 FORMAT(5F11.4)
        INDI=0
        DO  160 LLL=1,NORUNS
        READ 11,PRINT1,OPTION,EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
     11 FORMAT(7F11.4)
        DEODR=DEUNIT/DROD
```

```
      WRITE(6,210)
  210 FORMAT(1X,'VOUST/VBAR    WALL/VBAR    CORNER/VBAR')
      WRITE(6,211)VEL1,VEL2,VEL3
  211 FORMAT(1X,3E10.4)
   97 CONTINUE
      WRITE(6,122)
  122 FORMAT(1X,'AXIAL INCREM. FOR PRINT OPTION 2 EHSTA1      2     3      4
     1 COEFF FOR PERI. VEL.')
      WRITE(6,123) PRINT1,OPTION,EHSTA1,EHSTA2,EHSTA3,EHSTA4,C1
  123 FORMAT(1X,7E11.4/)
      WRITE(6,124)
  124 FORMAT(1X,'GBAR    HIN   BTU/LB. REF PRES.   AVG. HEAT FLUX VEL OPT')
      WRITE(6,125) GBAR,HIN,PREF,QBAR,OPVEL
  125 FORMAT(1X,5E11.4/)
      WRITE(6,132)
  132 FORMAT(1X,'CHANNEL NO.   ASTAR     HEAT GEN. PER UNIT VOL/FAX')
      INDI=INDI+1
      IF(OPVEL)70,70,71
   71 CALL HYDRO(V1,V2,V3)
   70  PREF=PREF
      HIN=HIN
      IPART=2
      SUM1=0.0
      DO   101 I=1,NCHANL
      ENTHAL(I)=HIN
      SUM1=SUM1+ENTHAL(I)*FLO(I)
  101 CONTINUE
      SUM4=0.0
      SUM3=0.0
      CALL PREP(IPART)
C      ENTERING  MAIN LOOP
C      CALL  AXIAL  PEAKING  FACTOR
   26 ZBAR=DZSTAR/2.0+ZSTAR
      ZBAR=ZBAR*DROD/LENGTH
      CALL CURVE(FAXL,ZBAR,FAX,AXIAL,NCOFAX,IERROE,1)
      PRINT 96,FAXL,ZBAR
   96 FORMAT(1X,2E11.4/)
      ALPSTA=12.0*CONAVG/(GBAR*CPAVG*DROD)
      DO  76   I=1,NCHANL
   76 QSTAR(I)=QTPRIM(I)*FAXL/QTPBAR
      DO 151 I=1,N2
      MM1=LC(I,1)
      MM2=LC(I,2)
      MM3=LC(I,3)
AA    HSTAR(500)=HSTAR(I)
      Z=(I-1)/6
      N=SQRT(Z)+1.0001
      IC=(I-6*N*N-1)/(2*N-1)+0.0001
```

AA

```
0211        IR=I-6*N*N-10*(2*N-1)+0.0001
0212        IF(N.EQ.NORING) GO TO 80
0213    150 EHSTAA=EHSTA1
0214        EHSTAB=EHSTA1
0215        ETAAST=ETA1ST
0216        ETABST=ETA1ST
0217        GO TO 81
0218     80 J=IR/2
0219        IF(IR.EQ.2*J) GO TO 150
0220        EHSTAA=EHSTA1
0221        EHSTAB=EHSTA2
0222        ETAAST=ETA1ST
0223        ETABST=ETA2ST
0224     81 CONTINUE
0225        DHDZST(I)=QSTAR(I)+(1.0/ASTAR(I))*((POD-1.0)*((EHSTAA+ALPST4)/ETA
           1ST)*(HSTAR(MM1)+HSTAR(MM2)-2.0*HSTAR(I))+((EHSTAB+ALPSTA)/ETABST)
           2 *(HSTAR(MM3)-HSTAR(I))*(POD-1.0))
0226        DHDZST(I)=DHDZST(I)*VEL1
0227    151 CONTINUE
0228        IF(N3-N2)155,155,156
0229    156 CONTINUE
0230        DO 85 I=NK1,N3,1
0231        MM1=LC(I,1)
0232        MM2=LC(I,2)
0233        MM3=LC(I,3)
0234        IF(MM2.GT.N3)GO TO 888
0235        ETASTR=ETA3ST
0236        GO TO 889
0237    888 ETASTR=ETA4ST
0238    889 CONTINUE
0239        IF(MM3.GT.N3)GO TO 890
0240        ETASTS=ETA3ST
0241        GO TO 891
0242    890 ETASTS=ETA4ST
0243    891 CONTINUE
0244        HSTAR(500)=HSTAR(I)
0245        DHDZST(I)=(1.0/ASTAR(I))*((GAPST)*((EHSTA[illegible]+ALPST[illegible])*(((HST[illegible]
           1HSTAR(I))/ETASTR)+((HSTAR(MM3)-HSTAR(I))/ETASTS))+[illegible]
           2HSTAR(I)))+(POD-1.0)*((( HSTA2+ALPS[illegible]
           [illegible]))))+QSTAR(I)
0246        DHDZST(I)=DHDZST(I)*VEL2
0247        [illegible]
0248        [illegible]
0249        [illegible]
```

NOTE: STATEMENTS (203 TO 227) STARTS BELOW 76 QSTAR--- AND ENDS AT 151 CØNTINUE. THIS REPLACES STATEMENTS IN THE OLDER VERSION OF ENERGY-I

WHICH STARTS BELOW 76 QSTAR--- AND WHICH ENDS AT '50 CØNTINUE.

```
      SUBROUTINE NUMB
      COMMON  PP(50),TT(50),RHOFF(50),RHOGG(50),HHF(50),HHG(50),
     1KKG(50),KKF(50),SSIGMA(50)
      COMMON  NCHANL,PREF,NODATA,HSAT,HVSAT,RHSAT,RHVSAT,VISSAT,TSAT,
     1CONSAT,SIGSAT,TAVGZ,CPAVG,CONAVG,RHAVG,N1,N2,N3,N4,VEL1,VEL2,VEL3
      COMMON    ENTHAL(500),TEMP(500)
      COMMON DROD,DWIRE,LEADOD,GAP,POD,NORING,AUNIT,AWALL,ACORN,WPUNIT,
     1WPWALL,WPCORN,DEUNIT,DEWALL,DECORN,HPUNIT,HPWALL,HPCORN
      COMMON    FLO(500)
      COMMON LC(500,3),MROD(500,3)
      COMMON ETA1,ETA2,ETA3,ETA4
C
C     SUBROUTINE FOR NUMBERING AUTOMATICALLY
C     THE SUBCHANNELS OF A HEXAGONAL FUEL BUNDLE
C
      NOTRG=6*NORING*NORING
      NOTG1=6*(NORING-1)*(NORING-1)
      NOG01=3*(NORING-1)*NORING
      LSTCH=NOTRG+6*(NORING+1)
      NFWCH=NOTRG+1
      NLWCH=LSTCH-6
C
C     TREATMENT OF TRIANGULAR SUBCHANNELS
C
      DO 7 I=1,NOTRG
      Z=(I-1)/6.
      N=SQRT(Z)+1.0001
      NOTR0=6*N*N
      NOTR1=6*(N-1)*(N-1)
      NOTR2=6*(N-2)*(N-2)
      NOT01=3*N*(N-1)
      NOT12=3*(N-1)*(N-2)
      IQ=(I-NOTR1-1)/(2*N-1)+0.0001
      IR=I-NOTR1-IQ*(2*N-1)+0.0001
      IY=1.6-1/N
      IF(I-NOTR1-1)901,902,901
  901 IF(I.EQ.NOTR0)GO TO 903
      J=IR/2
      IF(IR-J*2)905,905,904
C
C     TREATMENT OF A TRIANGULAR SUBCHANNEL
C     FACING THE INNER RING
C
  905 IZ=1.0001/(NOTR0-I)
      LC(I,1)=NOTR2+IQ*(2*N-3)+IR-1
      LC(I,2)=I-1
      LC(I,3)=I+1
      MROD(I,1)=1+NOT12+IQ*(N-1)+IR/2
      MROD(I,2)=MROD(I,1)+1-6*IZ*(N-1)
      MROD(I,3)=NOT01+IQ*N+IR/2+2
      GO TO 7
C
C     GENERAL TREATMENT OF A
C     TRIANGULAR SUBCHANNEL
C     FACING THE OUTER RING
C     (NOT FIRST OR LAST ONE OF A RING)
C
```

```
  904 LC(I,1)=I-1
      LC(I,2)=I+1
      MROD(I,1)=IY+NOT12+IQ*(N-1)+(IR+1)/2
      MROD(I,2)=1+NOT01+IQ*N+(IR+1)/2
      MROD(I,3)=MROD(I,2)+1
  908 IF(N.EQ.NORING)GO TO 906
C
C     THE THIRD ADJACENT SUBCHANNEL
C     IS A WALL SUBCHANNEL
C
      LC(I,3)=NOTR0+IQ*(2*N+1)+IR+1
      GO TO 7
C
C     THE THIRD ADJACENT SUBCHANNEL
C     IS A TRIANGULAR SUBCHANNEL
C
  906 LC(I,3)=NOTR0+IQ*N+(IR+1)/2
      GO TO 7
C
C     TREATMENT OF THE LAST SUBCHANNEL OF A RING
C
  903 LC(I,1)=NOTR1+1
      LC(I,2)=NOTR0-1
      MROD(I,1)=1+IY+NOT12
      MROD(I,2)=2+NOT01
      MROD(I,3)=1+3*N*(N+1)
      GO TO 908
C
C     TREATMENT OF THE FIRST SUBCHANNEL OF A RING
C
  902 LC(I,1)=NOTR1+2
      LC(I,2)=NOTR0
      MROD(I,1)=1+IY+NOT12
      MROD(I,2)=2+NOT01
      MROD(I,3)=MROD(I,2)+1
      GO TO 908
    7 CONTINUE
C
C     TREATMENT OF RECTANGULAR WALL SUBCHANNELS
C
      DO 8 I=NFWCH,NLWCH
      MROD(I,3)=500
      IZ=1.0001/(LSTCH-5-I)
      IQ=(I-NOTRG-1)/NORING+0.0001
      IR=I-NOTRG-IQ*NORING+0.0001
C
C     COMMON TO ALL WALL SUBCHANNELS
C
      LC(I,1)=NOTG1+IQ*(2*NORING-1)+2*IR-1
      MROD(I,1)=1+NOG01+IQ*NORING+IR
      MROD(I,2)=MROD(I,1)+1-6*IZ*NORING
      IF(IR.EQ.1)GO TO 911
      IF(IR.EQ.NORING)GO TO 912
C
C     SUBCHANNEL NOT ADJACENT TO ANY CORNER
C
      LC(I,2)=I-1
      LC(I,3)=I+1
      GO TO 8
```

```
C
C      SUBCHANNEL PRECEDING A CORNER
C
  912 LC(I,2)=I-1
      LC(I,3)=(1-IZ)*(LSTCH+IQ-4)+IZ*(I+1)
      GO TO 8
C
C      SUBCHANNEL FOLLOWING A CORNER
C
  911 LC(I,2)=LSTCH+IQ-5
      LC(I,3)=I+1
    8 CONTINUE
C
C      TREATMENT OF CORNER SUBCHANNELS
C
      DO 9 K=1,6
      I=NLWCH+K
      IQ=K-1
C
C      COMMON TREATMENT TO ALL CORNER SUBCHANNELS
C
      LC(I,3)=500
      MROD(I,1)=2+NOG01+IQ*NORING
      MROD(I,2)=500
      MROD(I,3)=500
      IF(IQ)913,914,913
C
C      TREATMENT OF ALL THE CORNERS
C      BUT THE FIRST ONE
C
  913 LC(I,1)=NOTRG+IQ*NORING
      LC(I,2)=LC(I,1)+1
      GO TO 9
C
C      TREATMENT OF THE FIRST CORNER
C
  914 LC(I,1)=I-1
      LC(I,2)=NOTRG+1
    9 CONTINUE
      RETURN
      END
```

SUBROUTINE FOR NUMBERING AUTOMATICALLY THE SUBCHANNELS OF A HEXAGONAL FUEL BUNDLE

Prepared by F.O. Carré and B.J. Chen

1. General

The SUBROUTINE NUMB generates two tables LC(I,J) and MROD(I,J) which describe the environment of subchannel I:

LC(I,J), J = 1,2,3 are the three adjacent subchannels

MROD(I,J), J = 1,2,3 are the three rods located at the corners of the triangular subchannels.

NUMB uses only one input parameter (NORING) transmitted from the MAIN program. (NORING is the number of rings of triangular subchannels.)

The three types of subchannels (interior, wall and corner) are successively treated.

The principal variables are defined in the nomenclature and a total map of the numbering for a 217 pin bundle is shown on Figure 1.

2. Flow Chart

In the following development, the position of each subchannel I is described by three figures.

- the number N of the ring of the bundle where I is located - (N ranges from 1 to NORING)

- the number IQ of the face of the ring N, where I is located = (IQ ranges from 0 to 5)

- the position IR in the face IQ of the ring N, where I is located - (IR ranges from 1 to 2N-1)

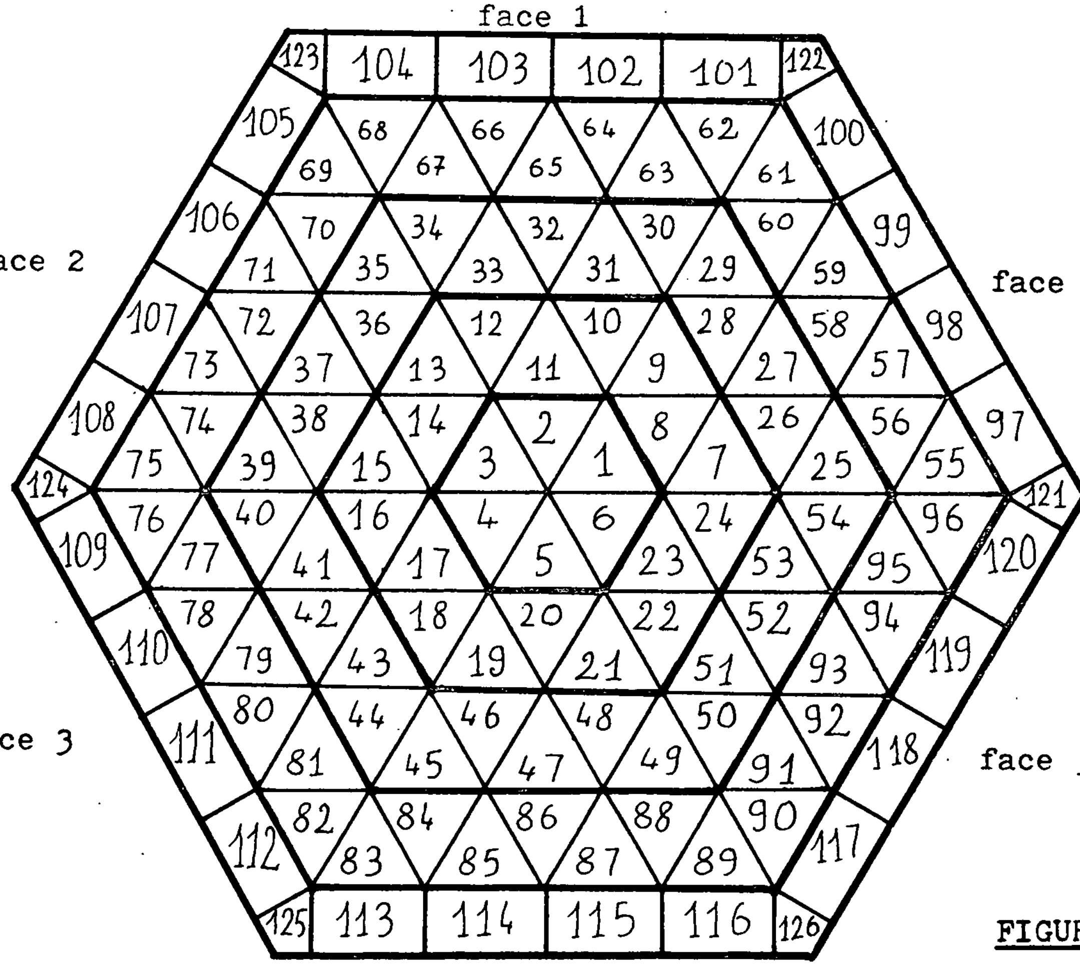
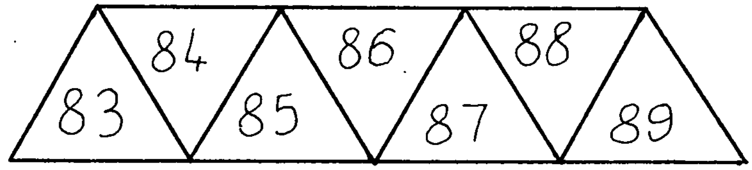


FIGURE 1a

TOTAL NUMBERING OF THE SUBCHANNELS OF A 61 PINS BUNDLE.

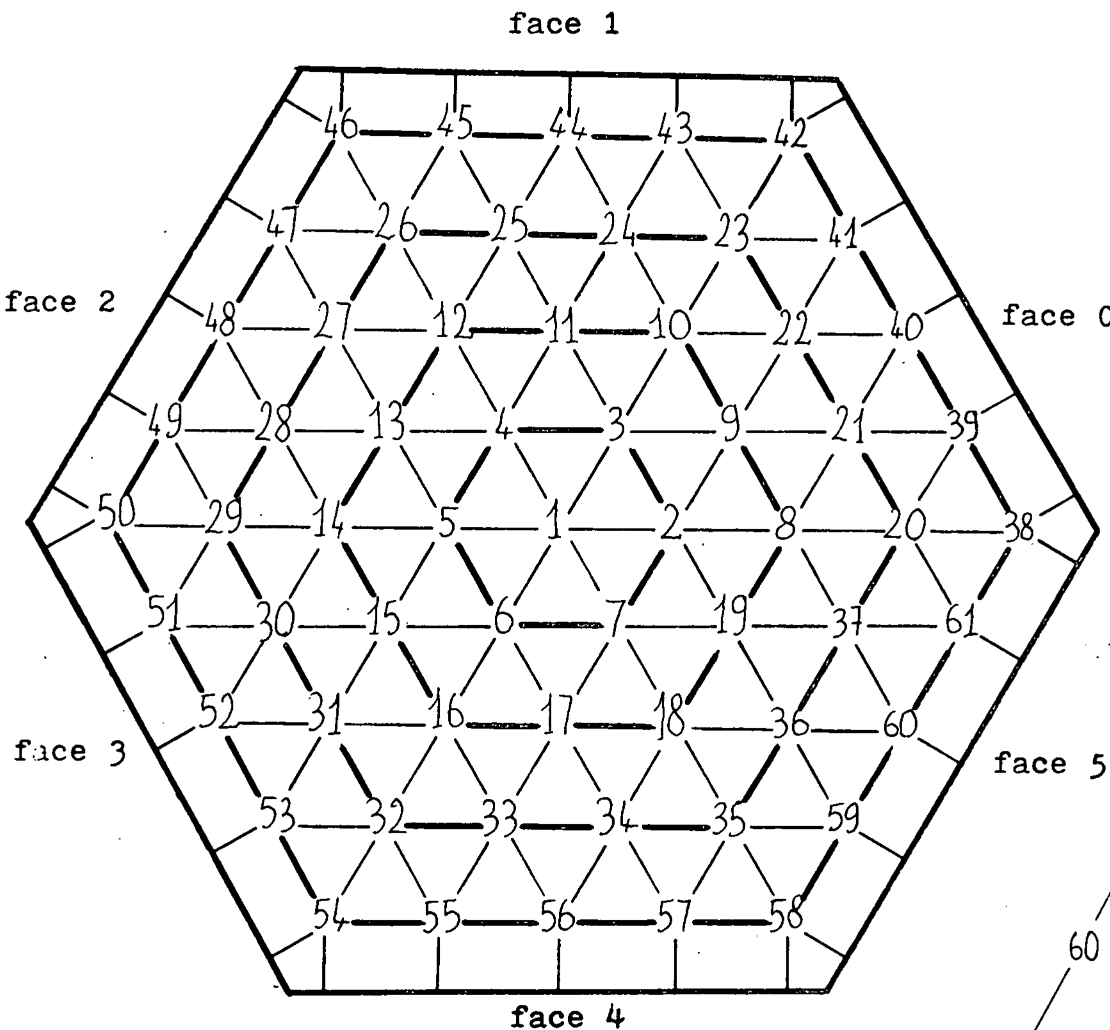


IR=1 IR=3 IR=5 IR=7 (2N-1 with N=4)

Detailed numbering of the face 4 of ring 4.
The subchannels face inwards for even values of IR, and outwards for odd values of IR.

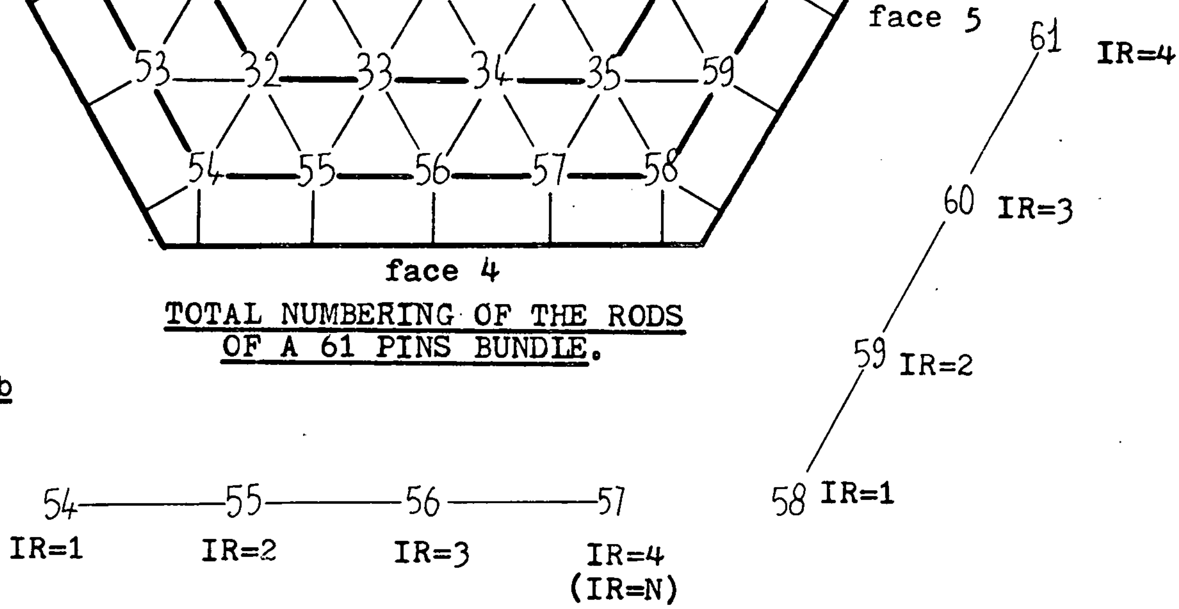
The same numbering is applied to the rings of rods.

The first ring is the central rod.



TOTAL NUMBERING OF THE RODS OF A 61 PINS BUNDLE.

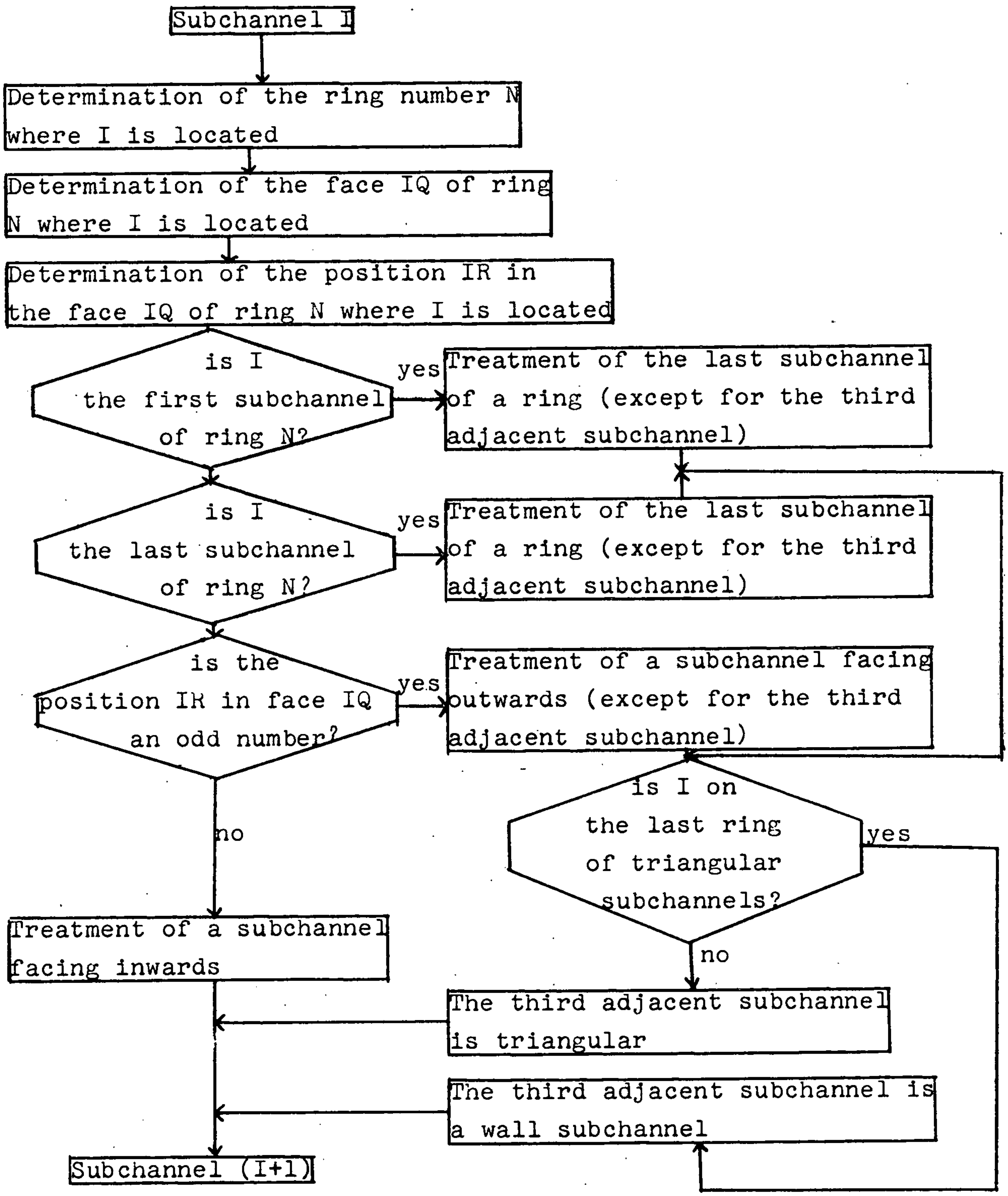
FIGURE 1b



Detailed numbering of the faces 4 and 5 of the 5th ring.

2.1 Interior (triangular) subchannels

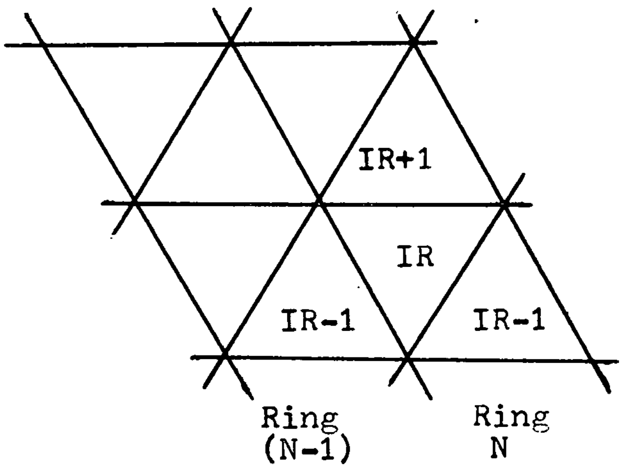
A DO loop with the index I ranging from 1 to NOTRG has the following logic:



2.1.1 Treatment of a general subchannel facing inwards

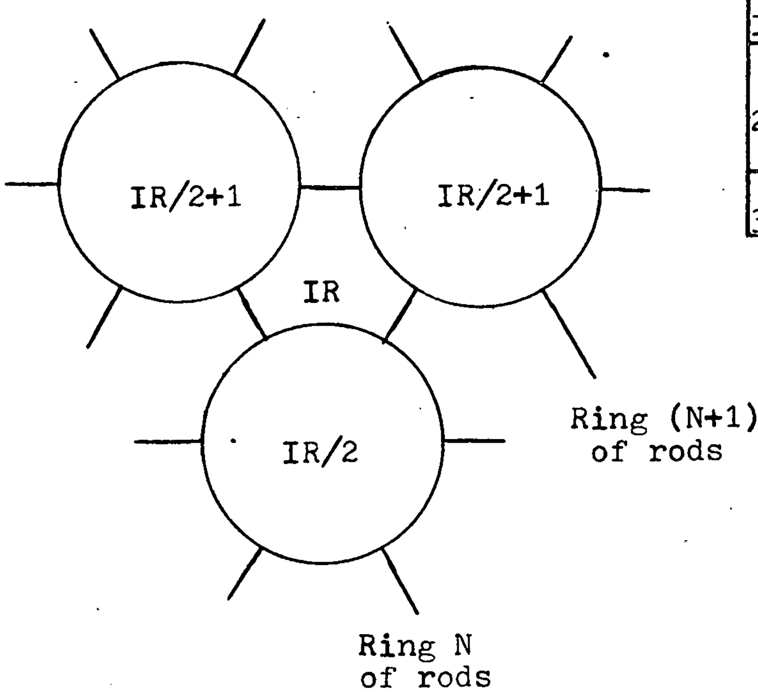
Adjacent subchannels

	Ring	Face	Position
1	N-1	IQ	IR-1
2	N	IQ	IR-1
3	N	IQ	IR+1



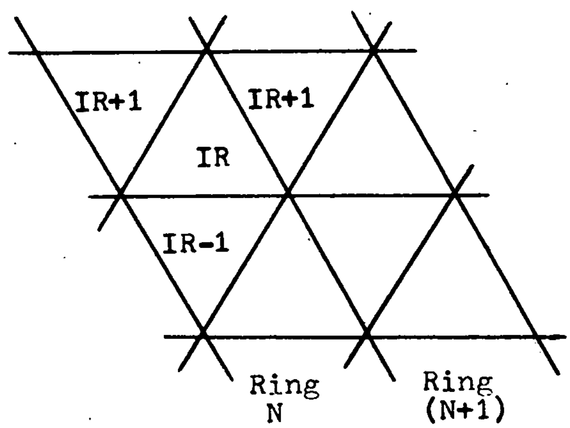
Adjacent rods

	Ring	Face	Position	
1	N	IQ	IR/2	
2	N	IQ	IR/2+1	(general case)
	N	0	1	(penultimate subchannel of ring N: IQ=5 IR=2N-2)
3	N+1	IQ	IR/2+1	



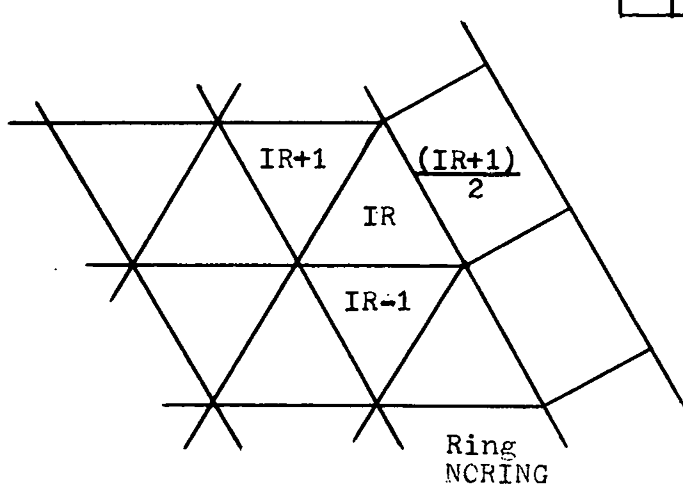
2.1.2 <u>Treatment of a general subchannel facing outwards:</u>
(not the first or the last one of a ring)

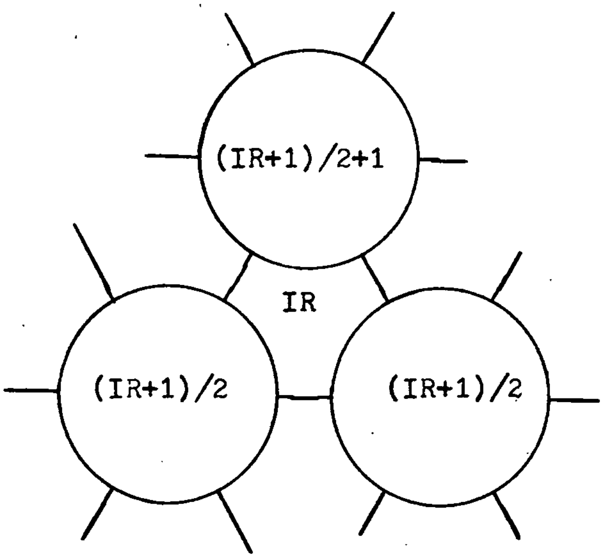
Subchannel I is at the position IR in the face IQ of the ring N.



Adjacent subchannels

	Ring	Face	Position	
1	N	IQ	IR-1	
2	N	IQ	IR+1	
3	N+1	IQ	IR+1	(If it is not a wall subchannel)
	N+1	IQ	(IR+1)/2	(If it is a wall subchannel)





Adjacent rods:

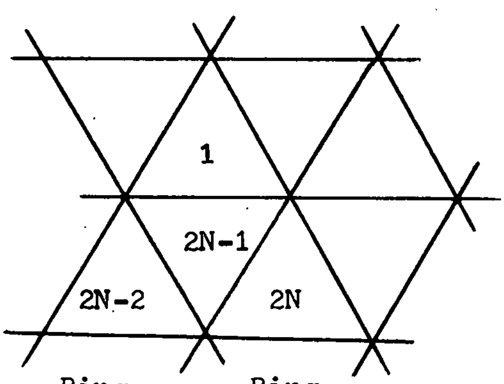
	Ring	Face	Position
1	N	IQ	(IR+1)/2
2	N+1	IQ	(IR+1)/2
3	N+1	IQ	(IR+1)/2+1

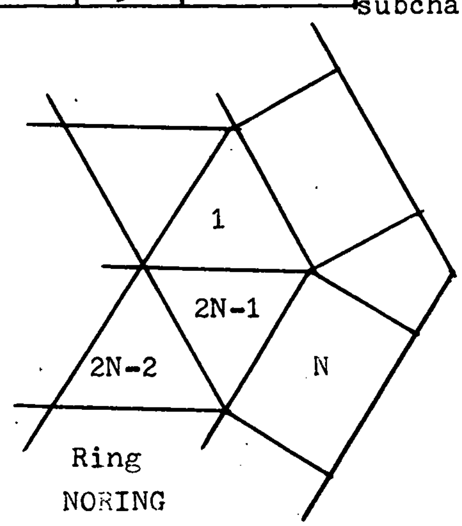
2.1.3 Treatment of the last subchannel of a ring

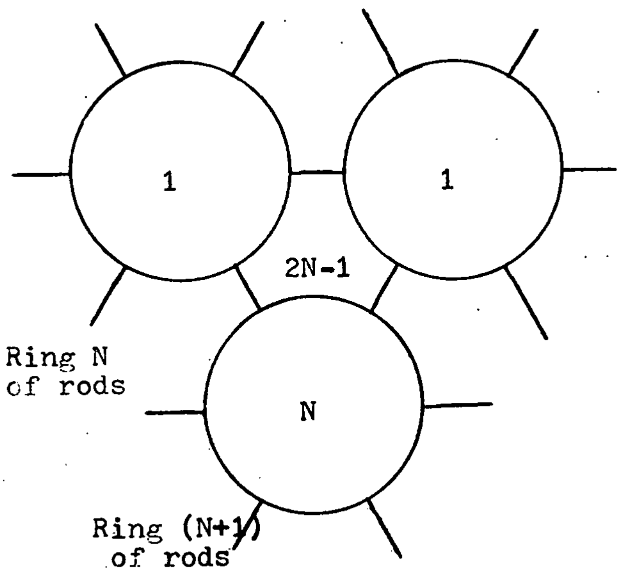
Subchannel I is at the position (2N-1) in the face 5 of the ring N.

Adjacent subchannels:

	Ring	Face	Position	
1	N	0	1	(first subchannel of the same ring)
2	N	5	(2N-2)	
3	N+1	5	2N	(if it is not a wall subchannel)
	N+1	5	N	(if it is a wall subchannel)







<u>Adjacent rods:</u>

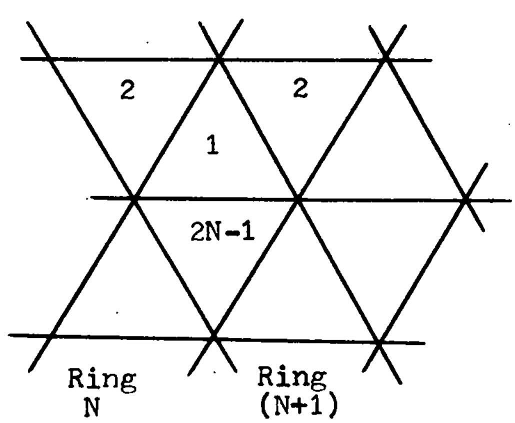
	Ring	Face	Position	
1	N	0	1	(first rod of ring N)
2	N+1	0	1	
3	N+1	5	N	(first and last rods of ring N)

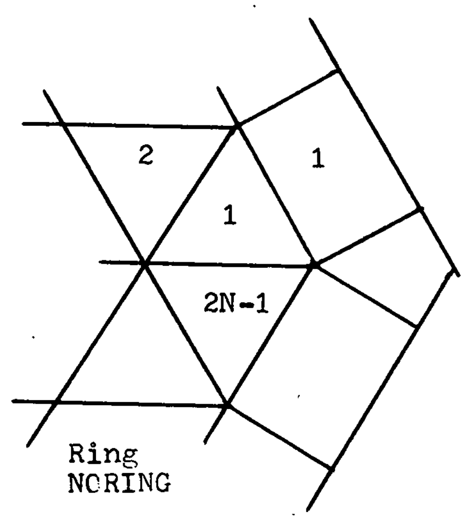
2.1.4 <u>Treatment of the first subchannel of a ring:</u>

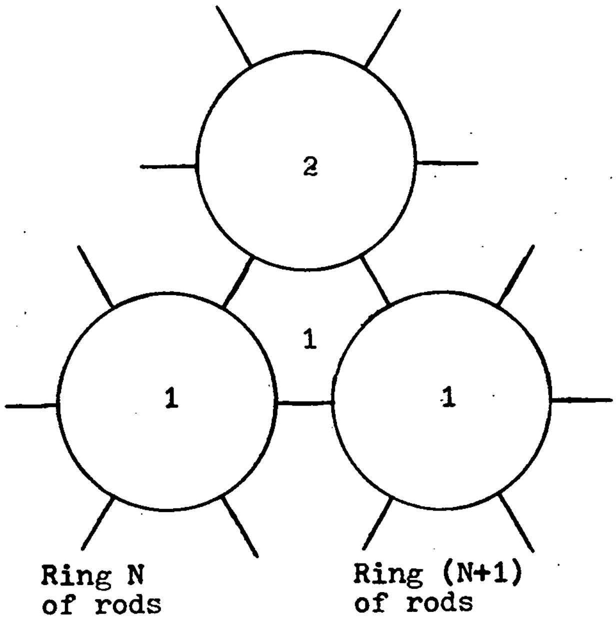
Subchannel I is at the position 1 in the face 0 of the ring N

<u>Adjacent subchannels:</u>

	Ring	Face	Position	
1	N	0	2	
2	N	5	(2N-1)	(last subchannel of the same ring)
3	N+1	0	2	(if it is not a wall subchannel)
	N+1	0	1	(if it is a wall subchannel)





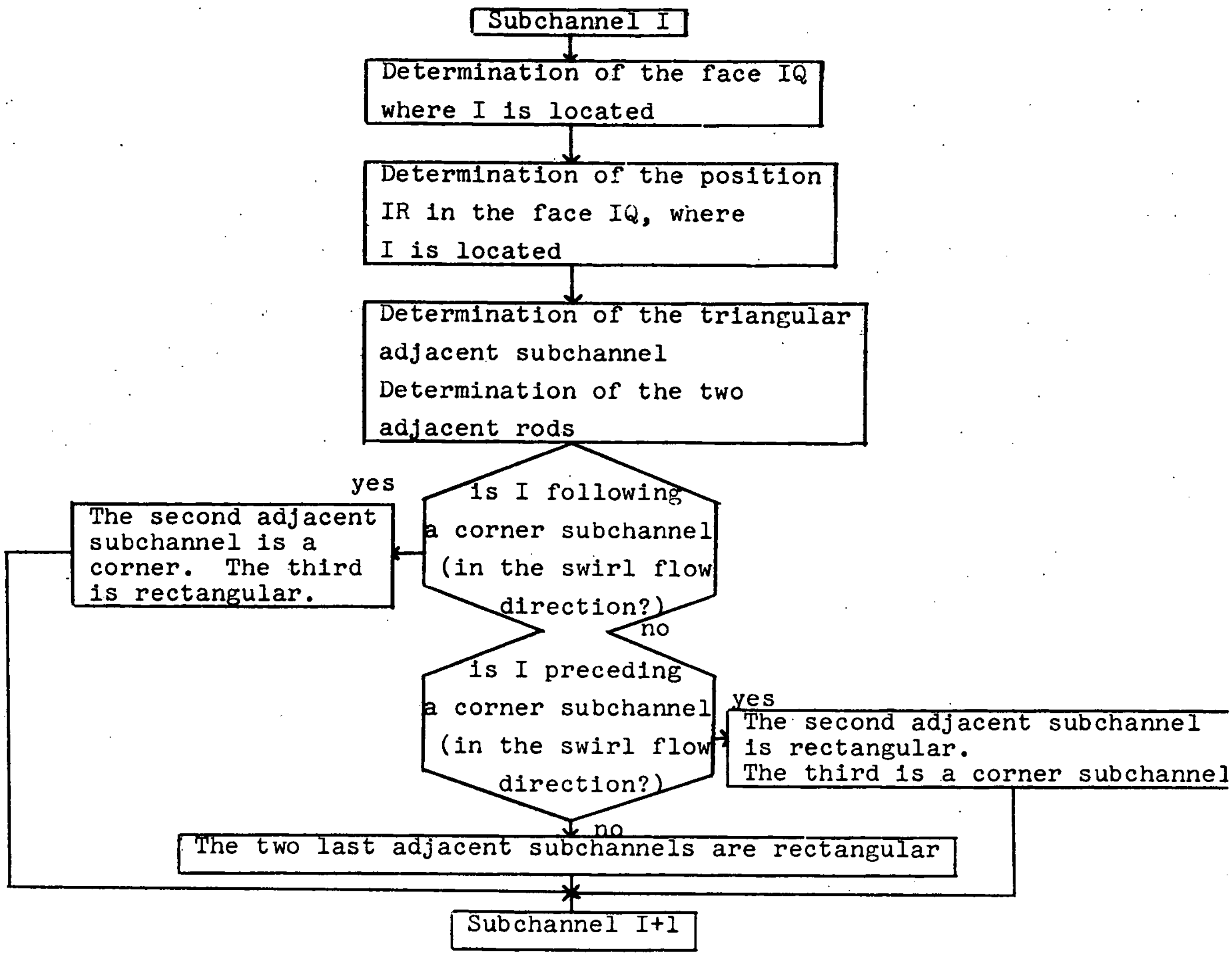


Adjacent rods

	Ring	Face	Position	
1	N	0	1	(first rod of ring N)
2	N+1	0	1	(first rod of ring N+1)
3	N+1	0	2	(second rod of ring N+1)

2.2 <u>Wall (rectangular) subchannels:</u>

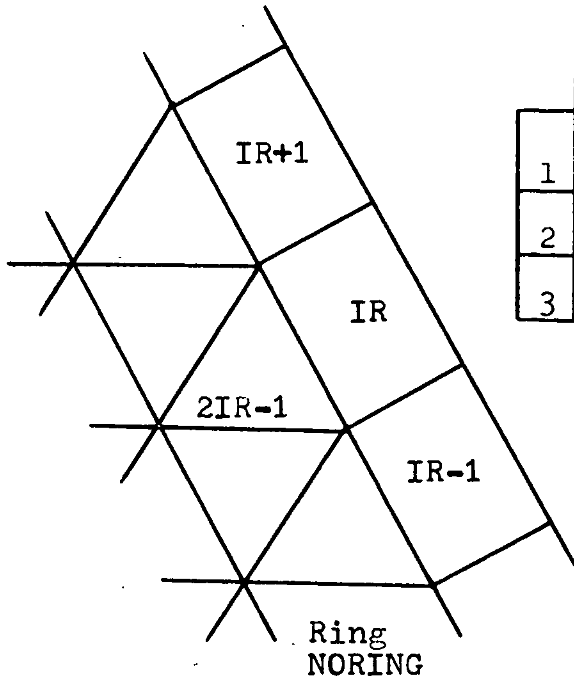
A DO loop with the index I ranging from NFWCH to NLWCH, has the following logic:



2.2.1 Treatment of a general wall subchannel:

(not adjacent to a corner)

Subchannel I is at the position IR in the face IQ

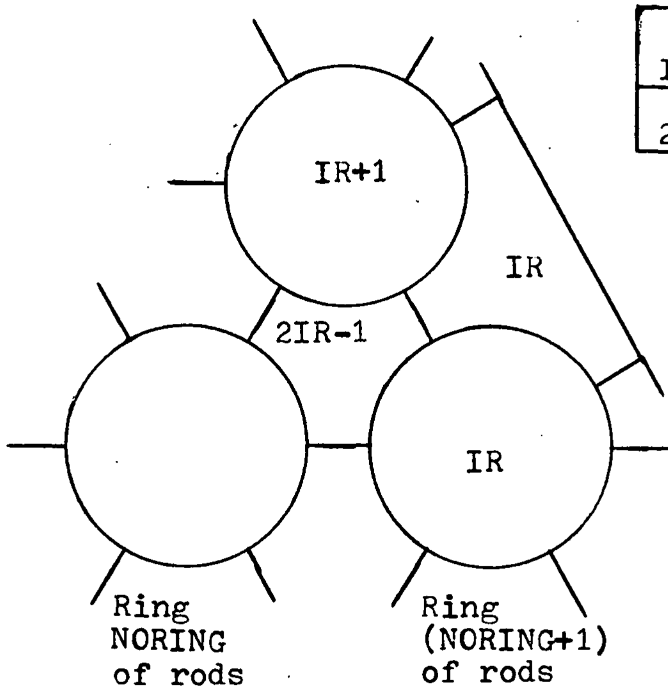


Adjacent subchannels:

	Ring	Face	Position
1	NORING	IQ	2 IR-1
2	Wall	IQ	IR-1
3	Wall	IQ	IR+1

Adjacent rods:

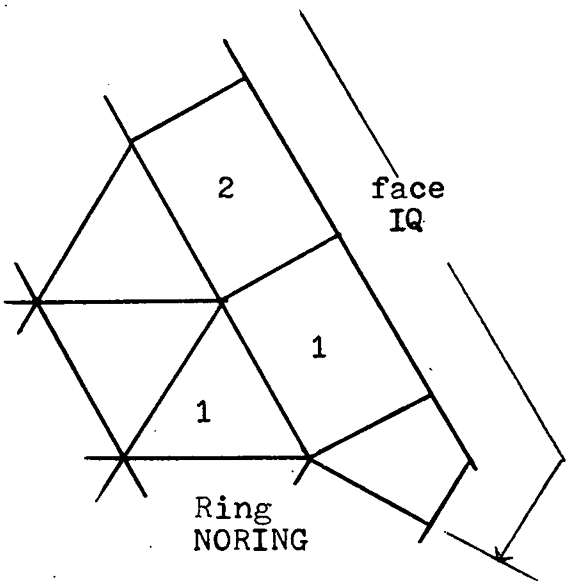
	Ring	Face	Position
1	NORING+1	IQ	IR
2	NORING+1	IQ	IR+1



2.2.2 Treatment of a wall subchannel following a corner:

(swirl flow direction taken as a reference)

Subchannel I is at the position 1 in the face IQ.



Adjacent subchannels:

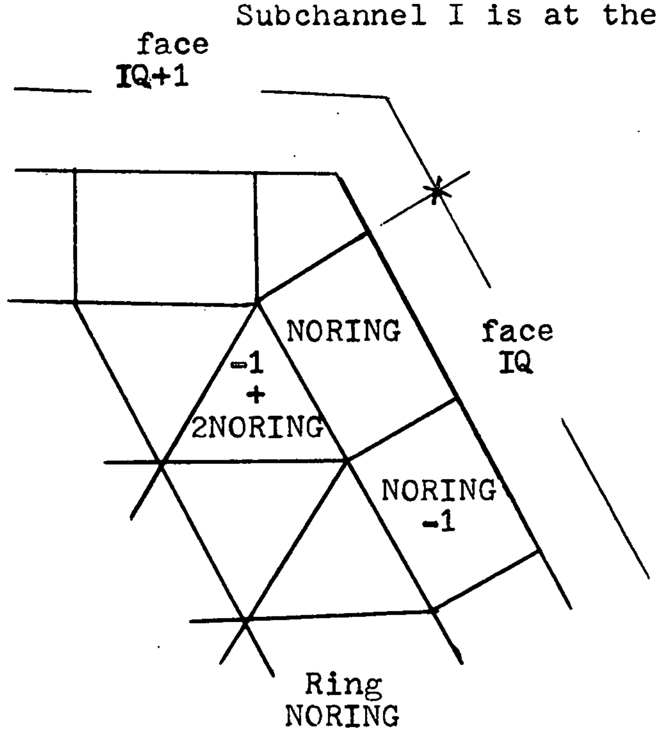
	Ring	Face	Position
1	NORING	IQ	1
2	wall	IQ	corner
3	wall	IQ	2

general treatment for the rods.

2.2.3 Treatment of a wall subchannel preceding a corner:

(swirl flow direction taken as a reference)

Subchannel I is at the position (NORING) in the face IQ.



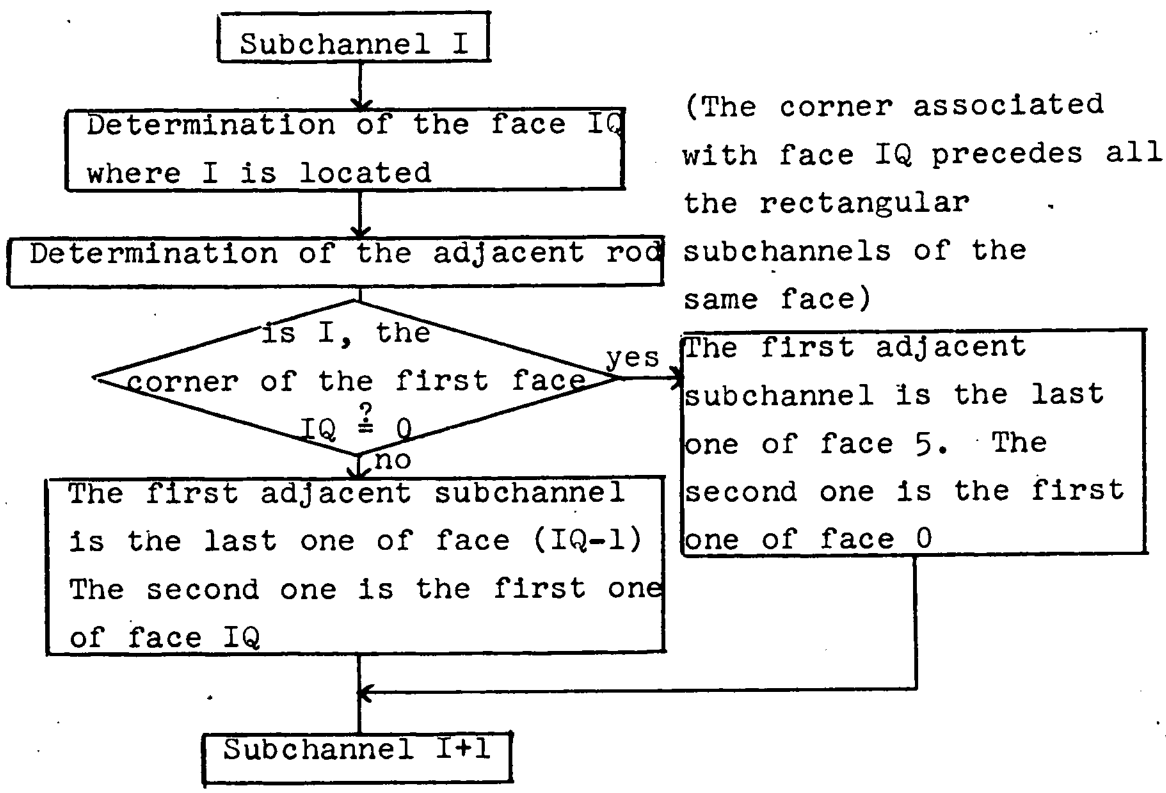
Adjacent subchannels:

	Ring	Face	Position
1	NORING	IQ	2 NORING-1
2	wall	IQ	NORING-1
3	wall	IQ+1	corner

general treatment for the rods.

2.3 Corner subchannels:

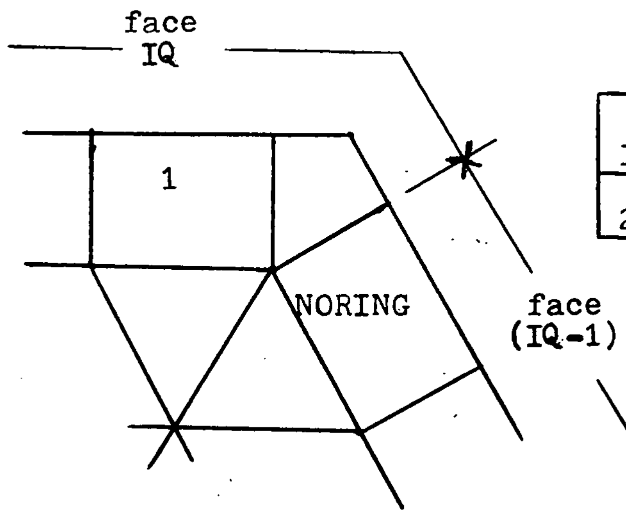
A DO loop with the index I ranging from (NLWCH+1) to (NLWCH+6), has the following logic:



2.3.1 Treatment of a general corner subchannel:

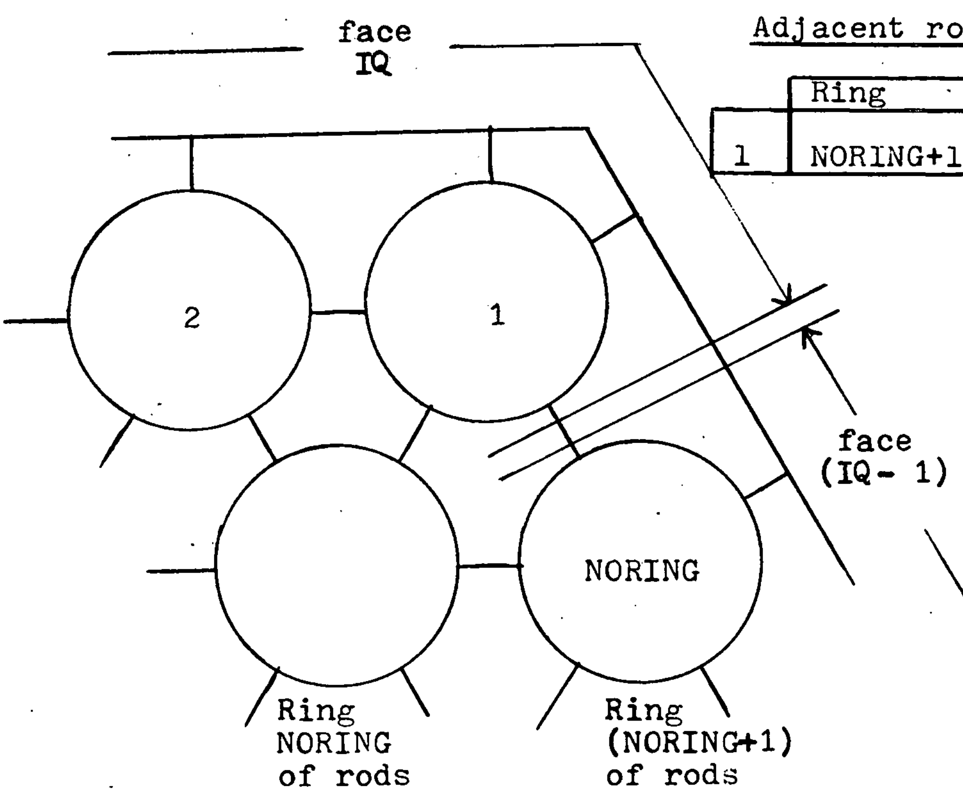
(not the corner of face 0)

Subchannel I is the corner of face IQ.



Adjacent subchannels:

	Ring	Face	Position
1	wall	IQ-1	NORING
2	wall	IQ	1

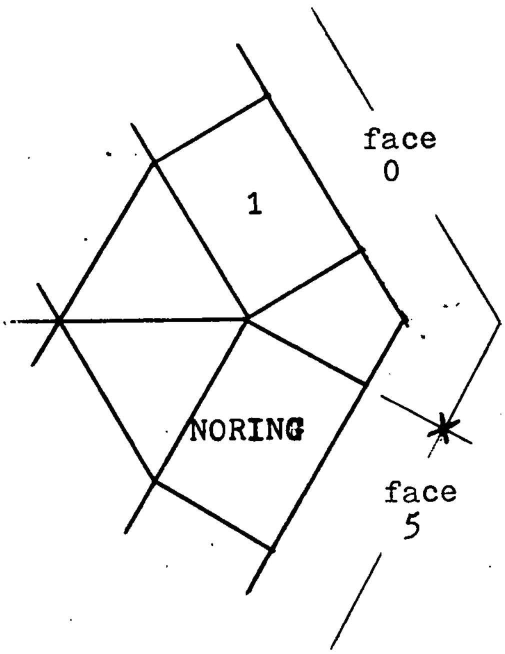


Adjacent rod:

	Ring	Face	Position
1	NORING+1	IQ	1

2.3.2 Treatment of the corner subchannel of face 0:

Subchannel I is the corner of face 0



Adjacent subchannels:

	Ring	Face	Position
1	wall	5	NORING
2	wall	0	1

general treatment for the rod

3. Conclusion:

For each subchannel I (corresponding to the parameters, N,IQ,IR), the adjacent subchannels or rods have been determined in terms of the same parameters (N,IQ,IR).

It is easy to relate these parameters to the number of the subchannel (or of the rod), when it has been noticed that:

- each face IQ of ring N counts (2N-1) triangular subchannels (in the inner region) or (N) rectangular subchannels (in the wall region)

- each face IQ of ring N counts (N-1) rods

For example:

. The number of the <u>triangular subchannel</u> characterized by (N,IQ,IR) is:

$$I = NOTR1 + (2N-1) \cdot IQ + IR$$

$$\text{with } NOTR1 = 6 \cdot (N-1)^2$$

. The number of the <u>rectangular subchannel</u> characterized by (IQ,IR) is:

$$I = NOTRG + (N) \cdot IQ + IR$$

$$\text{with } NOTRG = 6 \cdot (NORING)^2$$

. The number of the <u>corner subchannel</u> characterized by (IQ) is:

$$I = NLWCH + IQ + L$$

$$\text{with } NLWCH = 6 \cdot NORING\ (NORING + 1)$$

. The number of the <u>rod</u> characterized by (N,IQ,IR) is:

$$I = NOT12 + 1 + IQ \cdot (N-1) + IR$$

$$\text{with } NOT12 = 3 \cdot (N-1) \cdot (N-2)$$

- The SUBROUTINE NUMB uses this kind of equation;

- Given a subchannel I, inversion of these equations yields the parameters (N,IQ,IR)

- The algorithm of paragraph 2 yields the parameters (N,IQ,IR) of the adjacent subchannels and rods, from the parameters of the initial subchannel.

- Using the preceding equations directly yields the number of these adjacent subchannels and rods.

A listing of NUMB with further comments is included. The use of NUMB does not modify significantly the computing time needed by the former version of ENERGY I, without the necessity of reading numerous data cards (up to 438 for a 217 pin bundle case).

NOMENCLATURE

NORING	=	number of rings of triangular subchannels
NOTRG	=	total number of triangular subchannels
NOTG1	=	number of triangular subchannels in all the rings but the last one
NOGO1	=	total number of rods (minus one) in the NORING first rings of rods
LSTCH	=	total number of subchannels (or number of the last subchannel)
NFWCH	=	number of the first wall subchannel
NLWCH	=	number of the last wall subchannel
I	=	number of a subchannel
N	=	ring number where subchannel I is located
NOTRO	=	number of the last subchannel of ring N
NOTR1	=	number of the last subchannel of the preceding ring (N-1)
NOTR2	=	number of the last subchannel of ring number (N-2)
NOTO1	=	number of the last rod of ring N, minus one
NOT12	=	number of the last rod of ring (N-1), minus one
IQ	=	number of the face of ring N, where subchannel I is located (from 0 to 5)
IR	=	position of subchannel I inside the face IQ of ring N $\left\{\text{from 1 to } (2N-1)\right\}$

(continued)

IY	=	1 for the first ring and 0 for the others
IZ	=	1 for the last subchannel of a ring and 0 for the others
LC(I,J),J	=	1,2,3 numbers of the subchannels, adjacent to subchannel I
MROD(I,J),J	=	1,2,3 numbers of the rods, adjacent to subchannel I