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Department of Aerospace Engineering
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University of Cincinnati

COMPUTER PROGRAM FOR THE ANALYSIS OF THE CROSS FLOW IN A RADIAL INFLOW TURBINE SCROLL

BY

A. Hamed, S. Abdallah and W. Tabakoff

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16 Abstract

This report describes and explains the computer program that has been used to solve the governing equations of the potential flow in the cross-sectional planes of a radial inflow turbine scroll. The derivation of the governing equations and the description of the numerical solution can be found in NASA CR (to be assigned) Report entitled "Analysis of the Cross Flow in a Radial Inflow Turbine Scroll".

A list of the main program, the subroutines, and typical output example are included.

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SUMMARY

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A list of the main program, the subroutines, and typical output example are included.

COMPUTER PROGRAM

The Fortran computer program, which is used to solve the equations of potential flow in the cross-sectional plane of the centrifugal machine's volute or scroll will be described and listed. The input data to this program includes information about inlet flow properties, the cross section geometry, and its corresponding boundary conditions, which are shown in Figures 1 and 2. The maximum allowable number of mesh lines in the x and y directions are 50 and 30, respectively. The program output includes an echo print of the input data. At each grid point, the value of the potential function, the velocity components in the x and y directions, as well as the magnitude of the velocity vector and the angle it makes with the x axis are printed. Additional output is obtained in the form of plots of constant potential function contours, and arrows showing the direction of the velocity in the axial-radial plane.

The logical relations of the main program and subroutines are shown in Figures A-1, A-2 and A-3. A brief description of the main program and subroutines is given below.

Main Program:

The main program is primarily used to call the subroutines. The logic flow diagram is illustrated in Figure A-1.

Subroutine IRL(J):

It is called from the main program and the subroutines to determine IL(J) and IR(J), the first and last interior mesh points for the scroll cross-section at a given J mesh line (see Fig. A-4).

Subroutine INTPL(I):

It is called from the main program and the subroutines to determine JL(I) and JU(I), the lower and the upper interior mesh points for the scroll cross-section at a given I mesh line (see Fig. A-4).

Subroutine MESH(I,J):

It is called from the main program and the subroutines to identify the interior mesh point neighbors, calculate the coeffi-

cients of the five points Laplace difference operator, and to determine the most recent values of the potential functions at the interior mesh points.

Subroutine SHABAN:

It is called from the main program, to determine the source strength at every mesh point F(I,J), for a given mass flow rate and through flow velocity profile. The logic flow diagram is illustrated in Figure A-2.

Subroutine AWATEF:

It is called from the main program to determine the values of the potential function, at each grid point. The logic flow diagram of this subroutine is illustrated in Figure A-3.

Subroutine BCSI(I):

It is called from the subroutine AWATEF, to determine the values of the potential function at the boundary points on a given I mesh line.

Subroutine BCSJ(J):

It is called from the subroutine AWATEF, to determine the values of the potential function at the boundary points on a given J mesh line.

Subroutine HVVEL:

It is called from the main program to determine the values of the velocity components in the x and y directions, at every mesh point.

Subroutine ABDLAH:

It is called from the main program to calculate the magnitude of the velocity vector in the axial radial plane and the angle it makes with the x-axis.

Subroutine HOSNY:

It is called from the subroutine SHABAN to calculate the flow density at each grid point.

Subroutine PLTISO:

It is called from the main program to plot the contours of constant potential function.

Additional library subroutines, namely, PLOT (X1, X2, X3), SYMBOL (Y1, Y2, Y3, Y4, Y5, Y6), and ENDPLT, are called from the main program, and used in the plotting of both the potential contours and the velocity direction.

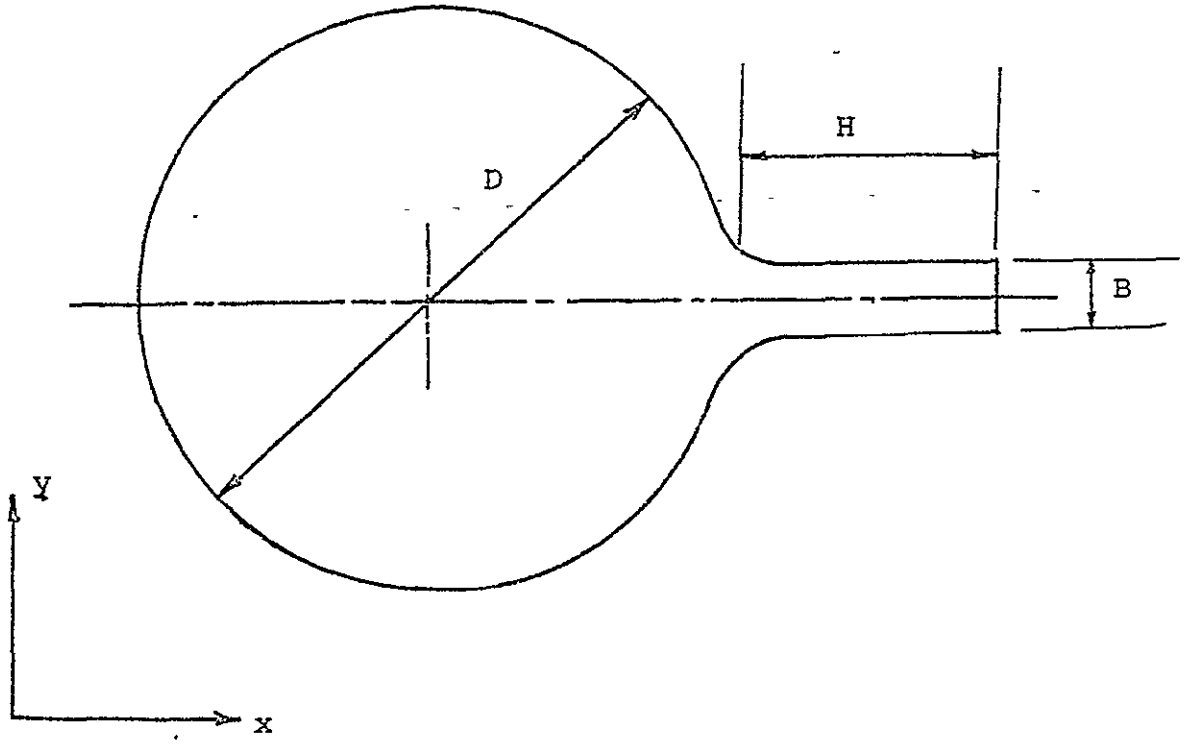

FIG. 1. SYMMETRIC SCROLL CROSS SECTION

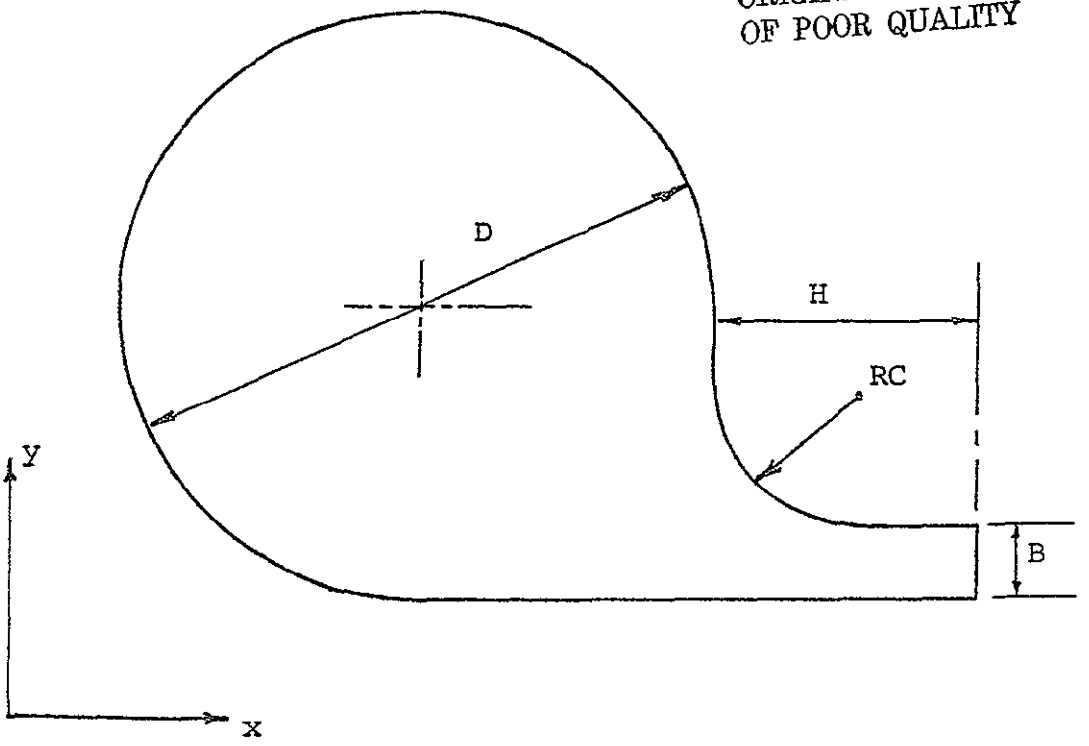

FIG. 2. NON SYMMETRIC SCROLL CROSS SECTION.

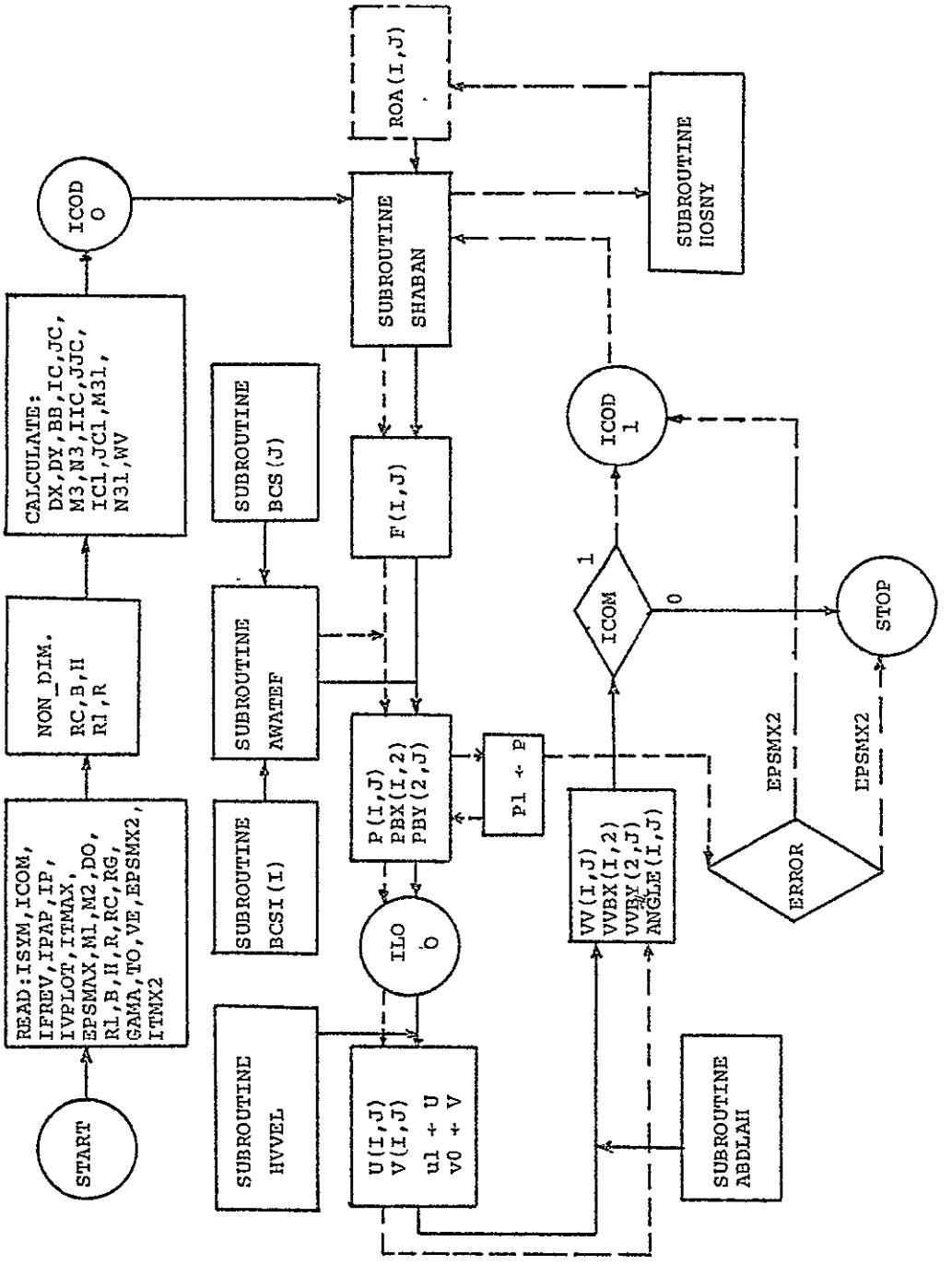

FIGURE (A-1) MAIN PROGRAM

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OF POOR QUALITY

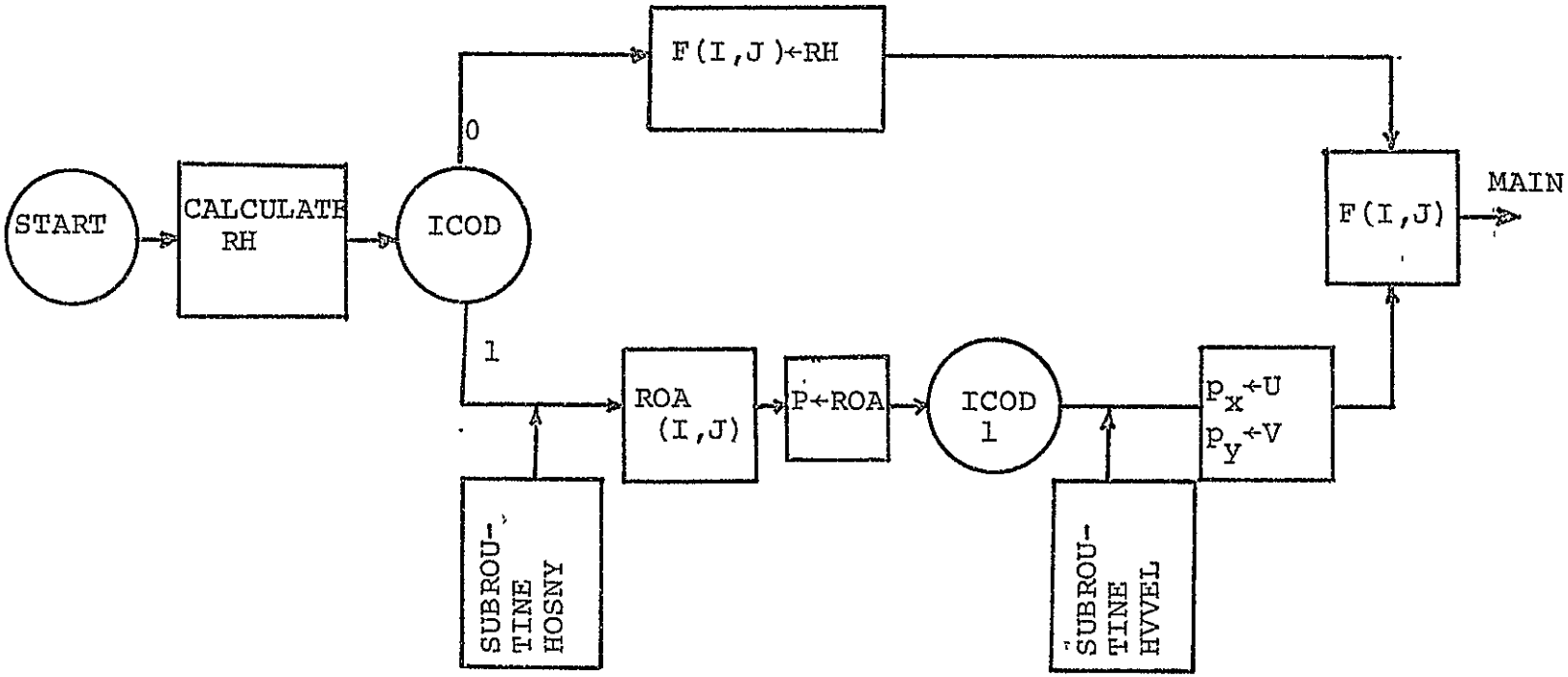

FIGURE (A-2) SUBROUTINE SHABAN

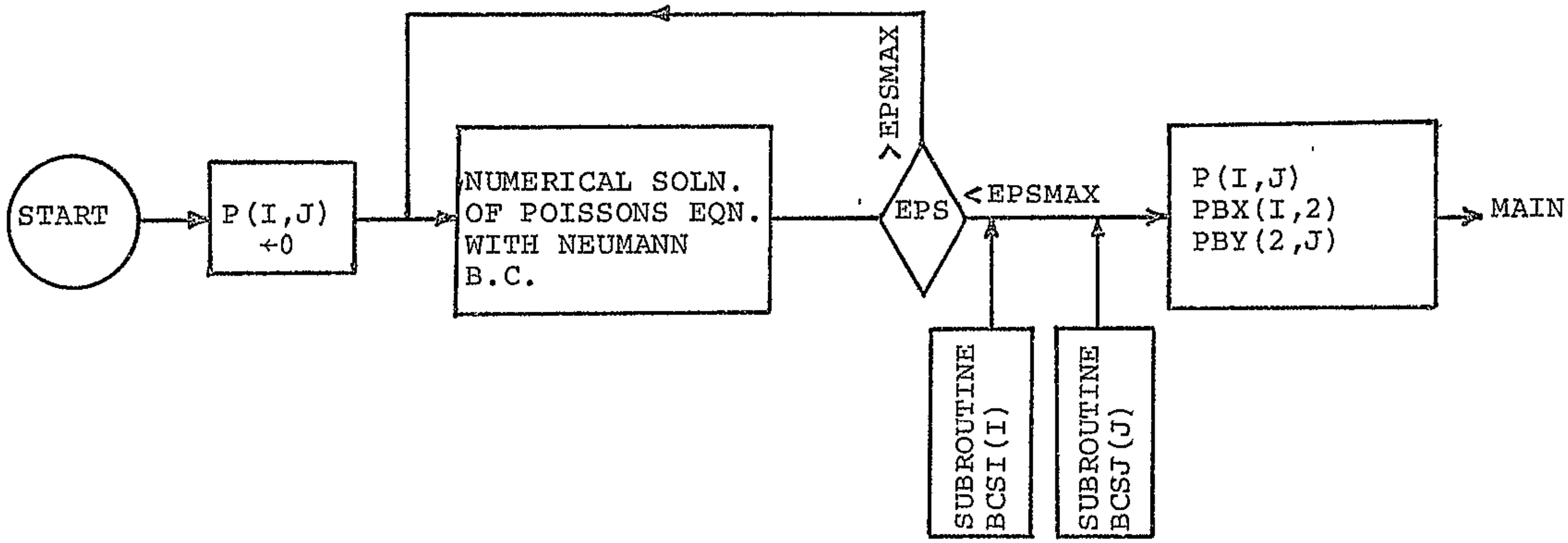

FIGURE (A-3) SUBROUTINE AWATEF

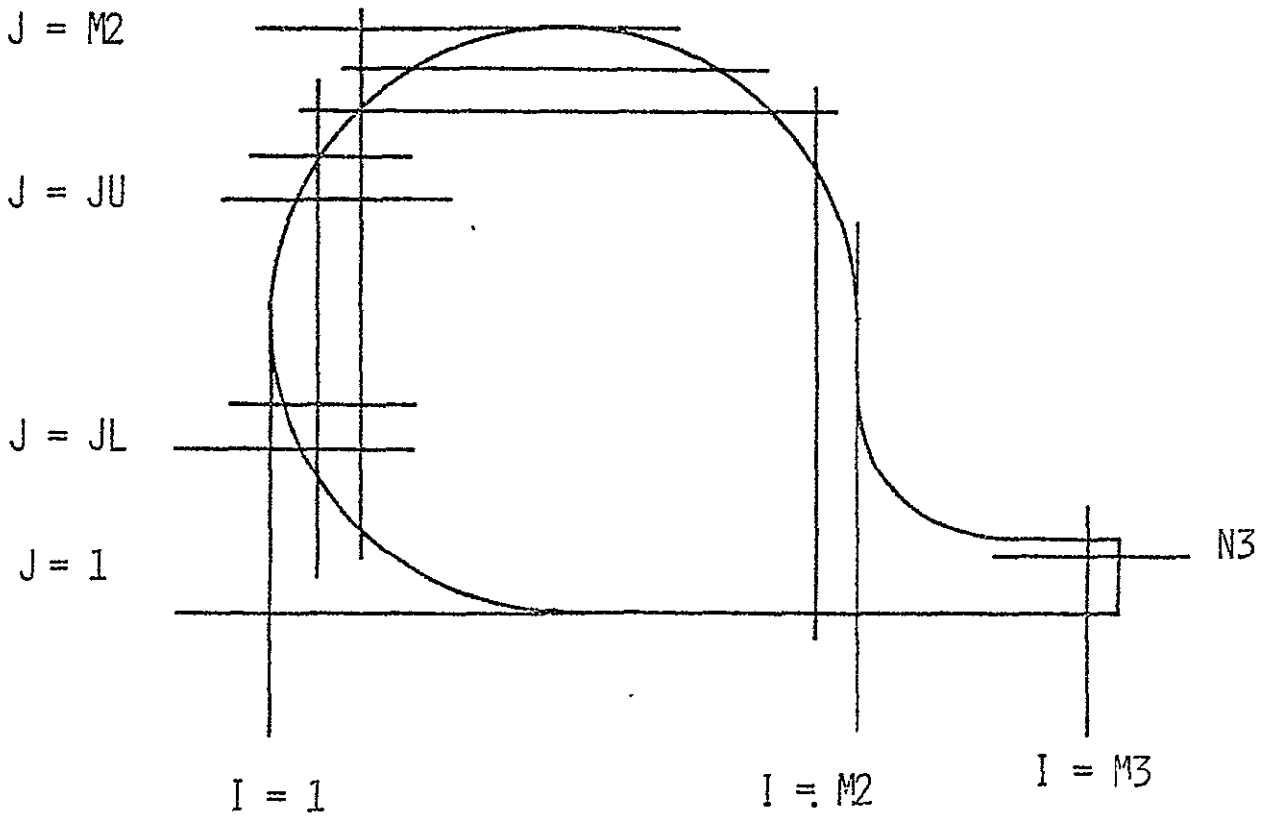

FIGURE (A-4)

DEFINITION OF SYMBOLS AND FORTRAN LISTING

Symbols	Description
B	Width of the scroll exit (Figs 1, 2).
DO	Scroll inlet diameter.
EPSMAX	The largest tolerable value of the square of the sum of the absolute values of the deviations of $\phi_{i,j}$ from their previously computed values.
F	Vector containing the values of Poisson's source strength at each grid point.
GAMA	Ratio of specific heats.
H	Length of scroll exit nozzle, Figs. 1 and 2.
ICOM	Parameter to control type of calculations. ICOM = 0 for incompressible flow and ICOM = 1 for compressible flow.
IFG, IPAP, IFREVO	Parameters to control the mass source distribution (i.e., the type of through flow velocity profile).
IP	Frequence of intermediate printout. Solutions are printed after every IP iteration.
IPLT	Number of contours in the output plot for the potential velocity.
ISYM	Parameter to control type of scroll cross section. For symmetric cross-section ISYM = 1, and for unsymmetric cross-section ISYM = 0.
ITMAX	Maximum allowable number of iterations.
IVPLOT	Parameter to control plotting of program output, IVPLOT = 1, a plot is prepared; if IVPLOT = 0, no plot is prepared.
M1,M2,M3,N3	Number of mesh lines of the scroll cross-section, Fig. (A-4).

Symbols	Description
P	Vector containing the values of the potential function ϕ at all grid points.
PBX,PBY	Vectors containing the values of ϕ on the scroll boundaries.
P_i (i=0,1,2,3,4)	The values of the potential function at the standard five points Laplace difference operator.
R	Radius of the scroll cross-section equal D/2, Figs. 1 and 2.
RC	Radius of exit portion of the unsymmetric cross-section, Fig. 3. (Ref. 1)
Rl	Radius of scroll exit
RG	Gas constant.
ROA	Vector containing the values of the density at all grid points.
ROBX,ROBY	Vectors containing the values of the density at the boundary points.
THETA	Vector containing the values of the angle between the velocity vector $\bar{V}$, and the x-axis at each grid point.
TO	Stagnation temperature
U,V	Vectors containing the values of the flow velocity, components in the x and y directions, respectively.
UBX,UBY	Vectors containing the values of the velocity component in the x-direction at the boundary points of all I and J mesh lines.
VBX,VBY	Vectors containing the values of the velocity component in the y-direction at the boundary points of all I and J mesh lines.
VE	Scroll exit velocity in radial direction.

Symbols	Description
VISOBR	Numerical values of the velocity potential contours to be plotted as output.
VV	Vector containing the absolute values of the velocity vector $\bar{V}$, at each grid point.
VVBX,VVBY	Vectors containing the absolute values of the velocity vector $\bar{V}$, at the boundary points for each I and J mesh lines, respectively.
WO,WOP	Successive relaxation factors. WO for interior mesh points, and WOP for the points adjacent to the boundaries.

PROGRAM LISTING

```
IV G LEVEL  21                    MAIN              DATE = 77263        21/45/41        PAGE 0001
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION X(50,21),Y(50,21),VAR(50,21),VRR(50,21)
      COMMON /ONE/ V1
      COMMON /TAO/ ILO,IWR,ISYM,IPAP,ICOO,IP,ICOM
      COMMON /FOUR/ R1,RF,IFREVO
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,BB
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      COMMON /PHI/ P(50,30),PBY(2,30),PBX(50,2),PP(50,30),PBY1(2,30),
     1   PBX1(50,2),F(50,30)
      COMMON /VEES/U(50,30),V(50,30),UBX(50,2),VBX(50,2),
     1  UBY(2,30),VBY(2,30),U1(50,30),V0(50,30),UBX1(50,2)
     1   ,VBX1(50,2),UBY1(2,30),VBY1(2,30),VV(50,30),ANGLE(50,30)
      COMMON /CAL/ M21,IC1,JC1,M11,N31,IC2
      COMMON /SH/ RG,GAMA,TO,WV,VE
      COMMON /40/ EPSMAX,EPSMX2,WO,WOP,ITMAX,ITMX2
      COMMON /RO/ ROA(50,30),ROBX(50,2),ROBY(2,30)
      COMMON /GO/ VVBX(50,2),VVBY(2,30),ANGL1(50,2),ANGL2(2,30)
      CALL UNFLW
C
CC CALCULATE 2-DIM. POTENSIONAL FUNCTION & VELOCITY VECTOR V IN THE
CC SCROLL CROSS SECTION FOR INCOMP. & COMP. FLOW
C
CC    READ INPUT DATA     ***********************************************
C
      READ(5,102) RG,GAMA,TO,VE
      READ(5,100) M1,M2,DO,R1,B,H,R,RC
      READ(5,101) ICOM,ISYM,IFG,IPAP,IFREVO
      READ(5,200) ITMAX,EPSMAX,WO,WOP
      READ(5,7177) IP,IVP_OT,IP_T
C
C
      ITMX2=ITMAX
      EPSMX2=EPSMAX
C
C
      V1=1.0D0
      RC=RC/(2*R)
      B=B/(2*R)
      IF(ISYM.EQ.1) B=B/2.0D0
      H=H/(2*R)
      P0=R1/DO
      R1=R1/(2*R)
      WV=16.0D0*R0*B*R/DO
      IF(ISYM.EQ.1) WV=2.0D0*WV
      RF=2.0D0*R
      R=R/(2*R)
      RATIO=(R1+H+R)/(2.0D0*R)
      DX=2*R/(M1-1)
      DY=2*R/(M2-1)
      IF(ISYM.EQ.1) DY=R/(M2-1)
      B1=DX/DY
      BB=B1*B1
```

```
      M21=M2-1
      IC=(M1+1)/2
      JC=(M2+1)/2
      IF(ISYM.EQ.1) JC=1
      N3=(B/DY-0.00010D0)+1
      M3=((R+R+H)/DX-0.00010D0)+1
      IC1=IC-1
      JC1=JC-1
      IC2=IC+1
      M11=M1-1
      N31=N3-1
      M31=M3-1
      IF(ISYM.EQ.1) GO TO 555
      IIC=(RC/DX-0.00010D0)+M1
      JJC=((B+RC)/DY-0.00010D0)+1
C
  555 DO 12 I=1,M3
      DO 12 J=1,M2
      ANGLE(I,J)=0.0D0
      ROA(I,J)=1.0D0
      ROBX(I,1)=1.0D0
      ROBX(I,2)=1.0D0
      ROBY(1,J)=1.0D0
      ROBY(2,J)=1.0D0
      F(I,J)=0.0D0
   12 CONTINUE
      IF(IFG.EQ.0) GO TO 5557
      DO 5552 I=2,M31
      CALL INTPL(I)
 5552 READ(5,5553)(F(I,J),J=JL,JU)
 5557 CONTINUE
C
CC    WRITE  INPUT DATA FOR CHECK    ************************************
C
      WRITE(6,1313)
      WRITE(6,405) RG,GAMA,TO,VE
      WRITE(6,340) M1,M2,R1,B,H,RC,RF,D0
      WRITE(6,310) ICOM,ISYM,IFS,IPAP,IFREVO
      WRITE(6,320) ITMAX,EPSMAX,W0,WOP
      WRITE(6,330) IP,IVPLOT,IPLT
      WRITE(6,301) DX,DY,IC,JC,M3,N3
C
CC SOLVE FOR INCOMP. FLOW    ************************************
C
      IWR=0
      ICOD=0
      CALL SHABAN
      CALL AWATEF
      ILO=0
      CALL VVSEL
      CALL ABD_AH
      IF(ICOM.EQ.0) GO TO 818
C
```

```
      CC SOLVE FOR COMP. FLOW      ****************************************
      C
            DO 2 I=2,M3
            CALL INTPL(I)
            DO 2 J=JL,JU
        2   PP(I,J)=1.0D0
            VEO=VE
            IT=0
            IWR=1
      717   IT=IT+1
            ERROR=0.0D0
            ICOD=1
            VE=VEO/RUBY(2,2)
            CALL SHABAN
            CALL AWATEF
            ILO=0
            CALL AVVEL
            CALL ABD_AH
            DO 7 I=2,M3
            CALL INTPL(I)
            DO 7 J=JL,JU
            SAV=PP(I,J)
        7   ERROR=ERROR+DABS(P(I,J)-SAV)**2
            DO 111 I=2,M3
            CALL INTPL(I)
            DO 111 J=JL,JU
      111   PP(I,J)=P(I,J)
            DO 112 I=2,M3
            DO 112 J=1,2
      112   PBX1(I,J)=PBX(I,J)
            DO 114 J=2,M21
            DO 114 I=1,2
      114   PBY1(I,J)=PBY(I,J)
            IF(IT.GE.ITMX2) GO TO 919
            IF(ERROR.GE.EPSMX2) GO TO 717
      919   WRITE(6,14)
            WRITE(6,407)
            DO 9 I=2,M3
        9   WRITE(6,408) I,(P(I,J),J=1,M21)
            WRITE(6,151) IT,ERROR,VE
            WRITE(6,404)
            DO 40 J=1,M21
       40   WRITE(6,400) J,(P(I,J),I=1,M3)
            IF(ISYM.EQ.1) GO TO 46
            WRITE(6,401)
            DO 42 I=2,M3
       42   WRITE(6,402) I,(PBX(I,J),J=1,2)
            GO TO 45
       46   WRITE(6,4005)
            DO 47 I=2,M3
       47   WRITE(6,406) I,PBX(I,2)
       45   WRITE(6,403)
            DO 44 J=1,M21
```

```
   44  WRITE(6,402) J,(PBY(I,J),I=1,2)
       IWR=0
       CALL HVVEL
       CALL ABD_AH
  818  CONTINUE
       IF(IVPLOT.EQ.0) GO TO 7007
C
CC PLOTTING OF THE FLOW DIRECTIONS  ********************************
C
       ISKIP=1
       JSKIP=1
       DXD=0.25
       CALL BEGP_T
       ICPM=2
       ICP=1
       DO 59 I=1,M3
       DO 58 J=1,M2
       X(I,J)=(I-1)*DXD
       Y(I,J)=(J-1)*DXD
   58  CONTINUE
   59  CONTINUE
       WRITE(6,14)
       WRITE(6,5001)
       DO 62 I=1,M3
   62  WRITE(6,20) (X(I,J),J=1,M2)
       WRITE(6,14)
       WRITE(6,5002)
       DO 64 I=1,M3
   64  WRITE(6,20) (Y(I,J),J=1,M2)
       WRITE(6,14)
   75  IF(ISYM.EQ.1) GO TO 76
       CALL PLOT(1.5,1.5,23)
       GO TO 77
   76  CALL PLOT(1.5,3.5,23)
   77  IUPDOW=1
       SIZE=0.14
       ISYMBL=75
       IF(ICP.EQ.1) GO TO 11
       IF(ICP.EQ.2) GO TO 133
   11  DO 50 I=2,M3
       DO 50 J=1,M21
       VRR(I,J)=270.0+ANGLE(I,J)
   50  CONTINUE
       CALL PLOT(0.0,0.0,3)
       DO 501 I=2,M31
       CALL INTPL(I)
       DO 511 J=JL,JU
       XXC=X(I,J)
       YYC=Y(I,J)
       CALL SYMBOL (XXC,YYC,SIZE,18,VRR(I,J),-1)
  511  CONTINUE
  501  CONTINUE
       CALL P_OT (0.0,0.0,3)
```

```
      ICP=ICP+1
      IF(ICP.GT.ICPM) GO TO 3
      CALL PAUSE
      CALL PAUSE
      GO TO 75
  133 CONTINUE
C
CC CONTOURS PLOT              ************************************ ****
C
      DO 510 I=1,M3
      DO 510 J=1,M2
  510 VAR(I,J)=P(I,J)
      DO 514 I=2,M3
      CALL INTPL(I)
      J1=JL-1
      J2=JU+1
      VAR(I,J2)=PBX(I,2)
      IF(ISYM.EQ.1) GO TO 514
      VAR(I,J1)=PBX(I,1)
  514 CONTINUE
      DO 515 J=2,M21
      CALL IRL(J)
      I1=IL-1
      I2=IR+1
      VAR(I1,J)=PBY(1,J)
  515 VAR(I2,J)=PBY(2,J)
      CALL PLOT (0.0,0.0,3)
      DO 222 IPL=1,IPLT
      READ(5,5) VISOBR
      CALL PLTISO(M21,ISYMBL,IUPOOW,SIZE,VISOBR,VAR,X,Y)
      CALL PLOT(0.0,0.0,23)
  222 CONTINUE
      CALL PLOT (0.0,0.0,3)
  3   CONTINUE
      CALL ENDPLT
 7007 CONTINUE
  5   FORMAT(F10.0)
  14  FORMAT(1H1)
  20  FORMAT(10(6X,F6.3))
 100 FORMAT(2I10,6F10.0)
 101 FORMAT(5I10)
 102 FORMAT(4F10.0)
 151 FORMAT(20X,'ITCOM=',I5,/,20X,'ERROR=',E20.9,/,20X,'V EX.=',E20.9)
 200 FORMAT(I10,3F10.0)
 301 FORMAT(20X,'DX    =',F10.5,5X,'DY    =',F10.5,5X,'IC    =',I10,/,
    1  20X,'JC    =',I10,    5X,'M3    =',I10,5X,'M3    =',I10,/)
 310 FORMAT(/,20X,'ICOM  =',I10,/,20X,'ISYM  =',I10,/,20X,'IFG   =',
    1   I10,/,20X,'IPAP  =',I10,/,20X,'IFREVO=',I10,/)
 320 FORMAT(/,20X,'ITMAX=',I10,/,20X,'EPSMAX=',F10.8,/,20X,'WO    =',
    1   F10.5,/,20X,'WOP   =',F10.5,/)
 330 FORMAT(/,20X,'IP    =',I10,/,20X,'IVPLOT=',I10,/,20X,'IPLT  =',
    1   I10,//)
 340 FORMAT(/,20X,'M1    =',I10,/,20X,'M2    =',I10,/,20X,'R1    =',F10.5
```

```
     1   ,/,20X,'B     =',F10.5,/,20X,'H     =',F10.5,/,20X,'RC    =',
     1   F10.3,/,20X,'U     =',F10.5,2X,'UNIT DIM.',/,20X,'U0    =',F10.5
     1   ,2X,'UNIT DIM.',/)
  400 FORMAT(//,7X,'J  =',I2,/,10(5X,5D15.6/))
  401 FORMAT(//,15X,'I     ',5X,'PBX1',15X,'PBX2')
  402 FORMAT(/,10X,I4,5X,2(5X,D15.6))
  403 FORMAT(//,15X,'J     ',5X,'PBY1',15X,'PBY2')
  404 FORMAT(//,20X,'VALUES OF VELOCITY POTENTIAL P(I,J) FOR COMPRESSIBL
     1E FLOW',/)
  405 FORMAT(//,20X,'GAS CONSTANT =',F10.5,/,20X,'GAMA          =',F10.5
     1   ,/,20X,'STAG. TEMP.  =',F10.5,/,20X,'RAD. EXIT VEL=',F10.5,/)
  406 FORMAT(/,15X,I4,10X,D15.6)
  407 FORMAT(/,10X,'POISSONS SOURCE DIS. AT EACH GRID POINT',//)
  408 FORMAT(//,7X,'I  =',I10,/,4(8F10.5))
 1313 FORMAT(//,10X,'INPUT DATA',//)
 4005 FORMAT(//,20X,'I    ',5X,'PBX2',/)
 5001 FORMAT(//,20X,'X-COORD. OF THE PLOTTING DOMAIN',//)
 5002 FORMAT(//,20X,'Y-COORD. OF THE PLOTTING DOMAIN',//)
 7177 FORMAT(3I10)
 5553 FORMAT(8(F10.))
 7177 FORMAT(3I10)
      STOP
      END
```

```
      SUBROUTINE AWATEF
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /ONE/ V1
      COMMON /TWO/ ILO,IUR,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,BB
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      COMMON /PHI/ P(50,30),PBY(2,30),PBX(50,2),PP(50,30),PBY1(2,30),
     1   PBX1(50,2),F(50,30)
      COMMON /CAL/ M21,IC1,JC1,M11,N31,IC2
      COMMON /HO/ EPSMAX,EPSMA2,WOP,ITMAX,ITMX2
C
C CALCULATE POTENTIAL VELOCITY DIST. IN THE SCROLL CROSS SECTION BY
CC SOLVING POISSONS EQN. WITH NEUMANN B. C. THE ITER. METHOD IS S.O.R.
C
    2 DO 1 I=1,M3
      DO 1 J=1,M2
    1 P(I,J)=0.0D0
      ITER=0
   15 ITER=ITER+1
      EPS=0.0D0
      DO 5 I=2,M3
      XX1=(IC-I)*DX
      X1=DABS(XX1)
      YY1=DABS(R*R-X1*X1)
      Y1=DSQRT(YY1)
      CALL INTP_(I)
      DO 4 J=JL,JU
      W=WO
      W1=1.0D0-W
      WB=W/(2.0D0+2.0D0*BB)
      OD=1.0D0-WB*BB
      WB1=1.0D0-WB
      YY2=(JC-J)*DY
      Y2=DABS(YY2)
      XX2=DABS(R*R-Y2*Y2)
      X2=DSQRT(XX2)
      SAVP=P(I,J)
      CALL IR_(J)
      CALL MESH(I,J)
      L11=1.0D0
      L33=1.0D0
      WB11=1.0D0-WB*L11
      WB12=1.0D0-WB*L33
      C24=1/(DY*DY*S2*S4)
      C13=1/(DX*DX*S1*S3)
      S24=1/(DY*DY*(S2+S4))
      S13=1/(DX*DX*(S1+S3))
      S1L=S13*L11
      S1K=S13*L33
      P11=L11*P1/S1
      P22=P2/S2
      P33=L33*P3/S3
```

```
      P44=P4/S4
      IF(I.EQ.M1.AND.J.EQ.JU) GO TO 923
      IF(I.EQ.IL.AND.J.EQ.JL) GO TO 80
      IF(I.EQ.I_.AND.J.EQ.JU) GO TO 85
      IF(I.EQ.IL) GO TO 90
      IF(I.EQ.IR.AND.J.EQ.JL) GO TO 91
      IF(I.EQ.IR.AND.J.EQ.JU) GO TO 92
      IF(I.EQ.IR) GO TO 93
      IF(J.EQ.JL) GO TO 94
      IF(J.EQ.JU) GO TO 95
      P(I,J)=(1.0D0-W0P)*P(I,J)+(W0P/(2+2*BB))*(L11*P1+L33*P3+
     1  BB*(P2+P4)-F(I,J)*DX*DX)
      GO TO 477
   80 CONTINUE
      IF(J.EQ.1) GO TO 81
      PB1=Y2*B1*P(I,J+1)/X2
      PB2=X1*P(I+1,J)/(B1*Y1)
      CK1=(W*S1_*((1/S1)-Y2*B1/X2)+W*S24*((1/S4)-X1/(B1*Y1)))/(C13+C24)
      IF(CK1.GT.0.9990D0.AND.C<1._T.1.001) GO TO 16
      CK=1.0D0-CK1
      GO TO 17
   16 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   17 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(PB1+P33)+S24*(P22+PB2)-F(I,J)/2)
     1    /(C13+C24))/CK
      GO TO 477
   81 CONTINUE
      P(I,J)=(W1*P(I,J)+W8*(2*BB*P2+P33-F(I,J)*DX*DX))/WB11
      GO TO 477
   85 CONTINUE
      PB1=Y2*B1*P(I,J-1)/X2
      PB2=X1*P(I+1,J)/(B1*Y1)
      CK1=(W*S1L*((1/S1)-Y2*B1/X2)+W*S24*((1/S2)-X1/(B1*Y1)))/(C13+C24)
      IF(CK1.GT.0.9990D0.AND.CK1.LT.1.001) GO TO 18
      CK=1.0D0-CK1
       GO TO 19
   18 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   19 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(PB1+P33)+S24*(P44+PB2)-F(I,J)/2)
     1    /(C13+C24))/CK
      GO TO 477
   90 CONTINUE
      IF(J.GT.JC) GO TO 909
      PB1=P(I,J+1)*Y2*B1/X2
      CK1=(W*S1L*((1/S1)-Y2*B1/X2))/(C13+C24)
      IF(CK1.GT.0.9990D0.AND.C<1.LT.1.001) GO TO 20
      CK=1.0D0-CK1
```

```
      GO TO 21
   20 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   21 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(PB1+P33)+S24*(P22+P44)-F(I,J)/2)
     1    /(C13+C24))/CK
      GO TO 477
  909 CONTINUE
      PB1=P(I,J-1)*Y2*B1/X2
      CK1=(W*S1L*((1/S1)-Y2*B1/X2))/(C13+C24)
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 22
      CK=1.0D0-CK1
      GO TO 23
   22 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   23 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(PB1+P33)+S24*(P22+P44)-F(I,J)/2)
     1    /(C13+C24))/CK
      GO TO 477
   91 CONTINUE
      IF(J.EQ.1) GO TO 910
      CK1=((W*S1K/S3)+W*S24/S4)/(C13+C24)
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 24
      CK=1.0D0-CK1
      GO TO 25
   24 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   25 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*P11+S1K*V1*DX+S24*P22-F(I,J)/2)
     1    /(C13+C24))/CK
      GO TO 477
  910 CK1=W*S1K/(S3*(C13+C24))
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 26
      CK=1.0D0-CK1
      GO TO 27
   26 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   27 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*P11+S1K*V1*DX+2*S24*P22-F(I,J)/2)
     1   /(C13+C24))/CK
      GO TO 477
   92 CONTINUE
      IF(J.GT.N3) GO TO 921
      CK1=((W*S1K/S3)+W*S24/S2)/(C13+C24)
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 28
```

```
      CK=1.0D0-CK1
      GO TO 29
   28 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   29 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*P11+S14*V1*DX+S24*P44-F(I,J)/2)
     1    /(C13+C24))/CK
      GO TO 477
  921 CONTINUE
      IF(ISYM.EQ.1) GO TO 922
      IF(J.GT.JJC) GO TO 922
      XC1=RC-(1-M1)*DX
      YYC1=DABS(RC*RC-XC1*XC1)
      YC1=DSQRT(YYC1)
      YC2=(RC+B)-(J-1)*DY
      XXC=DABS(RC*RC-YC2*YC2)
      XC2=DSQRT(XXC)
      PB2=XC1*P(I-1,J)/(B1*YC1)
      PB3=YC2*B1*P(I,J-1)/XC2
      CK1=(W*S24*((1/S2)-XC1/(B1*YC1))+W*S14*((1/S3)-YC2*B1/XC2))/(C13
     1      +C24)
      IF(CK1.GT.0.999000.AND.CK1.LT.1.001) GO TO 30
      CK=1.0D0-CK1
      GO TO 31
   30 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   31 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(PB3+P11)+S24*(P44+PB2)-F(I,J)/2)
     1    /(C13+C24))/CK
      GO TO 477
  922 CONTINUE
      PB3=Y2*B1*P(I,J-1)/X2
      PB2=X1*P(I-1,J)/(B1*Y1)
      CK1=(W*S14*((1/S3)-Y2*B1/X2)+W*S24*((1/S2)-X1/(B1*Y1)))/(C13+C24)
      IF(CK1.GT.0.999000.AND.CK1.LT.1.001) GO TO 32
      CK=1.0D0-CK1
      GO TO 33
   32 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   33 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(PB3+P11)+S24*(P44+PB2)-F(I,J)/2)
     1    /(C13+C24))/CK
      GO TO 477
   93 CONTINUE
      IF(J.GT.N3) GO TO 930
      CK1=W*S14/(S3*(C13+C24))
      IF(CK1.GT.0.999000.AND.CK1.LT.1.001) GO TO 34
```

```
      CK=1.0D0-CK1
      GO TO 35
   34 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   35 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*P11+S1K*V1*DX+S24*(P22+P44)-F(I,J)/2)
     1     /(C13+C24))/CK
      GO TO 477
  930 CONTINUE
      IF(ISYM.EQ.1) GO TO 932
      IF(J.GT.JJC) GO TO 931
      YC2=(RC+B)-(J-1)*DY
      XXC=DABS(RC*RC-YC2*YC2)
      XC2=DSQRT(XXC)
      PB3=YC2*B1*P(I,J-1)/XC2
      CK1=(W*S1K*((1/S3)-YC2*B1/XC2))/(C13+C24)
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 36
      CK=1.000-CK1
      GO TO 37
   36 CK1=CK1/A
      CK=1.0D0-CK1
      A1=0.0D0
      A=1.0D0
   37 CONTINUE
      P(I,J)=(A1*P(I,J)+W*(S13*(PB3+P11)+S24*(P22+P44)-F(I,J)/2)
     1     /(C13+C24))/CK
      GO TO 477
  931 CONTINUE
      IF(J.GT.JC)GO TO 932
      P(I,J)=(W1*P(I,J)+WB*(P11+BB*(P22+P44)-F(I,J)*DX*DX))/WB12
      GO TO 477
  932 CONTINUE
      PB3=Y2*B1*P(I,J-1)/X2
      CK1=(W*S1K*((1/S3)-Y2*B1/X2))/(C13+C24)
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 38
      CK=1.0D0-CK1
      GO TO 39
   38 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   39 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(PB3+P11)+S24*(P22+P44)-F(I,J)/2)
     1     /(C13+C24))/CK
      GO TO 477
   94 CONTINUE
      IF(J.EQ.1) GO TO 945
      IF(I.GE.IC) GO TO 940
      PB4=X1*P(I+1,J)/(B1*Y1)
      CK1=(W*S24*((1/S4)-X1/(B1*Y1)))/(C13+C24)
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 40
```

```
      CK=1.0D0-CK1
      GO TO 41
   40 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   41 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(P33+P11)+S24*(P22+PB4)-F(I,J)/2)
     1     /(C13+C24))/CK
      GO TO 477
  945 CONTINUE
      P(I,J)=W1*P(I,J)+A8*(P11+P33+2.0D0*BB*P22-F(I,J)*DX*DX)
      GO TO 477
  940 CONTINUE
      P(I,J)=(W1*P(I,J)+A8*(P11+P33+BB*P22-F(I,J)*DX*DX))/DD
      GO TO 477
   95 CONTINUE
      IF(I.GE.IC) GO TO 950
      PB2=X1*P(I+1,J)/(B1*Y1)
      CK1=(W*S24*((1/S2)-X1/(B1*Y1)))/(C13+C24)
      IF(CK1.GT.0.999000.AND.CK1.LT.1.001) GO TO 42
      CK=1.0D0-CK1
      GO TO 43
   42 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   43 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(P33+P11)+S24*(P44+PB2)-F(I,J)/2)
     1     /(C13+C24))/CK
      GO TO 477
  923 CONTINUE
      P(I,J)=0.0D0
      GO TO 477
  950 CONTINUE
      IF(I.GT.M1) GO TO 951
      PB2=X1*P(I-1,J)/(B1*Y1)
      CK1=(W*S24*((1/S2)-X1/(B1*Y1)))/(C13+C24)
      IF(CK1.GT.0.999000.AND.CK1.LT.1.001) GO TO 44
      CK=1.0D0-CK1
      GO TO 45
   44 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   45 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(P33+P11)+S24*(P44+PB2)-F(I,J)/2)
     1     /(C13+C24))/CK
      GO TO 477
  951 CONTINUE
      IF(ISYM.EQ.1) GO TO 952
      IF(I.GT.IIC) GO TO 952
      XC1=RC-(I-M1)*DX
```

```
      YYC1=DABS(RC*RC-XC1*XC1)
      YC1=DSQRT(YYC1)
      PB2=XC1*P(I-1,J)/(B1*YC1)
      CK1=W*S24*((1/S2)-XC1/(B1*YC1))/(C13+C24)
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 46
      CK=1.0D0-CK1
      GO TO 47
   46 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   47 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(P11+P33)+S24*(P44+PB2)-F(I,J)/2)
     1   /(C13+C24))/CK
      GO TO 477
  952 CONTINUE
      CK1=W*S24/(S2*(C13+C24))
      IF(CK1.GT.0.99900D0.AND.CK1.LT.1.001) GO TO 48
      CK=1.0D0-CK1
      GO TO 49
   48 CK1=CK1/W
      CK=1.0D0-CK1
      W1=0.0D0
      W=1.0D0
   49 CONTINUE
      P(I,J)=(W1*P(I,J)+W*(S13*(P11+P33)+S24*P44-F(I,J)/2)
     1   /(C13+C24))/CK
  477 CONTINUE
      EPS=EPS+DABS(P(I,J)-SAVP)**2
    4 CONTINUE
    5 CONTINUE
      IF(ITER/IP*IP .NE. ITER) GO TO 2222
      WRITE(6,102) EPS,ITER
      DO 900  J=1,M2
  900 WRITE(6,101)(P(I,J),I=1,M3)
      WRITE(6,104)
      DO 1000 I=1,M3
 1000 WRITE(6,103) I,(PBX(I,J),J=1,2)
      WRITE(6,105)
      DO 1100 J=1,M2
 1100 WRITE(6,103) J,(PBY(I,J),I=1,2)
 2222 CONTINUE
      IF(EPS.LT.1.0D0) GO TO 3
      WO=0.90D0*WO
      WOP=0.90D0*WOP
      GO TO 2
    3 IF(ITER .GE. ITMAX) GO TO 8
      IF(EPS .GE. EPSMAX) GO TO 15
    8 CONTINUE
      WRITE (6,102) EPS,ITER
      WRITE(6,14)
C
      DO 6 I=2,M3
```

```
      CALL INTPL(I)
      CALL BCSI(I)
    6 CONTINUE
      DO 7 J=1,M21
      CALL IRL(J)
      CALL BCSJ(J,V1)
    7 CONTINUE
      IF(IWR.EQ.1) GO TO 222
      WRITE(6,106)
      DO 9 J=1,M21
    9 WRITE(6,101) J,(P(I,J),I=1,M3)
      IF(ISYM.EQ.1) GO TO 333
      WRITE(6,104)
      DO 10 I=2,M3
   10 WRITE(6,103) I,(PBX(I,J),J=1,2)
      GO TO 444
  333 WRITE(6,107)
      DO 12 I=2,M3
   12 WRITE(6,108) I,PBX(I,2)
  444 WRITE(6,105)
      DO 11 J=1,M21
   11 WRITE(6,103) J,(PBY(I,J),I=1,2)
   14 FORMAT(///,'*************************************************
     1 ************************************************************',//)
  101 FORMAT(//,7X,'J  =',I2,/,10(5X,5D15.6/))
  102 FORMAT(//,10X,'EPS =',D12.4/10X,'NO. OF ITERATIONS=',I4)
  103 FORMAT(/,10X,I4,5X,2(5X,D15.6))
  104 FORMAT(//,15X,'I    ',5X,'PBX1',15X,'PBX2')
  105 FORMAT(//,15X,'J    ',5X,'PBY1',15X,'PBY2')
  106 FORMAT(//,20X,'VALUES OF POTENTIAL VELOCITY P(I,J) FOR  INCOMPRESS
     1IBLE  FLOW',/)
  107 FORMAT(//,20X,'I    ',5X,'PBX2',/)
  108 FORMAT(/,15X,I4,10X,D15.6)
  222 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ABD_AH
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /ONE/ V1
      COMMON /TWO/ ILO,IWR,ISYM,IPAP,ICOO,IP,ICOM
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      COMMON /VEES/U(50,30),V(50,30),UBX(50,2),VBX(50,2),
     1  UBY(2,30),VBY(2,30),U1(50,30),V0(50,30),UBX1(50,2)
     1   ,VBX1(50,2),UBY1(2,30),VBY1(2,30),VV(50,30),ANGLE(50,30)
      COMMON /CAL/ M21,IC1,JC1,M11,N31,IC2
      COMMON /GO/ VVBX(50,2),VVBY(2,30),ANGL1(50,2),ANGL2(2,30)
C
CC CALCULATE THE VELOCITY VECTOR V IN THE SCROLL CROSS SECTION BY
CC USING THE TWO COMPONENTS U,V IN THE X&Y DIRECTIONS
C
      IF(IWR.EQ.1) GO TO 5
      WRITE(6,14)
      WRITE(6,149)
      WRITE(6,150)
    5 CONTINUE
      DO 2 I=2,M3
      CALL INTPL(I)
      DO 2 J=JL,JU
      U2=DABS(U(I,J))
      V2=DABS(V(I,J))
      VV(I,J)=DSQRT(U2*U2+V2*V2)
      IF(U(I,J).GT.0.0D0.AND.V(I,J).LT.0.0D0) GO TO 82
      IF(U(I,J).LT.0.0D0.AND.V(I,J).GT.0.0D0) GO TO 83
      IF(U(I,J).LT.0.0D0.AND.V(I,J).LT.0.0D0) GO TO 84
      IF(U(I,J).EQ.0.0D0.AND.V(I,J).GT.0.0D0) GO TO 85
      IF(U(I,J).EQ.0.0D0.AND.V(I,J).LT.0.0D0) GO TO 86
      IF(U(I,J).GT.0.0D0.AND.V(I,J).EQ.0.0D0) GO TO 87
      IF(U(I,J).LT.0.0D0.AND.V(I,J).EQ.0.0D0) GO TO 88
      IF(U(I,J).EQ.0.0D0.AND.V(I,J).EQ.0.0D0) GO TO 87
      ANGLE(I,J)=(DATAN(V2/U2))*57.2960D0
      GO TO 1
   82 ANGLE(I,J)=(6.2830D0-(DATAN(V2/U2)))*57.2960D0
      GO TO 1
   83 ANGLE(I,J)=(3.1420D0-(DATAN(V2/U2)))*57.2960D0
      GO TO 1
   84 ANGLE(I,J)=(3.1420D0+(DATAN(V2/U2)))*57.2960D0
      GO TO 1
   85 ANGLE(I,J)=90.0D0
      GO TO 1
   86 ANGLE(I,J)=270.0D0
      GO TO 1
   87 ANGLE(I,J)=0.0D0
      GO TO 1
   88 ANGLE(I,J)=180.0D0
    1 CONTINUE
      IF(IWR.EQ.1) GO TO 2
      WRITE(6,100) I,J,VV(I,J), ANGLE(I,J)
    2 CONTINUE
```

```
      WRITE(6,200)
      DO 3 I=2,M3
      DO 3 J=1,2
      U2=DABS(UBX(I,J))
      V2=DABS(VBX(I,J))
      VVBX(I,J)=DSQRT(U2*U2+V2*V2)
      IF(UBX(I,J).GT.0.0D0.AND.VBX(I,J).LT.0.0D0) GO TO 72
      IF(UBX(I,J).LT.0.0D0.AND.VBX(I,J).GT.0.0D0) GO TO 73
      IF(UBX(I,J).LT.0.0D0.AND.VBX(I,J).LT.0.0D0) GO TO 74
      IF(UBX(I,J).EQ.0.0D0.AND.VBX(I,J).GT.0.0D0) GO TO 75
      IF(UBX(I,J).EQ.0.0D0.AND.VBX(I,J).LT.0.0D0) GO TO 76
      IF(UBX(I,J).GT.0.0D0.AND.VBX(I,J).EQ.0.0D0) GO TO 77
      IF(UBX(I,J).EQ.0.0D0.AND.VBX(I,J).EQ.0.0D0) GO TO 77
      ANGL1(I,J)=(DATAN(V2/U2))*57.2960D0
      IF(UBX(I,J).LT.0.0D0.AND.VBX(I,J).EQ.0.0D0) GO TO 78
      GO TO 10
   72 ANGL1(I,J)=(6.2830D0-(DATAN(V2/U2)))*57.2960D0
      GO TO 10
   73 ANGL1(I,J)=(3.1420D0-(DATAN(V2/U2)))*57.2960D0
      GO TO 10
   74 ANGL1(I,J)=(3.1420D0+(DATAN(V2/U2)))*57.2960D0
      GO TO 10
   75 ANGL1(I,J)=90.0D0
      GO TO 10
   76 ANGL1(I,J)=270.0D0
      GO TO 10
   77 ANGL1(I,J)=0.0D0
      GO TO 10
   78 ANGL1(I,J)=180.0D0
   10 CONTINUE
      IF(IWR.EQ.1) GO TO 3
      WRITE(6,100) I,J,VVBX(I,J),ANGL1(I,J)
    3 CONTINUE
      WRITE(6,300)
      DO 4 J=2,M21
      DO 4 I=1,2
      U2=DABS(UBY(I,J))
      V2=DABS(VBY(I,J))
      VVBY(I,J)=DSQRT(U2*U2+V2*V2)
      IF(UBY(I,J).GT.0.0D0.AND.VBY(I,J).LT.0.0D0) GO TO 62
      IF(UBY(I,J).LT.0.0D0.AND.VBY(I,J).GT.0.0D0) GO TO 63
      IF(UBY(I,J).LT.0.0D0.AND.VBY(I,J).LT.0.0D0) GO TO 64
      IF(UBY(I,J).EQ.0.0D0.AND.VBY(I,J).GT.0.0D0) GO TO 65
      IF(UBY(I,J).EQ.0.0D0.AND.VBY(I,J).LT.0.0D0) GO TO 66
      IF(UBY(I,J).GT.0.0D0.AND.VBY(I,J).EQ.0.0D0) GO TO 67
      IF(UBY(I,J).LT.0.0D0.AND.VBY(I,J).EQ.0.0D0) GO TO 68
      IF(UBY(I,J).EQ.0.0D0.AND.VBY(I,J).EQ.0.0D0) GO TO 67
      ANGL2(I,J)=(DATAN(V2/U2))*57.2960D0
      GO TO 20
   62 ANGL2(I,J)=(6.2830D0-(DATAN(V2/U2)))*57.2960D0
      GO TO 20
   63 ANGL2(I,J)=(3.1420D0-(DATAN(V2/U2)))*57.2960D0
      GO TO 20
```

```
      64  ANGL2(I,J)=(3.1420D0+(DATAN(V2/U2)))*57.2960D0
          GO TO 20
      65  ANGL2(I,J)=90.0D0
          GO TO 20
      66  ANGL2(I,J)=270.0D0
          GO TO 20
      67  ANGL2(I,J)=0.0D0
          GO TO 20
      68  ANGL2(I,J)=180.0D0
      20  CONTINUE
          IF(IWR.EQ.1) GO TO 4
          WRITE(6,100) I,J,VVBY(I,J),ANGL2(I,J)
      4   CONTINUE
      14  FORMAT(1H1)
      100 FORMAT(20X,I5,5X,I5,5X,E20.9,5X,F8.4)
      149 FORMAT(/,10X,'ABSOLUTE VELOCITY & ITS DIR. WITH THE X COO. ',//)
      150 FORMAT(//,20X,'I     ',5X,'J     ',5X,'VV    ',20X,'THETA',/)
      200 FORMAT(//,20X,'I     ',5X,'J     ',5X,'VVBX  ',20X,'THETA',/)
      300 FORMAT(//,20X,'I     ',5X,'J     ',5X,'VVBY  ',20X,'THETA',/)
          RETURN
          END
```

```
          SUBROUTINE SHABAN
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /ONE/ V1
      COMMON /TWO/ ILO,IWR,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /FOUR/ R1,RF,IFREVO
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,BB
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      COMMON /PHI/ P(50,30),PBY(2,30),PBX(50,2),PP(50,30),PBY1(2,30),
     1   PBX1(50,2),F(50,30)
      COMMON /VEES/U(50,30),V(50,30),UBX(50,2),VBX(50,2),
     1  UBY(2,30),VBY(2,30),U1(50,30),V0(50,30),UBX1(50,2)
     1   ,VBX1(50,2),UBY1(2,30),VBY1(2,30),VV(50,30),ANGLE(50,30)
      COMMON /CAL/ M21,IC1,JC1,M11,N31,IC2
      COMMON /SH/ RG,GAMA,TO,WV,VE
      COMMON /RO/ ROA(50,30),ROBX(50,2),ROBY(2,30)
      COMMON /GO/ VVBX(50,2),VVBY(2,30),ANGL1(50,2),ANGL2(2,30)
C
CC CALCULATE POISSONS SOURCE DIS. F(I,J)
C
      DO 400 I=1,M3
      IF(IPG.EQ.1) GO TO 101
      DO 400 J=1,M2
  400 F(I,J)=0.0D0
      IF(ISYM.EQ.1) IIC=M1
      IF(ISYM.EQ.1.AND.IPAP.EQ.1) GO TO 777
      AA=0.0D0
      DO 555 I=2,IC1
      CALL INTPL(I)
  555 AA=AA+(JU-JL)*DY*DX
      DO 5556 I=IC2,M11
      CALL INTPL(I)
 5556 AA=AA+(JU-JL)*DY*DX
      DO 666 I=M1,M3
      CALL INTPL(I)
  666 AA=AA+(JU-JL)*DY*DX
      A1=(M3-IIC)*(N3-2)*DX*DY
      IF(ISYM.EQ.1) A1=(M3-IIC)*(N3-1)*DX*DY
      RH=B/(AA-A1)
      IF(IFREVO.EQ.1) GO TO 3336
      GO TO 1
 3336 CONTINUE
      R11=R1+H+R
      DO 401 I=2,M1
      R22=R1+H+(M1-I)*DX
      CALL INTP_(I)
      DO 401 J=JL,JU
  401 F(I,J)=R11*RH/R22
      GO TO 3337
  777 CONTINUE
      DO 11 I=2,M11
      CALL INTPL(I)
      DO 12 J=JL,JU
```

```
      X=(I-IC)*DX
      Y=(J-JC)*DY
      F(I,J)=5.39090D0*3*(1.0D0-(X*X+Y*Y)/(R*R))
   12 CONTINUE
   11 CONTINUE
 3337 IF(ICOD.EQ.0) GO TO 7
    1 IF(ICOD.EQ.0) GO TO 17
      CALL HOSNY
      DO 2 I=2,M3
      CALL INTPL(I)
      DO 2 J=JL,JU
    2 P(I,J)=ROA(I,J)
      DO 3 I=2,M3
      PBX(I,1)=ROBX(I,1)
    3 PBX(I,2)=ROBX(I,2)
      DO 4 J=1,M21
      PBY(1,J)=ROBY(1,J)
    4 PBY(2,J)=ROBY(2,J)
      ILO=1
      CALL HVVEL
      IF(IPAP.EQ.1) RH=0.0D0
      IF(IFREVO.EQ.1) RH=0.0D0
      IF(ISYM.EQ.1) IIC=M1-1
      DO 5 I=2,M3
      IF(I.GT.IIC) RH=0.0D0
      CALL INTPL(I)
      DO 5 J=JL,JU
    5 F(I,J)=F(I,J)*(ROBY(2,2)/ROA(I,J))+RH*(ROBY(2,2)/ROA(I,J))-
     1   (U1(I,J)*U(I,J)+V0(I,J)*V(I,J))/ROA(I,J)
      GO TO 7
   17 DO 6 I=2,M3
      IF(I.GT.IIC) RH=0.0D0
      CALL INTPL(I)
      DO 8 J=JL,JU
    8 F(I,J)=RH
    7 AE=0.0D0
      DO 444 I=2,IC1
      CALL INTPL(I)
      J1=JL
      J2=JU-1
      DO 444 J=J1,J2
  444 AE=AE+((F(I,J)+F(I+1,J)+F(I,J+1)+F(I+1,J+1))/4)*DX*DY
      DO 4446 I=IC2,M11
      CALL INTPL(I)
      J1=JL
      J2=JU-1
      DO 4446 J=J1,J2
 4446 AE=AE+((F(I,J)+F(I-1,J)+F(I,J+1)+F(I-1,J+1))/4)*DX*DY
      DO 333 I=M1,M3
      CALL INTPL(I)
      J1=JL
      J2=JU-1
      DO 333 J=J1,J2
```

```
      333 AE=AE+((F(I,J)+F(I-1,J)+F(I,J+1)+F(I-1,J+1))/4)*DX*DY
          AN=(B-N31*DY)*V1*ROBY(2,2)
          DO 29 J=1,N31
       29 AN=AN+V1*DY*ROBY(2,2)
          IF(ISYM.EQ.1.AND.IPAP.EQ.1) AA=1.5714300*R*R
          DO 30 I=2,M3
          CALL INTPL(I)
          DO 30 J=JL,JU
       30 F(I,J)=F(I,J)-(AE-AN)/AA
      101 CONTINUE
          IF(IWR.EQ.1) GO TO 300
          WRITE(6,200)
          DO 9 I=2,M3
        9 WRITE(6,100) I,(F(I,J),J=1,M21)
          WRITE(6,14)
       14 FORMAT(///,'**********************************************************
         1 ************************************************************',//)
      100 FORMAT(//,7X,'I  =',I10,/,4(8F10.5))
      200 FORMAT(/,10X,'POISSONS SOURCE DIS. AT EACH GRID POINT',//)
      300 CONTINUE
          RETURN
          END
```

```
      SUBROUTINE HOSNY
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /TWO/ ILO,IWR,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /FOUR/ R1,RF,IFREVD
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,BB
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      COMMON /VEES/U(50,30),V(50,30),UBX(50,2),VBX(50,2),
     1  UBY(2,30),VBY(2,30),U1(50,30),V0(50,30),UBX1(50,2)
     1   ,VBX1(50,2),UBY1(2,30),VBY1(2,30),VV(50,30),ANGLE(50,30)
      COMMON /CAL/ M21,IC1,JC1,M11,N31,IC2
      COMMON /SH/ RG,GAMA,TO,WV,VE
      COMMON /RO/ ROA(50,30),ROBX(50,2),ROBY(2,30)
      COMMON /GD/ VVBX(50,2),VVBY(2,30),ANGL1(50,2),ANGL2(2,30)
C
CC CALCULATE DENSITY ROA(I,J) AT EACH GRID POIN
C
      CP=RG*GAMA/(GAMA-1.0D0)
      POWER=1.0D0/(GAMA-1.0D0)
   83 DK=VE*VE/(2.0D0*CP*TO)
      IF(IPAP.EQ.1) GO TO 4
      DO 1 I=2,M3
      CALL INTPL(I)
      DO 1 J=JL,JU
      VEL=VV(I,J)*VV(I,J)+WV*WV
      T=1.0D0-DK*VEL
      IF(T.LE.0.000010D0) GO TO 80
      ROA(I,J)=T**POWER
    1 CONTINUE
      GO TO 8
    4 CONTINUE
      DO 5 I=2,M3
      CALL INTPL(I)
      DO 5 J=JL,JU
      X=(I-IC)*DX
      Y=(J-JC)*DY
      WV=5.0900D0*B*(1.0D0/RF)*(1.0D0-(X*X+Y*Y)/(R*R))
      VEL=VV(I,J)*VV(I,J)+WV*WV
      T=1.0D0-DK*VEL
      IF(T.LE.0.000010D0) GO TO 80
      ROA(I,J)=T**POWER
    5 CONTINUE
    8 DO 2 I=2,M3
      DO 2 J=1,2
      VEL=VVBX(I,J)*VVBX(I,J)
      T=1.0D0-DK*VEL
      IF(T.LE.0.000010D0) GO TO 80
    2 ROBX(I,J)=T**POWER
      DO 3 J=2,M21
      DO 3 I=1,2
      VEL=VVBY(I,J)*VVBY(I,J)
      T=1.0D0-DK*VEL
      IF(T.LE.0.000010D0) GO TO 80
```

```
      3   ROBY(I,J)=T**POWER
          GO TO 90
      80  CONTINUE
          WRITE(6,82) I,J,T,VEL,DK
      82  FORMAT(5X,2I10,3F12.7)
          VE=.90D0*VE
          WRITE(6,84) VE
      84  FORMAT(20X,'VE=',F12.7,//)
          GO TO 83
      90  RETURN
          END
```

```
      SUBROUTINE INTPL(I)
C
CC SUBROUTINE INTPL(I) FOR DETERMINING BOUNDARY POINTS FOR A GIVEN
CC COLUMN I,(I,JL(I)) IS THE LOWER MOST INTERIOR POINT AND
CC (I,JU(I)) IS THE UPPER MOST INTERIOR POINT
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /TWO/ ILO,IWR,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,B8
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
C
      IF(I .GT. IC) GO TO 10                                          1
      X=(I-1)*DX-R                                                    2
      YY2=DABS(R*R-X*X)
      YY=DSQRT(YY2)
      IF(ISYM.EQ.1) GO TO 9
      Y1=R-YY                                                         5
      Y2=R+YY                                                         6
      JL=(Y1/DY+0.01000D0)+2
      JU=(Y2/DY-0.01000D0)+1
      GO TO 40                                                        9
    9 JL=1
      JU=(YY/DY-0.010D0)+1
      GO TO 40
   10 CONTINUE                                                        10
      IF(I.EQ.M1) GO TO 19                                            11
      IF(I.GT.M1) GO TO 20                                            12
      X=(I-1)*DX-R                                                    14
      YY2=DABS(R*R-X*X)
      YY=DSQRT(YY2)
      IF(ISYM.EQ.1) GO TO 18
      JL=2                                                            13
      Y2=R+YY                                                         17
      JU=(Y2/DY-0.01000D0)+1
      GO TO 40                                                        19
   18 JL=1
      JU=(YY/DY-0.010D0)+1
      IF(YY.LT.B) JU=N3
      GO TO 40
   20 CONTINUE                                                        20
      IF(ISYM.EQ.1) GO TO 30
      JL=2                                                            21
      IF(I.GT.IIC) GO TO 30
      X=RC-(I-M1)*DX                                                  24
      YY2=DABS(RC*RC-X*X)
      YY=DSQRT(YY2)
      Y1=(RC+B)-YY                                                    27
      JU=(Y1/DY-0.01000D0)+1
      GO TO 40                                                        29
   19 CONTINUE                                                        30
      IF(ISYM.EQ.1) GO TO 30
      JL=2                                                            31
```

```
      JU=JJC                                                        31M
      GO TO 40                                                      32
   30 CONTINUE                                                      33
      JL=2                                                          34
      IF(ISYM.EQ.1) JL=1
      JU=(B/DY-0.00100D0)+1
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MESH(I,J)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /TWO/ ILO,IWR,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,B8
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      COMMON /PHI/ P(50,30),PBY(2,30),PBX(50,2),PP(50,30),PBY1(2,30),
     1   PBX1(50,2),F(50,30)
C
CC DETERMINE THE STANDARD FIVE POINTS LAPLACE DIFF. OPERATOR AND
CC THEIR POSITIONS S1,S2,S3,S4 W.R.T. POINT O(X,Y)
C
      IF(J.EQ.JL.AND.J.EQ.JU) GO TO 101
      IF(J.EQ.JL) GO TO 50                                          0001
      IF(J.EQ.JJ) GO TO 60                                          0002
      S2=1.0D0
      P2=P(I,J+1)                                                   0004
      S4=1.0D0
      P4=P(I,J-1)                                                   0006
      GO TO 70                                                      0007
   50 CONTINUE                                                      0008
      IF(ISYM.EQ.1) GO TO 51
      IF(I.GT.IC) GO TO 51                                          0009
      S2=1.0D0
      P2=P(I,J+1)                                                   0011
      X=R-(I-1)*DX                                                  0012
      YY2=DABS(R*R-X*X)
      YY=DSQRT(YY2)
      Y1=YY-(JC-J)*DY
      S4=Y1/DY
      IF(S4.GT.1.0D0) S4=1.0D0
      P4=PBX(I,1)
      GO TO 70
   51 CONTINUE                                                      0019
      S2=1.0D0
      P2=P(I,J+1)                                                   0021
      S4=1.0D0
      P4=PBX(I,1)                                                   0023
      GO TO 70                                                      0024
   60 CONTINUE                                                      0025
      IF(I.EQ.M1) GO TO 62                                          0037
      IF(I.GT.M1) GO TO 65                                          0038
      X=(IC-I)*DX
      YY2=DABS(R*R-X*X)
      YY=DSQRT(YY2)
      Y1=YY-(J-JC)*DY                                               0030
      S2=Y1/DY                                                      0031
      IF(YY.LT.B) S2=(B-(J-1)*DY)/DY
      IF(S2.GT.1.0D0) S2=1.0D0
      P2=PBX(I,2)                                                   0032
      S4=1.0D0
      P4=P(I,J-1)                                                   0034
      GO TO 70                                                      0035
```

```
      62  CONTINUE                                                      0048
          IF(ISYM.EQ.1) GO TO 64
          S2=1.0D0
          P2=PBX(I,2)                                                   0050
          S4=1.0D0
          P4=P(I,J-1)                                                   0052
          GO TO 70                                                      0053
      65  CONTINUE                                                      0054
          IF(ISYM.EQ.1) GO TO 64
          IF(I.GT.IIC) GO TO 64                                         0055
          XC=RC-(I-M1)*DX                                               0056
          YY2=DABS(RC*RC-XC*XC)
          YY=DSQRT(YY2)
          YC=B+RC-YY-(J-1)*DY                                           0059
          S2=YC/DY                                                      0060
          IF(S2.GT.1.0D0) S2=1.0D0
          P2=PBX(I,2)                                                   0061
          S4=1.0D0
          P4=P(I,J-1)                                                   0063
          GO TO 70                                                      0064
      64  CONTINUE                                                      0065
          Y2=B-(J-1)*DY                                                 0066
          S2=Y2/DY                                                      0067
          IF(S2.GT.1.0D0) S2=1.0D0
          P2=PBX(I,2)                                                   0068
          S4=1.0D0
          P4=P(I,J-1)                                                   0070
          GO TO 70
     101  CONTINUE
          Y=B-(J-1)*DY
          S2=Y/DY
          IF(S2.GT.1.0D0) S2=1.0D0
          P2=PBX(I,2)
          S4=1.0D0
          P4=PBX(I,1)
      70  CONTINUE                                                      0071
          IF(I.EQ.IL) GO TO 80                                          0073
          IF(I.EQ.IR) GO TO 90                                          0074
          S1=1.0D0
          P1=P(I-1,J)                                                   0076
          S3=1.0D0
          P3=P(I+1,J)                                                   0078
          GO TO 100                                                     0079
      80  CONTINUE                                                      0080
          Y=(JC-J)*DY
          XX2=DABS(R*R-Y*Y)
          XX=DSQRT(XX2)
          X1=XX-(IC-I)*DX                                               0085
          S1=X1/DX                                                      0086
          IF(S1.GT.1.0D0) S1=1.0D0
          P1=PBY(I,J)                                                   0087
          S3=1.0D0
          P3=P(I+1,J)
```

```
      GO TO 100                                                          0090
   50 CONTINUE                                                           00101
      IF(J.GT.M3) GO TO 91                                               00102
      S1=1.0D0
      P1=P(I-1,J)                                                        00104
      XX=H-(M3-M1)*DX                                                    00105
      S3=XX/DX                                                           00106
      IF(S3.GT.1.0D0) S3=1.0D0
      P3=PBY(2,J)                                                        00107
      GO TO 100                                                          00108
   91 CONTINUE                                                           00109
      IF(ISYM.EQ.1) GO TO 93
      IF(J.GT.JJC) GO TO 92                                              00110
      S1=1.0D0
      P1=P(I-1,J)                                                        00112
      YC=B+RC-(J-1)*DY                                                   00113
      XXC=DABS(RC*RC-YC*YC)
      XC=DSQRT(XXC)
      X1=RC-XC-(I-M1)*DX
      S3=X1/DX                                                           00116
      IF(S3.GT.1.0D0) S3=1.0D0                                           00117
      P3=PBY(2,J)
      GO TO 100                                                          00118
   92 CONTINUE                                                           00119
      IF(J.GT.JC) GO TO 93                                               00120
      S1=1.0D0                                                           00121
      P1=P(I-1,J)
      S3=1.0D0                                                           00123
      P3=PBY(2,J)
      GO TO 100                                                          00125
   93 CONTINUE                                                           00126
      S1=1.0D0                                                           00127
      P1=P(I-1,J)
      Y=(J-JC)*DY                                                        00129
      XX2=DABS(R*R-Y*Y)                                                  00130
      XX=DSQRT(XX2)
      X1=XX-(I-IC)*DX
      S3=X1/DX                                                           00133
      IF(S3.GT.1.0D0) S3=1.0D0                                           00134
      P3=PBY(2,J)
  100 CONTINUE                                                           00135
      RETURN                                                             00136
      END                                                                00139
```

```
      SUBROUTINE IRL(J)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /TWO/ ILO,IWR,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,B3
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
C
CC SUBROUTINE  IRL(J) FOR DETERMINING BOUNDARY POINTS FOR A  IVEN
CC ROW J,(J,IL(J)) IS THE FIRST INTERIOR POINT &(J,IR(J)) IS THE MAXIMUM
CC INTERIOR POINT
C
      IF(J.GT.N3) GO TO 1000                                          01
      Y=(JC-J)*DY
      XX2=DABS(R*R-Y*Y)
      XX=DSQRT(XX2)
      X1=R-XX                                                         05
      IL=(X1/DX+0.01000D0)+2
      IR=M3                                                           07
      GO TO 4000                                                      08
 1000 CONTINUE                                                        09
      IF(ISYM.EQ.1) GO TO 3000
      IF(J.GT.JJC)  GO TO 2000                                        010
      Y=R-(J-1)*DY                                                    011
      XX2=DABS(R*R-Y*Y)
      XX=DSQRT(XX2)
      X1=R-XX                                                         014
      IL=(X1/DX+0.01000D0)+2
      YC=B+RC-(J-1)*DY                                                016
      XXC=DABS(RC*RC-YC*YC)
      XC=DSQRT(XXC)
      X1=RC-XC                                                        019
      IR=(X1/DX-0.01000D0)+M1
      GO TO 4000                                                      021
 2000 CONTINUE                                                        022
      IF(J.GT.JC) GO TO 3000                                          023
      Y=(J-1)*DY-R                                                    024
      XX2=DABS(R*R-Y*Y)
      XX=DSQRT(XX2)
      X1=R-XX                                                         027
      IL=(X1/DX+0.01000D0)+2
      IR=M1-1                                                         029
      GO TO 4000                                                      030
 3000 CONTINUE                                                        031
      Y=(J-JC)*DY
      XX2=DABS(R*R-Y*Y)
      XX=DSQRT(XX2)
      X1=R-XX                                                         035
      IL=(X1/DX+0.01000D0)+2
      IR=(XX/DX-0.01000D0)+IC
 4000 CONTINUE                                                        040
      RETURN
      END
```

```
      SUBROUTINE ECSI(I)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /TWO/ ILD,I*R,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,BB
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IK
      COMMON /PHI/ P(50,30),PBY(2,30),PBX(50,2),PP(50,30),PBY1(2,30),
     1   PBX1(50,2),F(50,30)
      COMMON /INPC/ PL,PU,PT,PR
C
CC CALCULATE POTENTIAL FUNCTION ALONG THE B. FOR EACH I (PBX1,PBX2)
C
      IF(I .GE. IC) GO TO 180                                          1
      J=JL                                                             2
      CALL IRL(J)
      CALL  MESH(I,J)                                                  3
      X=(IC-I)*DX                                                      4
      YY=DABS(R*R-X*X)
      Y=DSQRT(YY)
      IF(ISYM.EQ.1) GO TO 100
      SS=S4*DY*X+DX*Y                                                  7
      PL=(1+S4)*P(I+1,J)-S4*P(I+1,J+1)
      PBX(I,1)=(S4*DY*X*PL+DX*Y*P(I,J))/SS
      GO TO 101
  100 PBX(I,1)=P(I,J)
      PL=PBX(I,1)
  101 J=JU
      CALL IRL(J)
      CALL MESH(I,J)
      SS=S2*DY*X+DX*Y                                                  11
      PU=(1+S2)*P(I+1,J)-S2*P(I+1,J-1)                                 12
      PBX(I,2)=(DX*Y*P(I,J)+DY*S2*X*PU)/SS                             13
      GO TO 900                                                        14
  180 CONTINUE                                                         15
      IF(I .GT. IC) GO TO 190                                          16
      J=JL                                                             17
      PBX(I,1)=P(I,J)                                                  18
      PL=PBX(I,1)
      J=JU                                                             19
      PBX(I,2)=P(I,J)                                                  20
      PU=PBX(I,2)
      GO TO 900                                                        21
  190 CONTINUE                                                         22
      IF(I .GE. M1) GO TO 210                                          23
      J=JL                                                             24
      PBX(I,1)=P(I,J)                                                  25
      PL=PBX(I,1)
      J=JU                                                             26
      IF(J.LE.N3) GO TO 216
      CALL IRL(J)
      CALL MESH(I,J)                                                   27
      X=(I-IC)*DX                                                      28
      YY=DABS(R*R-X*X)
```

```
      Y=DSQRT(YY)
      SS=DY*S2*X+DX*Y                                              31
      PU=(1+S2)*P(I-1,J)-S2*P(I-1,J-1)                             32
      PBX(I,2)=(DX*Y+P(I,J)+S2*DY*X*PU)/SS                         33
      GO TO 900                                                    34
  215 PBX(I,2)=P(I,J)
      PU=PBX(I,2)
      GO TO 900
  210 CONTINUE                                                     35
      IF(ISYM.EQ.1) GO TO 214
      IF(I.GT.M1) GO TO 212                                        36
      J=JL                                                         37
      PBX(I,1)=P(I,J)                                              38
      PL=PBX(I,1)
      J=JJ                                                         39
      PBX(I,2)=P(I-1,J+1)                                          40
      PU=PBX(I,2)
      GO TO 900                                                    41
  212 CONTINUE                                                     42
      IF(I.GT.IIC) GO TO 214                                       43
      J=JL                                                         44
      PBX(I,1)=P(I,J)                                              45
      PL=PBX(I,1)
      J=JU                                                         46
      CALL IRL(J)
      CALL MESH(I,J)                                               47
      X=RC-(I-M1)*DX                                               48
      YY=DABS(RC*RC-X*X)
      Y=DSQRT(YY)
      SS=DY*S2*X+DX*Y                                              51
      PU=(1+S2)*P(I-1,J)-S2*P(I-1,J-1)                             52
      PBX(I,2)=(DY*S2*X*PU+DX*Y*P(I,J))/SS                         53
      GO TO 900                                                    54
  214 CONTINUE
      J=JL
      PBX(I,1)=P(I,J)                                              56
      PL=PBX(I,1)
      J=JU                                                         57
      PBX(I,2)=P(I,J)                                              58
      PU=PBX(I,2)
  900 CONTINUE                                                     59
      RETURN
      END
```

```
      SUBROUTINE BCSJ(J,V1)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /TWO/ IL,IR,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,B3
      COMMON /GRM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      COMMON /PHI/ P(50,30),PBY(2,30),PBX(50,2),PP(50,30),PBY1(2,30),
     1   PBX1(50,2),F(50,30)
      COMMON /INPO/ PL,PU,PT,PR
C
CC CALCULATE POTENTIAL FUNCTION ALONG THE B. FOR EACH J (PBY1,PBY2)
C
      IF(J .GE. JC) GO TO 200
      I=IL
      CALL INTPL(I)
      CALL MESH(I,J)
      Y=(JC-J)*DY
      XX=DABS(R*R-Y*Y)
      X=DSQRT(XX)
      SS=DY*X+DX*S1*Y
      PT=(1+S1)*P(I,J+1)-S1*P(I+1,J+1)
      PBY(1,J)=(DY*X*P(I,J)+DX*S1*Y*PT)/SS
      I=IR
      CALL INTPL(I)
      CALL MESH(I,J)
      IF(J .GT. N3) GO TO 110
      PBY(2,J)=P(I,J)+DX*S3*V1
      PR=PBY(2,J)
      GO TO 900
  110 CONTINUE
      IF(J .GT. JJC) GO TO 120
      Y=B+RC-(J-1)*DY
      XX=DABS(RC*RC-Y*Y)
      X=DSQRT(XX)
      SS=DX*S3*Y+DY*X
      PR=(1+S3)*P(I,J-1)-S3*P(I-1,J-1)
      PBY(2,J)=(DY*X*P(I,J)+DX*S3*Y*PR)/SS
      GO TO 900
  120 CONTINUE
      PBY(2,J)=P(I,J)
      PR=PBY(2,J)
      GO TO 900
  200 CONTINUE
      IF(J .GT. JC) GO TO 210
      I=IL
      PBY(1,J)=P(I,J)
      PT=PBY(1,J)
      I=IR
      CALL INTPL(I)
      CALL MESH(I,J)
      IF(ISYM.EQ.1) GO TO 101
      PBY(2,J)=P(I,J)
      GO TO 102
```

```
      101 PBY(2,J)=P(I,J)+DX*S3*V1
      102 PR=PBY(2,J)
          GO TO 900
      210 CONTINUE
          I=IL
          CALL INTPL(I)
          CALL MESH(I,J)
          Y=(J-JC)*DY
          XX=DABS(R*R-Y*Y)
          X=DSQRT(XX)
          SS=DX*S1*Y+DY*X
          PT=(1+S1)*P(I,J-1)-S1*P(I+1,J-1)
          PBY(I,J)=(DX*S1*Y*PT+DY*X*P(I,J))/SS
          I=IR
          CALL INTPL(I)
          CALL MESH(I,J)
          IF(ISYM.EQ.0) GO TO 260
          IF(J.GT.N3) GO TO 260
          PBY(2,J)=P(I,J)+DX*S3*V1
          PR=PBY(2,J)
          GO TO 900
      260 Y=(J-JC)*DY
          XX=DABS(R*R-Y*Y)
          X=DSQRT(XX)
          SS=DX*S3*Y+DY*X
          PP=(1+S3)*P(I,J-1)-S3*P(I-1,J-1)
          PBY(2,J)=(DY*X*P(I,J)+DX*S3*Y*PR)/SS
      900 CONTINUE
          RETURN
          END
```

```
      SUBROUTINE HVVEL
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /ONE/ V1
      COMMON /TWO/ ILU,IWR,ISYM,IPAP,ICOD,IP,ICOM
      COMMON /DIMS/ R,RC,H,B,DX,DY,B1,BB
      COMMON /FORM/ M1,M2,IC,JC,IIC,JJC,M3,N3
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      COMMON /PHI/ P(50,30),PBY(2,30),PBX(50,2),PP(50,30),PBY1(2,30),
     1   PBX1(50,2),F(50,30)
      COMMON /VEES/U(50,30),V(50,30),UBX(50,2),VBX(50,2),
     1  UBY(2,30),VBY(2,30),U1(50,30),V0(50,30),UBX1(50,2)
     1   ,VBX1(50,2),UBY1(2,30),VBY1(2,30),VV(50,30),ANGLE(50,30)
      COMMON /INPO/ PL,PU,PT,PR
C
CC CALCULATE VELOCITY COMPONENTS U,V IN THE X&Y  DIR. (U=DP/DX ,V=DP/DY)
C
      IF(IWR.EQ.1) GO TO 25
      WRITE(6,14)
      WRITE(6,400)
      WRITE(6,107)
   25 CONTINUE
      DO 10 I=2,M3
      CALL INTPL(I)
      DO 20 J=JL,JU
      CALL IRL(J)
      CALL MESH(I,J)
      C13=S1/(S3*(S3+S1))
      C31=S3/(S1*(S3+S1))
      C1=(S1-S3)/(S1*S3)
      C24=S2/(S4*(S2+S4))
      C42=S4/(S2*(S2+S4))
      C2=(S4-S2)/(S2*S4)
      U(I,J)=(P3*C13-P1*C31-P(I,J)*C1)/DX
      IF(J.EQ.1) P4=P2
      V(I,J)=(P2*C42-P4*C24-P(I,J)*C2)/DY
      IF(ILO.EQ.1) GO TO 20
      U1(I,J)=U(I,J)
      V0(I,J)=V(I,J)
      IF(IWR.EQ.1) GO TO 20
      WRITE(6,111) I,J,U(I,J),V(I,J)
   20 CONTINUE
   10 CONTINUE
      IF(IWR.EQ.1) GO TO 30
      IF(ISYM.EQ.1) GO TO 666
      WRITE(6,108)
      GO TO 30
  666 WRITE(6,109)
   30 IF(ISYM.EQ.1) IIC=M1
      DO 50 I=2,M3
      CALL INTPL(I)
      IF(I.EQ.M3) GO TO 100
      J=JL
      CALL IRL(J)
```

```
      CALL MESH(I,J)
      CALL BCSI(I)
      IF(I.GE.IC) PL=PBX(I+1,1)
      UBX(I,1)=(PL-PBX(I,1))/DX
      VBX(I,1)=(P(I,J)-PBX(I,1))/(S4*DY)
      J=JU
      CALL IRL(J)
      CALL MESH(I,J)
      CALL BCSI(I)
      IF(I.GE.IIC) PU=PBX(I+1,2)
      UBX(I,2)=(PU-PBX(I,2))/DX
      IF(I.GT.IC) UBX(I,2)=-UBX(I,2)
      IF(I.GE.IIC) UBX(I,2)=-UBX(I,2)
      VBX(I,2)=(PBX(I,2)-P(I,J))/(S2*DY)
      GO TO 900
  100 CONTINUE
      J=JL
      UBX(I,1)=(PBX(I,1)-PBX(I-1,1))/DX
      VBX(I,1)=(P(I,J)-PBX(I,1))/DY
      J=JJ
      CALL IRL(J)
      CALL MESH(I,J)
      CALL BCSI(I)
      UBX(I,2)=(PBX(I,2)-PBX(I-1,2))/DX
      VBX(I,2)=(PBX(I,2)-P(I,J))/(S2*DY)
  900 CONTINUE
      IF(ILO.EQ.1) GO TO 50
      UBX1(I,1)=UBX(I,1)
      VBX1(I,1)=VBX(I,1)
      UBX1(I,2)=UBX(I,2)
      VBX1(I,2)=VBX(I,2)
      IF(IWR.EQ.1) GO TO 50
      IF(ISYM.EQ.1) GO TO 103
      WRITE(6,310) UBX(I,1),VBX(I,1),UBX(I,2),VBX(I,2)
      GO TO 50
  103 WRITE(6,210) UBX(I,2),VBX(I,2)
   50 CONTINUE
      M21=M2-1
      IF(IWR.EQ.1) GO TO 15
      WRITE(6,777)
   15 CONTINUE
      DO 60 J=2,M21
      CALL IRL(J)
      I=IL
      CALL INTPL(I)
      CALL MESH(I,J)
      CALL BCSJ(J,V1)
      UBY(1,J)=(P(I,J)-PBY(I,J))/(S1*DX)
      VBY(1,J)=(PT-PBY(I,J))/DY
      IF(J.GE.JC) VBY(1,J)=-VBY(1,J)
      I=IR
      CALL INTPL(I)
      CALL MESH(I,J)
```

```
      CALL BCSJ(J,V1)
      IF(J.GT.N3) GO TO 180
      UBY(2,J)=(PBY(2,J)-P(I,J))/(S3*DX)
      VBY(2,J)=0.000
      GO TO 2000
  180 CONTINUE
      IF(ISYM.EQ.1) GO TO 240
      IF(J.GT.JJC) GO TO 190
      UBY(2,J)=(PBY(2,J)-P(I,J))/(S3*DX)
      VBY(2,J)=(PBY(2,J)-PR)/DY
      GO TO 2000
  190 CONTINUE
      IF(J.GE.JC) GO TO 220
      UBY(2,J)=(PBY(2,J)-P(I,J))/DX
      VBY(2,J)=(PBY(2,J+1)-PBY(2,J))/DY
      GO TO 2000
  220 CONTINUE
      IF(J .GT. JC) GO TO 240
      UBY(2,J)=(PBY(2,J)-P(I,J))/DX
      VBY(2,J)=(PBY(2,J)-PBY(2,J-1))/DY
      GO TO 2000
  240 CONTINUE
      UBY(2,J)=(PBY(2,J)-P(I,J))/(S3*DX)
      VBY(2,J)=(PBY(2,J)-PR)/DY
 2000 CONTINUE
      IF(ILD.EQ.1) GO TO 60
      UBY1(1,J)=UBY(1,J)
      VBY1(1,J)=VBY(1,J)
      UBY1(2,J)=UBY(2,J)
      VBY1(2,J)=VBY(2,J)
      IF(IWR.EQ.1) GO TO 60
      WRITE(6,310) UBY(1,J),VBY(1,J),UBY(2,J),VBY(2,J)
   60 CONTINUE
   14 FORMAT(1H1)
  107 FORMAT(//,10X,'I     ',5X,'J     ',5X,'U     ',20X,'V     ')
  108 FORMAT(//,10X,'UBX1  ',15X,'VBX1  ',15X,'UBX2  ',15X,'VBX2  ')
  111 FORMAT(10X,I5,5X,I5,10X,D15.6,10X,D15.6)
  210 FORMAT(//,10X,2(5X,D15.6))
  310 FORMAT(//,10X,4(5X,D15.6))
  400 FORMAT(10X,'VELOCITY COMP. U&V IN THE X& Y DIR.',//)
  777 FORMAT(//,10X,'UBY1    ',15X,'VBY1    ',15X,'UBY2    ',15X,'VBY2')
  109 FORMAT(//,15X,'UBX2  ',15X,'VBX2  ',/)
      RETURN
      END
```

```
      SUBROUTINE PLTISO(JMAXO,ISYMBL,IUPODW,SIZE,VISOBR,VAR,X,Y)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /MSH/ S1,S2,S3,S4,P1,P2,P3,P4,JL,JU,IL,IR
      DIMENSION VAR(32,21),X(32,21),Y(32,21)
      IC=ISYMBL
      ICA=IUPODW
      JMAXO1=JMAXO-1
      NNN=1
 1115 CONTINUE
 1113 DO 1128 J=1,JMAXO1
      CALL IRL(J)
      DO 1130 INV=IL,IR
      IIB=1
      I=IR+IL-INV
 1103 IF((VAR(I,J).GT.VISOBR).AND.(VAR(I ,J+1).GT.VISOBR)) GO TO 1117
      IF((VAR(I,J).LT.VISOBR).AND.(VAR(I ,J+1).LT.VISOBR)) GO TO 1117
      IIB=1
      DS= X(I,J+1)- X(I,J)
      DSS=DS*(VISOBR-VAR(I,J))/(VAR(I,J+1)-VAR(I,J))
C     YYB=          ( Y(I,J)+ Y(I,J+1))/2.
      DN= Y(I,J+1)- Y(I,J)
      DNN=DN*(VISOBR-VAR(I,J))/(VAR(I,J+1)-VAR(I,J))
      XXB=          ( X(I,J)+DSS)
      YYB=          ( Y(I,J+1)-(DN-DNN))
      WRITE(6,1114) XXB,YYB,I,J,VISOBR,VAR(I,J+1),VAR(I,J),DS,DN
 1114 FORMAT(2X,'XXB=',F10.5,2X,'YYB=',F10.6,2X,'I=',I3,2X,'J=',I2,2X,
     1 'VISOBR=',F14.6,3X,4(F10.6))
      IF(NNN.EQ.1) GO TO 1116
      CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-1  )
C     CALL SYMBOL (-YYB,XXB,SIZE,IC,0.,-1)
CCC   CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-ICA)
      GO TO 1120
 1116 NNN=0
      CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-1)
C     CALL SYMBOL (-YYB,XXB,SIZE,IC,0.,-1)
      GO TO 1120
 1117 IIB=2
      IF((VAR(I,J).GT.VISOBR).AND.(VAR(I-1,J).GT.VISOBR)) GO TO 1123
      IF((VAR(I,J).LT.VISOBR).AND.(VAR(I-1,J).LT.VISOBR)) GO TO 1125
 1109 DN=( Y(I,J)- Y(I-1,J))
      DNN=DN*(VISOBR-VAR(I-1,J))/(VAR(I,J)-VAR(I-1,J))
      YYB=          ( Y(I,J)-(DN-DNN))
      DS= X(I,J)- X(I-1,J)
      DSS=DS*(VISOBR-VAR(I-1,J))/(VAR(I,J)-VAR(I-1,J))
      XXB=          ( X(I,J)-(DS-DSS))
      WRITE(6,1114) XXB,YYB,I,J,VISOBR,VAR(I-1,J),VAR(I,J),DS,DN
      IF(NNN.EQ.1) GO TO 1118
      ICA=2
      IF(IIB.EQ.2) ICA=1
      CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-ICA)
C     CALL SYMBOL (-YYB,XXB,SIZE,IC,0.,-1)
      IF(IIB.EQ.1) GO TO 1127
      GO TO 1124
```

```
 1118 NNN=0
      CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-1)
C     CALL SYMBOL (-YYB,XXB,SIZE,IC,0.,-1)
      IF(IIB.EQ.1) GO TO 1127
      GO TO 1124
 1120 IF((VAR(I-1,J+1).GT.VISOBR).AND.( VAR(I,J+1).GT.VISOBR)) GO TO
     1 1124
      IF((VAR(I-1,J+1).LT.VISOBR).AND.( VAR(I,J+1).LT.VISOBR)) GO TO
     1 1124
 1121 DN=( Y(I,J+1)- Y(I-1,J+1))
      DNN=DN*(VISOBR-VAR(I-1,J+1))/(VAR(I,J+1)-VAR(I-1,J+1))
      YYB=        ( Y(I,J+1)-(DN-DNN))
      DS= X(I,J+1)- X(I-1,J+1)
      DSS=DS*(VISOBR-VAR(I-1,J+1))/(VAR(I,J+1)-VAR(I-1,J+1))
      XXB=        ( X(I,J+1)-(DS-DSS))
      WRITE(6,1114) XXB,YYB,I,J,VISOBR,VAR(I-1,J+1),VAR(I,J+1),DS,DN
      IF(NNN.EQ.1) GO TO 1122
      CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-2  )
C     CALL SYMBOL (-YYB,XXB,SIZE,IC,0.,-1)
CCC   CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-ICA)
      GO TO 1127
 1122 NNN=0
      CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-1)
C     CALL SYMBOL (-YYB,XXB,SIZE,IC,0.,-1)
      GO TO 1127
 1124 IF((VAR(I-1,J).GT.VISOBR).AND.(VAR(I-1,J+1).GT.VISOBR).AND.(IIB.EQ
     1.1)) GO TO 1109
      IF((VAR(I-1,J).LT.VISOBR).AND.(VAR(I-1,J+1).LT.VISOBR).AND.(IIB.EQ
     1.1)) GO TO 1109
      IF((VAR(I-1,J).GT.VISOBR).AND.(VAR(I-1,J+1).GT.VISOBR).AND.(IIB.EQ
     1.2)) GO TO 1121
      IF((VAR(I-1,J).LT.VISOBR).AND.(VAR(I-1,J+1).LT.VISOBR).AND.(IIB.EQ
     1.2)) GO TO 1121
      GO TO 1125
 1123 IIB=5
      IF((VAR(I-1,J).GT.VISOBR).AND.(VAR(I-1,J+1).GT.VISOBR)) GO TO 1127
      IF((VAR(I-1,J).LT.VISOBR).AND.(VAR(I-1,J+1).LT.VISOBR)) GO TO 1127
 1125 DS= X(I-1,J+1)- X(I-1,J)
      DSS=DS*(VISOBR-VAR(I-1,J))/(VAR(I-1,J+1)-VAR(I-1,J))
      XXB=        ( X(I-1,J)+DSS)
      DN= Y(I-1,J+1)- Y(I-1,J)
      DNN=DN*(VISOBR-VAR(I-1,J))/(VAR(I-1,J+1)-VAR(I-1,J))
      YYB=        ( Y(I-1,J+1)-(DN-DNN))
      WRITE(6,1114) XXB,YYB,I,J,VISOBR,VAR(I-1,J),VAR(I-1,J+1),DS,DN
      IF(NNN.EQ.1) GO TO 1126
      ICA=2
      IF(IIB.EQ.5) ICA=1
      CALL SYMBOL(XXB,YYB,SIZE,IC,0.,-ICA)
      IF(IIB.EQ.5) GO TO 1121
      GO TO 1127
 1126 NNN=0
      CALL SYMBOL (XXB,YYB,SIZE,IC,0.,-1)
C     CALL SYMBOL (-YYB,XXB,SIZE,IC,0.,-1)
```

```
      IF(IIB.EQ.5) GO TO 1121
 1127 CONTINUE
 1130 CONTINUE
 1128 CONTINUE
      NNN=1
      RETURN
      END
```

INPUT DATA

In the following, the different parameters used to specify the cases that can be computed using the computer program, will be explained, then a description in details of how to prepare the input data will be given.

Control Parameters for Computations

1. (a) Symmetric scroll cross section, ISYM = 1.
   (b) Nonsymmetric scroll cross section, ISYM = 0.
2. The type of through flow profile is specified using the parameters IFG, IFREVO, and IPAP.
   (a) IFG = 1, IPAP = 0, IFREVO = 0, for an arbitrary source distribution. In this case the source strength is fed as an input at all the interior mesh points.
   (b) IPAP = 1, IFG = 0, IFREVO = 0, for a circular paraboloid source distribution.
   (c) IFREVO = 1, IPAP = 0, IFG = 0, for free vortex source distribution.
   (d) IFG = 0, IPAP = 0, IFREVO = 0, represents uniform source distribution.
3. Either compressible or incompressible flow solutions are obtained by specifying the value of the parameter ICOM. Compressible flow solutions specify ICOM = 1, and for incompressible flow case ICOM = 0.

How to Prepare the Input

The input is divided into seven sets, and is given in the following.

First Set (Fluid Properties), one card

READ: RG, GAMA, TO, VE

according to format (4F10.0)

Second Set (Scroll Geometry), one card

READ: M1, M2, DO, R1, B, H, R, RC

according to format (2I10, 6F10.0)

Third Set (Control Parameters), one card

READ: ICOM, ISYM, IFG, IPAP, IFREVO

according to format (5I10)

Fourth Set (Numerical Parameters), one card

READ: ITMAX, EPSMAX, WO, WOP

according to format (I10, 3F10.0)

Fifth Set (Output Control Parameters), one card

READ: IP, IVPLOT, IPLT

according to format (3I10)

Sixth Set (Values for Velocity Potential Contour Plotting), number of cards is equal to IPLT

READ: VISOBR

according to format (F10.0)

VISOBR Numerical values of the velocity potential contours to be plotted as output.

Seventh Set (Arbitrary Source Distribution)

Is required only in the case of arbitrary source distribution, i.e., IFG = 1. The value of the source distribution F(I,J) is read in DO loop according to format (8F10.0). The input data is fed starting from I = 1 to I = M_3, and marching in J direction from J = JL, JU as shown in Fig. 3a. (Ref. 1)

OUTPUT

The program output includes a printout of the pertinent flow properties at all the grid points every IP iteration and of two figures, one for the desired velocity potential contours as specified by IPLT and VISOBR and the second showing the velocity direction in the cross-sectional plane.

Samples of the program output are included in Ref. 1.