数值传热学

第11章 求解二维椭圆型流动与换热问题通用程序介绍（续）

主讲 陶文铨

西安交通大学能源与动力工程学院
热流科学与工程教育部重点实验室
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Numerical Heat Transfer
(数值传热学)

Chapter 11 General Code for 2D Elliptical Fluid Flow and Heat Transfer Problems (Ctd.)

Instructor Tao, Wen-Quan

CFD-NHT-EHT Center
Key Laboratory of Thermo-Fluid Science & Engineering
Xi'an Jiaotong University
Xi'an, 2015-Dec.-16

11. 6 Methods of application and explanation of MAIN

11.6.1 Methods of application

11.6.2 Explanation of MAIN Program

MODULE START_L

PROGRAM MAIN

SUBROUTINE DIFLOW

SUBROUTINE SOLVE

SUBROUTINE SETUP

SUBROUTINE SUPPLY

11. 6 Methods of Application and Explanation of MAIN

11.6.1 Methods of application

1.**Establishing** complete mathematical formulation and comparing with the standard equation:

$$\frac{\partial(\rho^{*}\phi)}{\partial t}+div(\rho^{*}\vec{u}\phi)=div(\Gamma_{\Phi}grad\,\phi)+S_{\phi}^{*}$$

Determine S_{ϕ}^{*}, Γ_{ϕ}, and ρ_{ϕ}^{*}

2.**Calling（调用）** a USER similar to the problem studied, retaining MODULE part, modifying other part and saving with a new name;

3. Using a few nodes, 5～7 in each direction, and setting a small value of LAST, say 3－5, to go through grammatical examination; Then gradually increasing the complexity . For example, for turbulent heat transfer simulation, computing laminar flow first .

4.For the six-ENTRY in USER, making correspondent modifications according to the problem studied , especially for following parts:

(1) LSOLVE(NF)—for variable NF to be solved: .TRUE.

(2) LPRINT(NF)—for variable NF to be printed out: .TRUE.

(3) **TITLE(NF)**—for variable NF to be printed out specifying title (within seven letters).

(4) **LBLK(NF)**—for variable NF to be solved by block correction: .TRUE., otherwise .FALSE., Its default value is .T. .

(5) **LAST**—Given iteration times, default values is 5.

(6) **NTIMES(NF)**—Default values equals 1, steady nonlinear : 1 to 2; unsteady linear: 5 to 6

(7) **DT**—Time step, default value is 10^{30}

For fully implicit scheme, in the b-term there is a term of $a_P^0 = \frac{\rho \Delta V}{\Delta t}$, if $\Delta t \to \infty, a_P^0 \to 0$, leading to steady state results.

(8) **RELAX(NF)**—Default value is 1.

(9) **IPREF,JPREF:** i, j of **pressure** reference point , default values are 1,1;

5 If a new dependent variable is defined, say **C(NI,NJ)**, then **EQUIVALENCE** is used in MODULE START_L to relate **F(NI,NJ,NFX4)** to **C(i,j)** by **EQUIVALENCE (F(1,1,5),C(1,1)).**

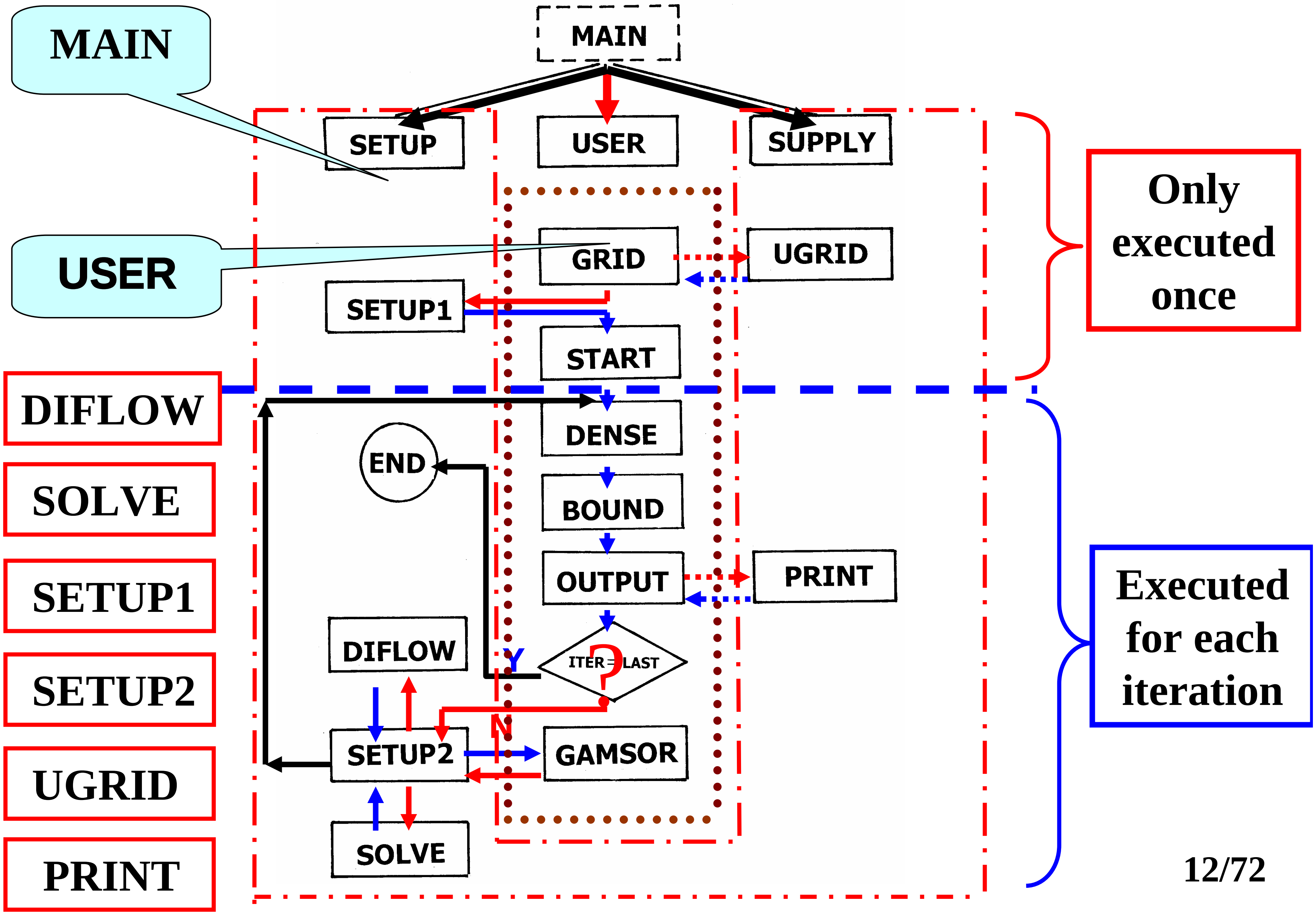
11-6-2 Explanation of MAIN programs

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C  This computer program was copied from the graduate student course
C  program of the University of Minnesota.  Part of it was re-formulated
C  to meet the microcomputer environment.  Some inappropriate
C  expressions were also corrected. The program is used only for the
C  teaching purpose.  No part of it may be published. You may use it
C  as a frame to re-develop your own code for research purpose.
C --------Instructor of Numerical Heat Transfer, XJTU,2013.18---------------
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C The current version of the program was updated from Fortran 77 to
C Fortran 95  by Dr. Li Chen,  Dr.Kong Lin,  Dr. Yu-Tong Mu of NHT group
C of XJTU during 2013.01-04
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C***********************************************************
```

```
MODULE START_L
PARAMETER(NI=100,NJ=200,NIJ=NI,NFMAX=10,NFX4=NFMAX+4)
C*****************************************
CHARACTER*8 TITLE(NFX4)
LOGICAL LSOLVE(NFX4),LPRINT(NFX4),LBLK(NFX4),LSTOP
REAL*8,DIMENSION(NI,NJ,NFX4)::F    ! One 3D function
REAL*8,DIMENSION(NI,NJ,6)::COF,COFU,COFV,COFP  ! Four 3D functions
REAL*8,DIMENSION(NI,NJ)::P,RHO,GAM,CP,CON,AIP,AIM,AJP,AJM,AP
REAL*8,DIMENSION(NI):: U,V,PC,T,DU,DV,UHAT,VHAT
REAL*8,DIMENSION(NI):: X,XU,XDIF,XCV,XCVS,XCVI,XCVIP
REAL*8,DIMENSION(NJ)::Y,YV,YDIF,YCV,YCVS,YCVR,YCVRS,ARX,ARXJ,
1    ARXJP,R,RMN,SX,SXMN
REAL*8,DIMENSION(NI)::FV,FVP,FX,FXM
REAL*8,DIMENSION(NJ)::FY,FYM
REAL*8,DIMENSION(NIJ)::PT,QT
REAL*8 RELAX(NFX3),TIME,DT,XL,YL,RHOCON
INTEGER*4 NF,NP,NRHO,NGAM,NCP,L1,L2,L3,M1,M2,M3,
1    IST,JST,ITER,LAST,MODE,NTIMES(NFX3),IPREF,JPREF
  REAL*8 SMAX,SSUM
  REAL*8 FLOW,DIFF,ACOF
```

```
C*****************************************
      EQUIVALENCE(F(1,1,1),U(1,1)),(F(1,1,2),V(1,1)),(F(1,1,3),PC(1,1))
     1, (F(1,1,4),T(1,1))
      EQUIVALENCE(F(1,1,11),P(1,1)),(F(1,1,12),RHO(1,1)),(F(1,1,13)
     1,GAM(1,1)),(F(1,1,14),CP(1,1))
      EQUIVALENCE(COF(1,1,1),CON(1,1)),(COF(1,1,2),AIP(1,1)),
     1(COF(1,1,3),AIM(1,1)),(COF(1,1,4),AJP(1,1)),
     2(COF(1,1,5),AJM(1,1)),(COF(1,1,6),AP(1,1))
      REAL*8,DIMENSION(NI)::TH,THU,THDIF,THCV,THCVS
      REAL*8 THL
      EQUIVALENCE(X,TH),(XU,THU),(XDIF,THDIF),(XCV,THCV),
     1(XCVS,THCVS),(XL,THL)
       DATA LSTOP,LSOLVE,LPRINT/.FALSE.,NFX4*.FALSE., NFX4*.FALSE./
       DATA LBLK/NFX4*.TRUE./
       DATA MODE,LAST,TIME,ITER/1,5,0.,0/
       DATA RELAX,NTIMES/NFX4*1.,NFX4*1/
       DATA DT,IPREF,JPREF,RHOCON,CPCON/1.E+30, 1,1,1.,1./
       END MODULE
```

```
C***************************************************************
C----------------------------MAIN PROGRAM----------------------------------
C***************************************************************
   PROGRAM MAIN
   USE START_L
   IMPLICIT NONE
C**************************************************************
   OPEN(8,FILE='RESULT.txt') ! Result file for output
   CALL GRID     !Grid generation
   CALL SETUP1  !Set up 1-D array not changed in iteration
   CALL START   !Set up initial field
   DO WHILE (.NOT.LSTOP）   !  Controlled  by ITER
   CALL DENSE    !Set up fluid density
   CALL BOUND   !Set up boundary condition
   CALL OUTPUT !Print out
   CALL SETUP2  !Key module
   ENDDO
   CALL OUTPUT!Print out some results
   CLOSE(8)  !Simulation completed  close file RESULT.TXT
   STOP       !Terminate computation
   END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```


MAIN
USER
DIFLOW
SOLVE
SETUP1
SETUP2
UGRID
PRINT
MAIN
SETUP
USER
SUPPLY
GRID
UGRID
SETUP1
START
DENSE
END
BOUND
OUTPUT
PRINT
DIFLOW
Y
ITER=LAST
?
N
SETUP2
GAMSOR
SOLVE
Only executed once
Executed for each iteration

```
      STOP
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE DIFLOW
C*******************************************************************
      USE START_L
      IMPLICIT NONE
      REAL*8 TEMP
C*******************************************************************
C*****************************************************************
      ACOF=DIFF
      IF(FLOW==0.) RETURN
      TEMP=DIFF-ABS(FLOW)*0.1
      ACOF=0.
      IF(TEMP<=0.) RETURN
      TEMP=TEMP/DIFF
      ACOF=DIFF*TEMP**5
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE SOLVE
      USE START_L
      IMPLICIT NONE
      INTEGER*4 ISTF,JSTF,IT1,IT2,JT1,JT2,NT,N,I,J,II,JJ
      REAL*8 BL,BLP,BLM,BLC,DENOM,TEMP
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
   SUBROUTINE DIFLOW !
```
$D\bullet A(|P_\Delta|)$ of power law scheme

```
   USE START_L
   IMPLICIT NONE
   REAL*8 TEMP
C***********************************************************
   ACOF=DIFF  !
```
$A(|P_\Delta|)=D$

```
   IF(FLOW== 0.) RETURN  !
```
No flow, only diffusion

```
   TEMP=DIFF-ABS(FLOW)*0.1  !
```
$D-0.1|F|=D(1-0.1|P_\Delta|)$

```
   ACOF=0.
```
$$\{A(|P_{\Delta e}|)=\max[0,(1-0.1|P_{\Delta e}|)^5]\begin{cases}0 & |P_{\Delta e}|>10\\(1-0.1|P_{\Delta e}|)^5 & |P_{\Delta e}|<10\end{cases}$$

```
   IF(TEMP.<= 0.) RETURN !
```
$|P_{\Delta e}|>10$

```
   TEMP=TEMP/DIFF  !
```
$1-0.1|P_{\Delta e}|$

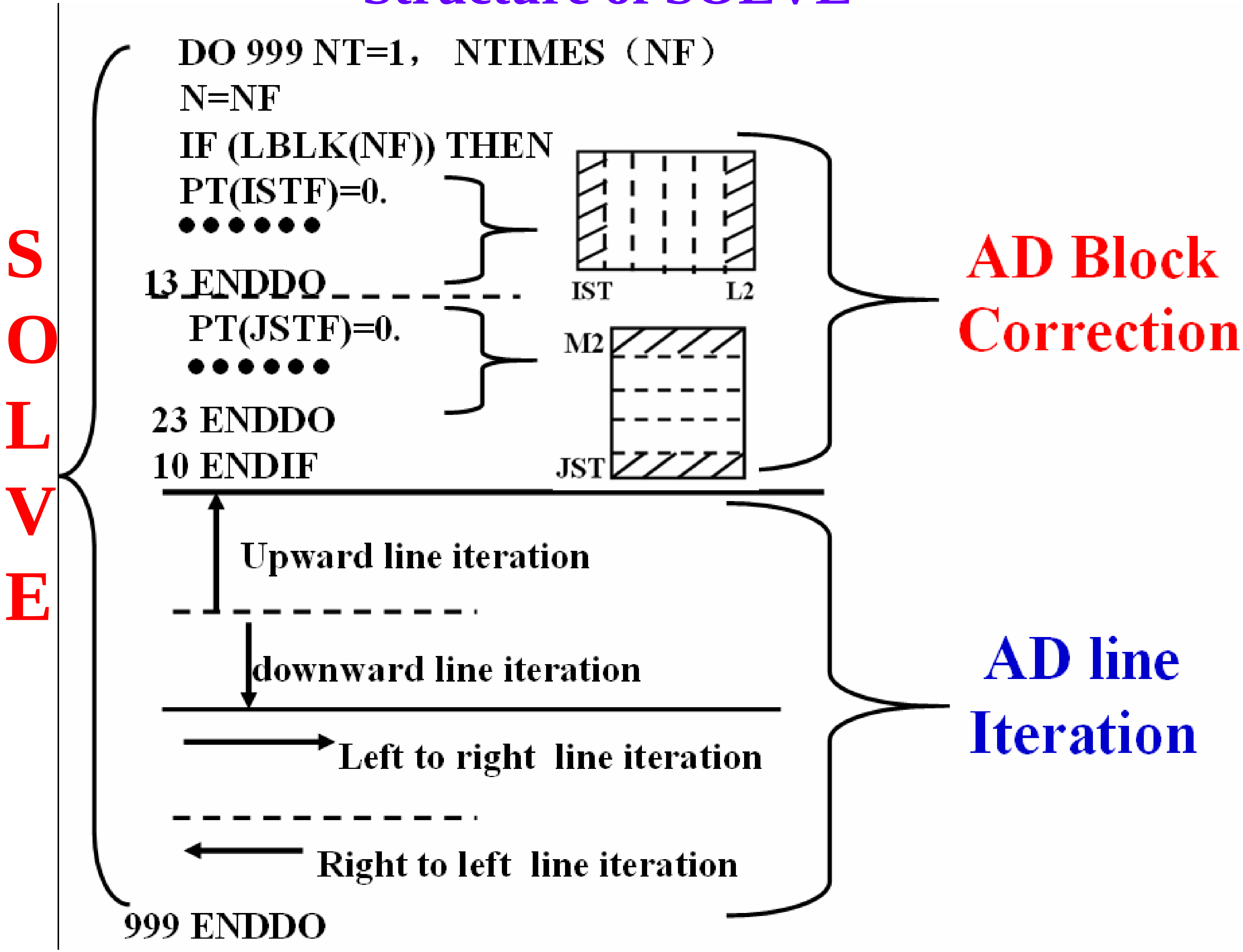
```
   ACOF=DIFF*TEMP**5  !
```
$D\cdot(1-0.1|P_{\Delta e}|)^5=D\bullet A(|P_{\Delta e}|)$

```
   RETURN
```
!In SETUP2: $a_E=D_eA(|P_{\Delta e}|)+[0,-F_e]$

```
   END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
    SUBROUTINE SOLVE   !ADI  line iteration+Block correction
    USE START_L
    IMPLICIT NONE
    INTEGER*4 ISTF, JSTF, IT1, IT2, JT1, JT2, NT, N,I,J,II,JJ
    REAL*8 BL, BLP, BLM,  BLC, DENOM, TEMP
C*****************************************************************
```

Structure of SOLVE



Review on block correction

$$(BL)\overline{\phi}'_i = (BLP)\overline{\phi}'_{i+1} + (BLM)\overline{\phi}'_{i-1} + BLC, i = IST, ...L2$$

$$BL = \sum_{j=JST}^{M2}(AP) - \sum_{j\neq M2}(AJP) - \sum_{i\neq JST}(AJM) \qquad BLP = \sum_{j=JST}^{M2}(AIP)$$

$$BLM = \sum_{j=JST}^{M2}(AIM) \qquad BLC = \sum_{j=JST}^{M2} CON + \sum_{j=JST}^{M2}(AJP)\phi^*_{i,j+1} + \sum_{j=JST}^{M2}(AJM)\phi^*_{i,j-1}$$

$$+ \sum_{j=JST}^{M2}(AIP)\phi^*_{i+1,j} + \sum_{j=JST}^{M2}(AIM)\phi^*_{i-1,j} - \sum_{j=JST}^{M2}(AP)\phi^*_{i,j}$$

$BL=A, BLP = B,$

$BLM = C$

$$A_i\overline{\phi}'_i = B\overline{\phi}'_{i+1} + C_i\overline{\phi}'_{i-1} + D_i,\ i = 1,2,.....M1 \rightarrow \overline{\phi}'_{i-1} = P_{i-1}\overline{\phi}'_i + Q_{i-1}$$

$$P_i = \frac{B_i}{A_i - C_iP_{i-1}};\quad Q_i = \frac{D_i + C_iQ_{i-1}}{A_i - C_iP_{i-1}};\qquad P_1 = \frac{B_1}{A_1};\quad Q_1 = \frac{D_1}{A_1}$$

DENOM=BL-PT(I-1)*BLM

DENOM

C***

$$(BL)\bar{\phi}'_i = (BLP)\bar{\phi}'_{i+1} + (BLM)\bar{\phi}'_{i-1} + BLC, i = IST,....L2$$

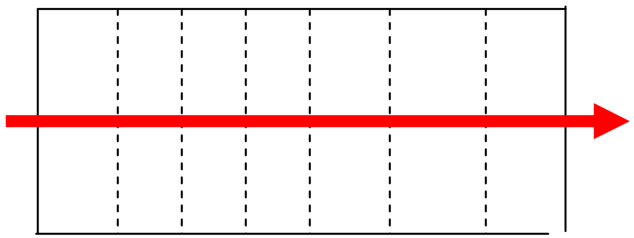
$$A_i\phi_i = B\bar{\phi}_{i+1} + C_i\phi_{i-1} + D_i,\ i = 1,2,.....M1$$

$$\bar{\phi}'_{i-1} = P_{i-1}\bar{\phi}'_i + Q_{i-1}$$

```
ISTF=IST-1
JSTF=JST-1
IT1=L2+IST    ! SOLVE-temporary
IT2=L3+IST    ! SOLVE-temporary
JT1=M2+JST    ! SOLVE-temporary
JT2=M3+JST    ! SOLVE-temporary
C***********************************************************************
DO 999  NT=1,NTIMES(NF) !Solution of algebraic equation
N=NF  !  NF: 1＝U， 2＝V， 3＝P， ……….
C-----------------------------------------------------------------------
IF(LBLK(NF)) THEN !When LBLK is true, execute Block-correction
PT(ISTF)=0.   !  Coefficient in TDMA
QT(ISTF)=0.   ! Constant in TDMA
DO 11 I=IST,L2
BL=0.     !Initial value in B-correction
BLP=0.    !Initial value in B-correction
BLM=0. ! Initial value in B-correction
```

P_{IST-1}

Q_{IST-1} I –direction B.Cor.



$$(BL)\overline{\phi}_i' = (BLP)\overline{\phi}_{i+1}' + (BLM)\overline{\phi}_{i-1}' + BLC, i = IST,..L2$$

```
      BLC=0. !Initial value
      DO  12 J=JST,M2
      BL=BL+AP(I,J)
      IF(J /= M2)  BL=BL-AJP(I,J)
      IF(J /= JST) BL=BL-AJM(I,J)
      BLP=BLP+AIP(I,J)
      BLM=BLM+AIM(I,J)
      BLC=BLC+CON(I,J)+AIP(I,J)*F(I+1,J,N)+AIM(I,J)*F(I-1,J,N)
    1 +AJP(I,J)*F(I,J+1,N)+AJM(I,J)*F(I,J-1,N)-AP(I,J)*F(I,J,N)
   12 ENDDO
      DENOM=BL-PT(I-1)*BLM
      IF(ABS(DENOM/BL) <1.E-10) DENOM=1.E25 !Ensure a meaningful correction
      PT(I)=BLP/DENOM
      QT(I)=(BLC+BLM*QT(I-1))/DENOM
   11 ENDDO
```

$$BL = \sum_{j=JST}^{M2}(AP) - \sum_{j\neq M2}(AJP) - \sum_{i\neq JST}(AJM)$$

$$BLP = \sum_{j=JST}^{M2}(AIP) \qquad BLM = \sum_{j=JST}^{M2}(AIM)$$

$$BLC = \sum_{j=JST}^{M2} CON + \sum_{j=JST}^{M2}(AJP)\phi^*_{i,j+1} + \sum_{j=JST}^{M2}(AJM)\phi^*_{i,j-1} + \sum_{j=JST}^{M2}(AIP)\phi^*_{i+1,j} + \sum_{j=JST}^{M2}(AIM)\phi^*_{i-1,j} - \sum_{j=JST}^{M2}(AP)\phi^*_{i,j}$$

$$\overline{\phi}_{i-1}' = P_{i-1}\overline{\phi}_i' + Q_{i-1} \qquad P_i = \frac{B_i}{A_i - C_i P_{i-1}}; \qquad Q_i = \frac{D_i + C_i Q_{i-1}}{A_i - C_i P_{i-1}};$$

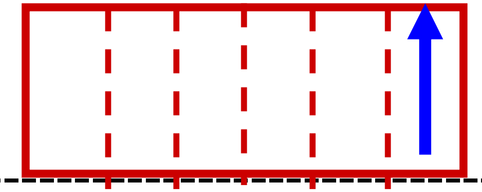
```
BL=0.   (Initial set up)
DO 13 II=IST,L2
I=IT1-II
BL=BL*PT(I)+QT(I)
DO 14 J=JST,M2
F(I,J,N)=F(I,J,N)+BL!
14 ENDDO
13 ENDDO
```

IT1=L2+IST

I=IT1-II＝L2＋IST-IST＝L2-Begin

I=IT1-II＝L2＋IST-L2＝IST-End

Correcting by BL for the same column

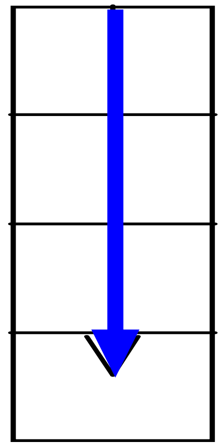


```
C-------------------------------------------------------------------------------------
PT(JSTF)=0.
QT(JSTF)=0.
DO 21 J=JST,M2
BL=0.
BLP=0.
BLM=0.
BLC=0.
DO 22  I=IST,L2
BL=BL+AP(I,J)
IF(I /= L2) BL=BL-AIP(I,J)
IF(I /= IST) BL=BL-AIM(I,J)
BLP=BLP+AJP(I,J)
```

$$T_{i-1} = P_{i-1} T_i + Q_{i-1}$$

BL=BL*PT(I)+QT(I)

TDMA: from L2 to IST



Y –direction
B-correction

```
   BLM=BLM+AJM(I,J) !
   BLC=BLC+CON(I,J)+AIP(I,J)*F(I+1,J,N)+AIM(I,J)*F(I-1,J,N)
  1 +AJP(I,J)*F(I,J+1,N)+AJM(I,J)*F(I,J-1,N)-AP(I,J)*F(I,J,N)
22 ENDDO
   DENOM=BL-PT(J-1)*BLM  !
   IF(ABS(DENOM/BL)<1.E-10) DENOM=1.E25
   PT(J)=BLP/DENOM  !
   QT(J)=(BLC+BLM*QT(J-1))/DENOM
 21 ENDDO
    BL=0.
    DO  23 JJ=JST,M2
    J=JT1-JJ
    BL=BL*PT(J)+QT(J)
    DO 24 I=IST,L2
    F(I,J,N)=F(I,J,N)+BL !Correcting by BL for the same row
 24 ENDDO
 23 ENDDO
 10 ENDIF
C-----------------------------------------------------------
!  Above is block correction, following is ADI line iteration
```

Solving in I-direction， scanning in J direction, SLUR

```
C-----------------------------------------------------------------------------------------
   DO 90 J=JST,M2
   PT(ISTF)=0.
   QT(ISTF)=F(ISTF,J,N)
   DO 70 I=IST,L2
   DENOM=AP(I,J)-PT(I-1)*AIM(I,J) ,
   PT(I)=AIP(I,J)/DENOM        ,
   TEMP=CON(I,J)+AJP(I,J)*F(I,J+1,N)+AJM(I,J)*F(I,J-1,N)
   QT(I)=(TEMP+AIM(I,J)*QT(I-1))/DENOM
  70 ENDDO
   DO 80 II=IST,L2
   I=IT1-II  !Recursive
   F(I,J,N)=F(I+1,J,N)*PT(I)+QT(I)
  80 ENDDO
  90 ENDDO
C-----------------------------------------------------------------------------------------
```

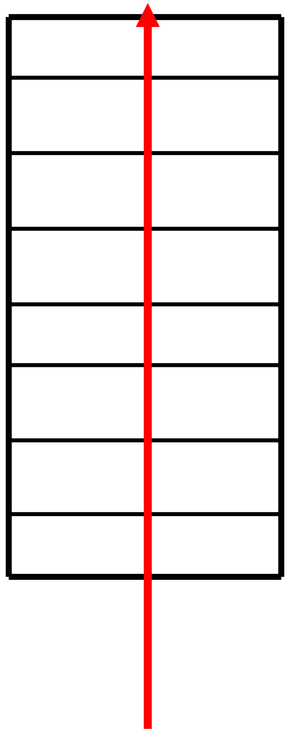
$$T_{i-1} = P_{i-1} Ti + Q_{i-1}$$

PT=0， QT=given boundary value

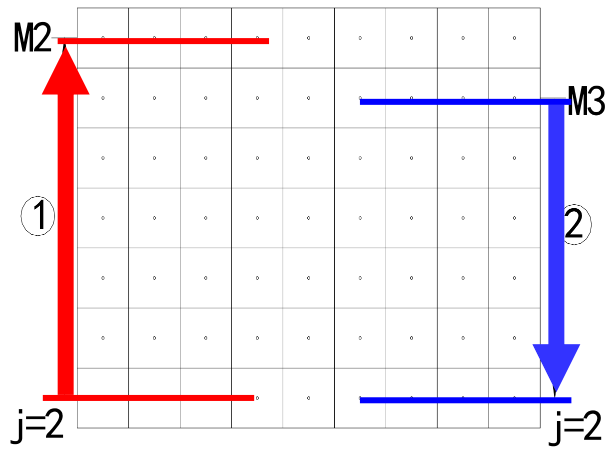
ISTF=IST-1

$$P_i = \frac{B_i}{A_i - C_i P_{i-1}};$$

$$Q_i = \frac{D_i + C_i Q_{i-1}}{A_i - C_i P_{i-1}};$$



```
C-------------------------------------------------------------------------------------
    DO 190 JJ=JST,M3 !  Solving in I-direction， scanning from top to bottom
    J=JT2-JJ  !Starting from JT2 ,rather than from JT1
    PT(ISTF)=0.
    QT(ISTF)=F(ISTF,J,N)
    DO 170 I=IST,L2
    DENOM=AP(I,J)-PT(I-1)*AIM(I,J)
    PT(I)=AIP(I,J)/DENOM
    TEMP=CON(I,J)+AJP(I,J)*F(I,J+1,N)+AJM(I,J)*F(I,J-1,N)
    QT(I)=(TEMP+AIM(I,J)*QT(I-1))/DENOM
 170 ENDDO
    DO 180 II=IST,L2
    I=IT1-II  !Recursive solution
    F(I,J,N)=F(I+1,J,N)*PT(I)+QT(I)
 180 ENDDO
 190 ENDDO
C---------------------------------------------------------------
```



```
C-----------------------------------------------------------------------------
    DO 290 I=IST,L2 ! Solving in J-direction, scanning from left to right
    DO 270 J=JST,M2
    DENOM=AP(I,J)-PT(J-1)*AJM(I,J)
    PT(J)=AJP(I,J)/DENOM
    TEMP=CON(I,J)+AIP(I,J)*F(I+1,J,N)+AIM(I,J)*F(I-1,J,N)
    QT(J)=(TEMP+AJM(I,J)*QT(J-1))/DENOM  !
 270 ENDDO
    DO 280 JJ=JST,M2
    J=JT1-JJ  !Recursive solution
    F(I,J,N)=F(I,J+1,N)*PT(J)+QT(J)  !  P100(a),
 280 ENDDO
 290 ENDDO
C-----------------------------------------------------------------------------
```

```
C----------------------------------------------------------------------------------------------------
   DO 390 II=IST,L3  ! Solving in J-direction, scanning from right to left
   I=IT2-II
   PT(JSTF)=0.
   QT(JSTF)=F(I,JSTF,N)
   DO 370 J=JST,M2
   DENOM=AP(I,J)-PT(J-1)*AJM(I,J)
   PT(J)=AJP(I,J)/DENOM ,
   TEMP=CON(I,J)+AIP(I,J)*F(I+1,J,N)+AIM(I,J)*F(I-1,J,N)
   QT(J)=(TEMP+AJM(I,J)*QT(J-1))/DENOM
 370 ENDDO
   DO 380 JJ=JST,M2
   J=JT1-JJ  !Recursive solution
   F(I,J,N)=F(I,J+1,N)*PT(J)+QT(J)  !  P100(a),
 380 ENDDO
 390 ENDDO
C************************************************************************************
```

```
C***************************************************************
  999 ENDDO   !（End of solution of ABEqs )

     ENTRY RESET  !（CON，AP are accumulatively used）
     DO 400 J=2,M2
     DO 401 I=2,L2
     CON(I,J)=0.
     AP(I,J)=0.
 401 ENDDO
 400 ENDDO
     RETURN
     END

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
  SUBROUTINE SETUP
C*****************************************************************************************
   USE START_L
   IMPLICIT NONE
   INTEGRER*4 I, J， K,N
   REAL*8  REL, FL, FLM, FLP, GM, GMM, VOL, APT, AREA, SXT,
  1 SXB, ARHO
C*****************************************************************************************
```


(To P. 39页）

```
C*****************************************************************
  1 FORMAT(//15X,'COMPUTATION  IN  CARTESIAN  COORDINATES'
     ! Print out title for Cartesian coordinate
  2 FORMAT(//15X,'COMPUTATION FOR AXISYMMETRIC SITUATION')
     ! Print out title for cylindrical coordinate
  3 FORMAT(//15X,'COMPUTATION   IN   POLAR   COORDINATES')
     ! Print out title for polar coordinate
  4 FORMAT(14X,40(1H*),//)

C-----------------------------------------------------------------
```

Review of SIMPLER algorithm

1. **Assuming initial fields, determine coefficients of discretized *u, v* eqs.;**
2. **Calculating pseudo-velocity** $\tilde{u}, \tilde{v}$ **;**
3. **Solving pressure equation, obtaining** p^* **;**

$$a_E = \rho(\frac{A_e}{a_e})\Delta y \qquad a_N = \rho(\frac{A_n}{a_n})\Delta x$$

Coefficients of *u,v* momentum equations are needed for determining coefficients of pressure equation.

4. **Solving momentum equations based on** p^* **, obtaining** u^*, v^*

5. Solving pressure correction equation based on u^*, v^* , obtaining p'

In pressure equation: $$b = [(\rho\tilde{u})_w - (\rho\tilde{u})_s]A_e + [(\rho\tilde{v})_s - (\rho\tilde{v})_n]A_n$$

In pressure correction equation: $$b = [(\rho u^*)_w - (\rho u^*)_s]A_e + [(\rho v^*)_s - (\rho v^*)_n]A_n$$

Boundary velocities take the specified values.

6. Correcting velocity $u = u^* + u'; v = v^* + v'$**, where** u' and v' **are determined based on** p'

7. Taking the updated velocity , repeating steps 1-6, until convergence is reached.

Structure of SETUP

ENTRY SETUP1
Setup 28 one dimensional geometric parameters;
Setup initial values
RETURN

ENTRY SETUP2
Coefficient for u equation
Coefficient for v equation
Calculate UHAT and VHAT
Coefficient for pressure equation and solve pressure
Solve u equation and v equation.
Coefficient for pressure correction equation and solve it.
Correction velocity
Coefficient for other equation and solve it (from NF=5 to 10 in order)
RETURN

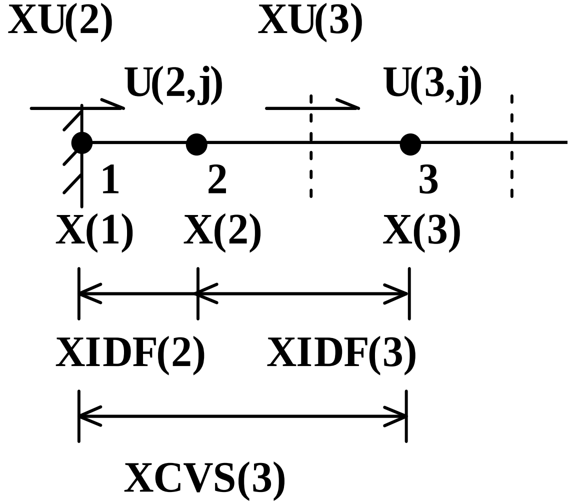
S
E
T
U
P

```
C-----------------------------------------------------------------------
   ENTRY SETUP1 !Set up 1D arrays not changed  during iteration
   NP=NFMAX+1  ! NFMAX=10，NP＝11
   NRHO=NP +1  ! NRHO＝12
   NGAM=NRHO+1  ! NGAM＝13
   NCP=NGAM+1  ! NCP＝14
   L2=L1-1       ! Set up L2,L3,M2,M3
   L3=L2-1
   M2=M1-1
   M3=M2-1
   X(1)=XU(2)  ! X(1)＝XU(2)＝0
   DO 5 I=2,L2
   X(I)=0.5*(XU(I+1)+XU(I))            ! Practice B
  5 ENDDO
   X(L1)=XU(L1)
   Y(1)=YV(2)            !Y(1)=YV(2)＝0
   DO 10 J=2,M2
   Y(J)=0.5*(YV(J+1)+YV(J)) !Practice B
 10 ENDDO
```

```
   Y(M1)=YV(M1)
   DO 15 I=2,L1
   XDIF(I)=X(I)-X(I-1)
15 ENDDO
   DO 18 I=2,L2
   XCV(I)=XU(I+1)-XU(I)
18 ENDDO
   DO 20 I=3,L2
   XCVS(I)=XDIF(I)    ! Width of CV U (I,J) in x direction
20 ENDDO
   XCVS(3)=XCVS(3)+XDIF(2)! Width of CV U connected with left boundary
   XCVS(L2)=XCVS(L2)+XDIF(L1) ! Width of CV U with right boundary
   DO 22 I=3,L3
   XCVI(I)=0.5*XCV(I)  ! (δx)_{e-}
   XCVIP(I)=XCVI(I)    ! (δx)_{e+}
22 ENDDO
   XCVIP(2)=XCV(2)
   XCVI(L2)=XCV(L2)
   DO 35 J=2,M1
   YDIF(J)=Y(J)-Y(J-1)
35 ENDDO
```

$(\delta x)_{e^-}$

$(\delta x)_{e^+}$



```
   DO 40 J=2,M2
   YCV(J)=YV(J+1)-YV(J)  !Width of main CV in y-direction
40 ENDDO
   DO 45 J=3,M2
   YCVS(J)=YDIF(J)   ! Width of V (I,J) in y-direction
45 ENDDO
   YCVS(3)=YCVS(3)+YDIF(2)
   YCVS(M2)=YCVS(M2)+YDIF(M1)
   IF(MODE= =1) THEN
   DO 52 J=1,M1
   RMN(J)=1.0    ! Nominal radius=1
   R(J)=1.0          ! for Cartesian coordinate
52 ENDDO
   ELSE
   DO 50 J=2,M1           !Cylindrical and polar coordinates
   R(J)=R(J-1)+YDIF(J)  !R(1) has defined
50 ENDDO
   RMN(2)=R(1)
   DO 60 J=3,M2
60 RMN(J)=RMN(J-1)+YCV(J-1)   ! Radius of position of V(I,J)
60 ENDDO
   RMN(M1)=R(M1)
   ENDIF
```

R＝1 for Cartesian coordinate

```
    DO 57 J=1,M1
    SX(J)=1.
    SXMN(J)=1.
    IF(MODE.== 3) THEN
    SX(J)=R(J)
    IF(J /= 1) SXMN(J)=RMN(J)
    ENDIF
57  ENDDO
    DO 62 J=2,M2
    YCVR(J)=R(J)*YCV(J)        ! E-W conduction area of main CV
    ARX(J)=YCVR(J)
    IF(MODE = = 3) THEN
    ARX(J)=YCV(J)
62  ENDDO
```

Set up scaling Factor for polar coordinate

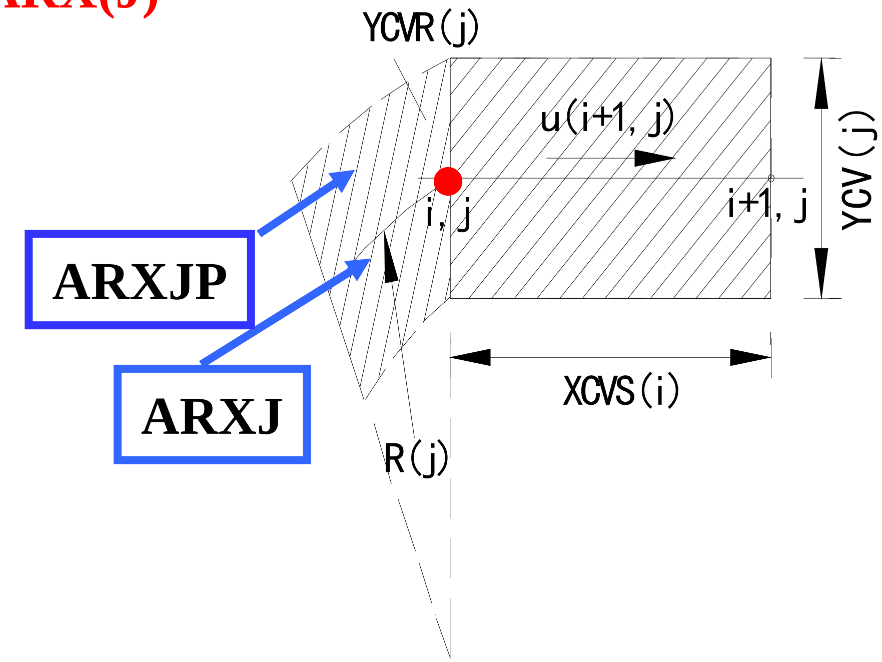
Interface starts from J=2

$$ARXJ(J)=\frac{1}{2}\left(R(j)+RMN(j)\right)\cdot\frac{YCV(j)}{2}=$$

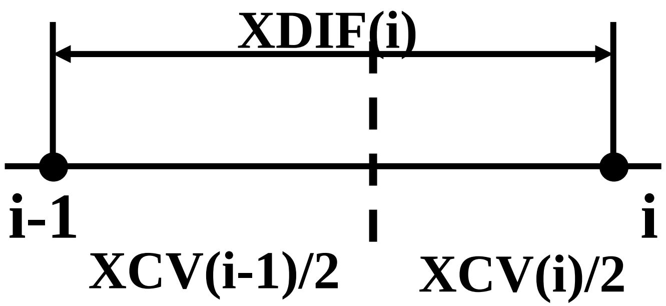
$$0.25\left[1+\frac{RMN(j)}{R(j)}\right]\cdot R(j)\cdot YCV(j)=$$

$$0.25\left[1+\frac{RMN(j)}{R(j)}\right]\cdot ARX(j)$$

```
    DO 64 J=4,M3
    YCVRS(J)=0.5*(R(J)+R(J-1))*YDIF(J)
64 ENDDO
    YCVRS(3)=0.5*(R(3)+R(1))*YCVS(3)
    YCVRS(M2)=0.5*(R(M1)+R(M3))*YCVS(M2)
    IF(MODE = = 2) THEN
    DO 65 J=3,M3
    ARXJ(J)=0.25*(1.+RMN(J)/R(J))*ARX(J)
    ARXJP(J)=ARX(J)-ARXJ(J)
65 ENDDO
    ELSE
    DO 66 J=3,M3
    ARXJ(J)=0.5*ARX(J)
    ARXJP(J)=ARXJ(J)
66 ENDDO
    ENDIF
    ARXJP(2)=ARX(2)
    ARXJ(M2)=ARX(M2)
```



```
      DO 70 J=3,M3
      FV(J)=ARXJP(J)/ARX(J)
      FVP(J)=1.-FV(J) !Interpolation coefficient
   70 ENDDO
      DO 85 I=3,L2
      FX(I)=0.5*XCV(I-1)/XDIF(I) !Interpolation  in x-direction
      FXM(I)=1.-FX(I)
   85 ENDDO
      FX(2)=0.
      FXM(2)=1.
      FX(L1)=1.
      FXM(L1)=0.
      DO 90 J=3,M2
      FY(J)=0.5*YCV(J-1)/YDIF(J) ! Interpolation in y-direction
      FYM(J)=1.-FY(J)
   90 ENDDO
      FYM(2)=1.
      FY(M1)=1.
      FYM(M1)=0.
C CON,AP,U,V,RHO,PC AND P ARRAYS ARE INITIALIZED HERE
```



$$\phi_{i-1/2} = \phi_{i-1}\frac{\text{XCV(i)/2}}{\text{XDIF(i)}} + \phi_i\frac{\text{XCV(i-1)/2}}{\text{XDIF(i)}}$$

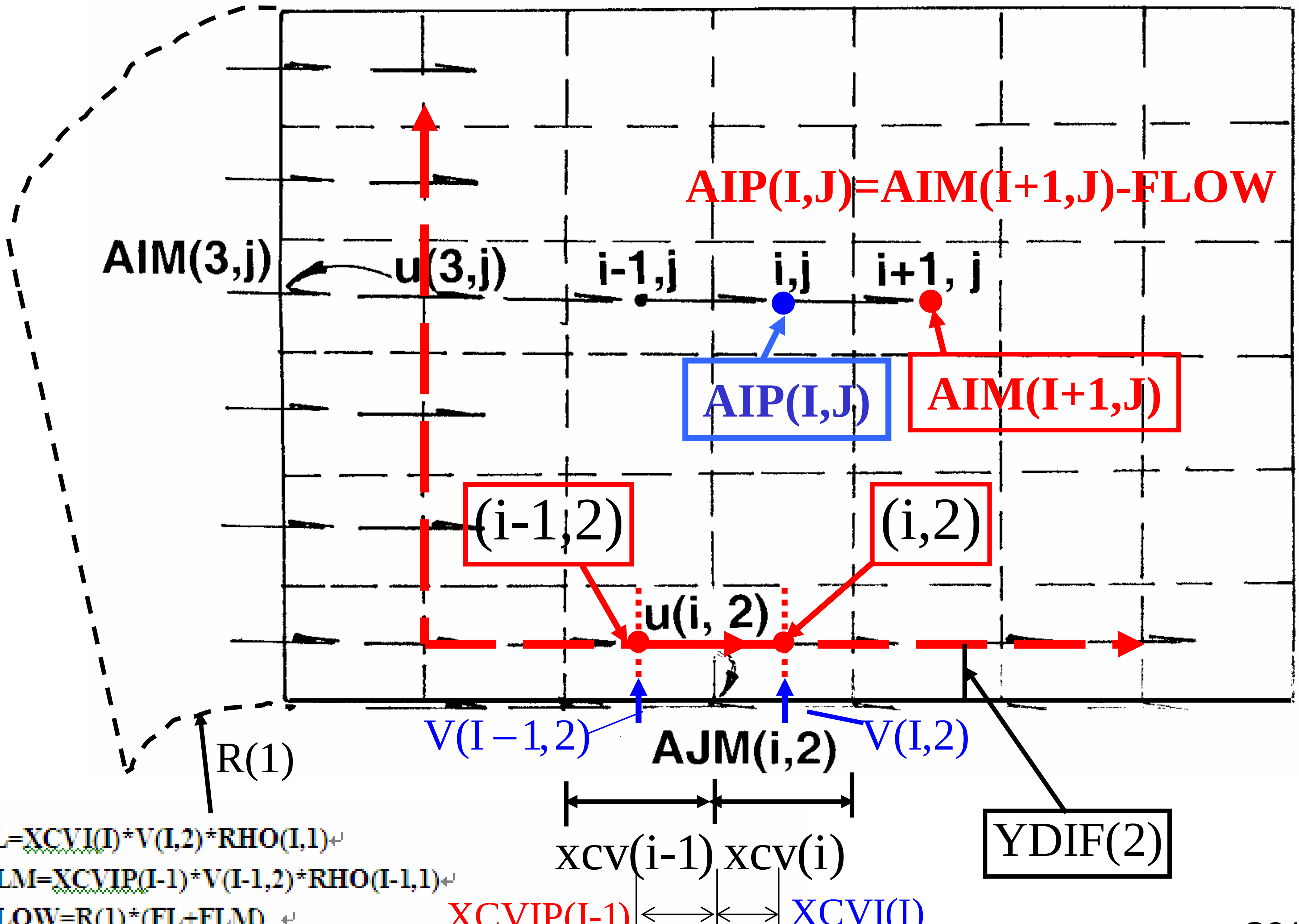
$$= \phi_{i-1}FXM(i) + \phi_i FX(i)$$

The first letter C is also used to indicate that this is an explanation line

```
    DO 96 J=1,M1
    DO 95 I=1,L1
    PC(I,J)=0.
    U(I,J)=0.
    V(I,J)=0.
    CON(I,J)=0.
    AP(I,J)=0.
    RHO(I,J)=RHOCON
    CP（I,J)=CPCON
    P(I,J)=0.
95 ENDDO
96 ENDDO
    IF(MODE= =1) PRINT 1
    IF(MODE= =1) WRITE(8,1)
    IF(MODE= =2) PRINT 2
    IF(MODE= =2) WRITE(8,2)
    IF(MODE= =3) PRINT 3
    IF(MODE= =3) WRITE(8,3)
    PRINT 4
    WRITE(8,4)（20151216）
    RETURN
C------------------------------------------------------------------
```

Set up initial fields for iteration

Print out coordinate title of out put data



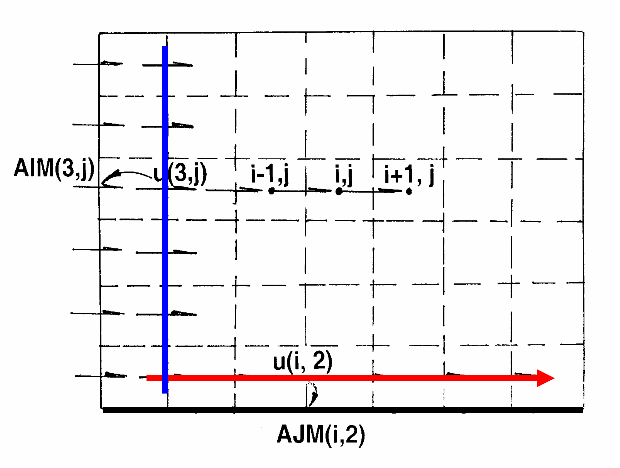
FL=XCVI(I)*V(I,2)*RHO(I,1)

FLM=XCVIP(I-1)*V(I-1,2)*RHO(I-1,1)

FLOW=R(1)*(FL+FLM)

DIFF=R(1)*(XCVI(I)*GAM(I,1)+XCVIP(I-1)*GAM(I-1,1))/YDIF(2)

```
C-----------------------------------------------------------------------------------
  ENTRY SETUP2
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
COEFFICIENTS FOR THE U EQUATION
    NF=1  ! NF=1：U；NF=2：V；NF=3：P'; NF=NP: P
    IF(LSOLVE(NF)) THEN      !
    IST=3
    JST=2
    CALL GAMSOR
    REL=1.-RELAX(NF) ! （U）underrelaxation
    DO 102 I=3,L2  !Coefficient of south boundary
    FL=XCVI(I)*V(I,2)*RHO(I,1)
    FLM=XCVIP(I-1)*V(I-1,2)*RHO(I-1,1)
    FLOW=R(1)*(FL+FLM) ! Flow rate through s
    DIFF=R(1)*(XCVI(I)*GAM(I,1)+XCVIP(I-1)*GAM(I-1,1))/YDIF(2)
    CALL DIFLOW !Get D.A(|P|);
    AJM(I,2)=ACOF+AMAX1(0.,FLOW)    Coefficient a_S
102 ENDDO
```



```
DO 103 J=2,M2
FLOW=ARX(J)*U(2,J)*RHO(1,J)
DIFF=ARX(J)*GAM(1,J)/(XCV(2)*SX(J))
CALL DIFLOW        ! Get A(|P|)
AIM(3,J)=ACOF+AMAX1(0.,FLOW)  !Coefficient aW
DO 104 I=3,L2
IF(I = = L2) THEN
FLOW=ARX(J)*U(L1,J)*RHO(L1,J)
DIFF=ARX(J)*GAM(L1,J)/(XCV(L2)*SX(J)) ! DW
ELSE
FL=U(I,J)*(FX(I)*RHO(I,J)+FXM(I)*RHO(I-1,J))
FLP=U(I+1,J)*(FX(I+1)*RHO(I+1,J)+FXM(I+1)*RHO(I,J))
FLOW=ARX(J)*0.5*(FL+FLP)
DIFF=ARX(J)*GAM(I,J)/(XCV(I)*SX(J))
ENDIF
CALL DIFLOW  !  A(|P|)
AIM(I+1,J)=ACOF+AMAX1(0.,FLOW)
AIP(I,J)=AIM(I+1,J)-FLOW  ! Relationship between coefficients
```

$$D \bullet A(|P_\Delta|) + [[0, F]]$$

```
 IF(J = = M2) THEN
 FL=XCVI(I)*V(I,M1)*RHO(I,M1)
 FLM=XCVIP(I-1)*V(I-1,M1)*RHO(I-1,M1)
 DIFF=R(M1)*(XCVI(I)*GAM(I,M1)+XCVIP(I-1)*GAM(I-1,M1))/YDIF(M1)
 ELSE
 FL=XCVI(I)*V(I,J+1)*(FY(J+1)*RHO(I,J+1)+FYM(J+1)*RHO(I,J))
 FLM=XCVIP(I-1)*V(I-1,J+1)*(FY(J+1)*RHO(I-1,J+1)+FYM(J+1)*
1 RHO(I-1,J))
  GM=GAM(I,J)*GAM(I,J+1)/(YCV(J)*GAM(I,J+1)+YCV(J+1)*GAM(I,J)+
1 1.0E-30)*XCVI(I)
  GMM=GAM(I-1,J)*GAM(I-1,J+1)/(YCV(J)*GAM(I-1,J+1)+YCV(J+1)*
1 GAM(I-1,J)+1.E-30)*XCVIP(I-1)
  DIFF=RMN(J+1)*2.*(GM+GMM)
  ENDIF
  FLOW=RMN(J+1)*(FL+FLM)
  CALL DIFLOW  ! A(|P|)
 AJM(I,J+1)=ACOF+AMAX1(0.,FLOW)
 AJP(I,J)=AJM(I,J+1)-FLOW   !Relationship between coefficients
```

```
VOL=YCVR(J)*XCVS(I)        !Volume of velocity CV
APT=(RHO(I,J)*XCVI(I)+RHO(I-1,J)*XCVIP(I-1))
1/(XCVS(I)*DT)  ! Unsteady term ρ/△t;  DT---△t;
AP(I,J)=AP(I,J)-APT             !  AP (I,J)  at right side is SP
CON(I,J)=CON(I,J)+APT*U(I,J)
AP(I,J)=(-AP(I,J)*VOL+AIP(I,J)+AIM(I,J)+AJP(I,J)+AJM(I,J))
1/RELAX(NF) !Underrelaxation is organized during solution procedure
CON(I,J)=CON(I,J)*VOL+REL*AP(I,J)*U(I,J) !  REL=1−α
DU(I,J)=VOL/(XDIF(I)*SX(J))
DU(I,J)=DU(I,J)/AP(I,J) !  de in velocity correction
104 ENDDO
103 ENDDO
```

$$a_P^0 = \frac{\rho_P \Delta V}{\Delta t}$$

$$b = S_c \Delta V + a_p^0 \phi_p^0 + (1-\alpha)\frac{a_P}{\alpha}\phi_P^0$$

$$a_p = (\sum a_{nb} + a_p^0 - S_p \Delta V)/\alpha$$

COFU(IST:L2, JST:M2, 1:6)=COF(IST:L2,JST:M2,1:6)

! Store coefficients of U temporary:

COF(I,J,1)	COF(I,J,2)	COF(I, J,3)	COF(I,J,4)	COF(I,J,5)	COF(I,J,6)
CON（I,J）	AIP(I,J)	AIM(I, J)	AJP(I,J)	AJM(I,J)	AP(I,J)

! In SIMPLER to solve pressure eq., coefficients of both u eq.and
! v-eq. are needed. Only u-coefficients are not enough. Thus
! u-coefficients are temporary stored, and v-eq. coefficients
! are computed

COEFFICIENTS FOR THE V EQUATION-（Determine coefficients of V

```
NF=2            !
CALL RESET          !Set zero values for AP(I,J),CON(I,J)
IST=2
JST=3
CALL GAMSOR
REL=1.-RELAX(NF)
```

```
    DO 202 I=2,L2
    AREA=R(1)*XCV(I)
    FLOW=AREA*V(I,2)*RHO(I,1)
    DIFF=AREA*GAM(I,1)/YCV(2)
    CALL DIFLOW
    AJM(I,3)=ACOF+AMAX1(0.,FLOW)  ! a_S
202 ENDO
    DO 203 J=3,M2
    FL=ARXJ(J)*U(2,J)*RHO(1,J)
    FLM=ARXJP(J-1)*U(2,J-1)*RHO(1,J-1)
    FLOW=FL+FLM
    DIFF=(ARXJ(J)*GAM(1,J)+ARXJP(J-1)*GAM(1,J-1))/(XDIF(2)*SXMN(J))
    CALL DIFLOW
    AIM(2,J)=ACOF+AMAX1(0.,FLOW) ! a_W
    DO 204 I=2,L2
    IF(I.E= = L2) THEN
    FL=ARXJ(J)*U(L1,J)*RHO(L1,J)
    FLM=ARXJP(J-1)*U(L1,J-1)*RHO(L1,J-1)
    DIFF=(ARXJ(J)*GAM(L1,J)+ARXJP(J-1)*GAM(L1,J-
   1 1))/(XDIF(L1)*SXMN(J))
```

```
 ELSE
 FL=ARXJ(J)*U(I+1,J)*(FX(I+)*RHO(I+1,J)+FXM(I+1)*RHO(I,J))
 FLM=ARXJP(J-1)*U(I+1,J-1)*(FX(I+1)*RHO(I+1,J-1)+FXM(I+1)*RHO(I,J-1))

 GM=GAM(I,J)*GAM(I+1,J)/(XCV(I)*GAM(I+1,J)+XCV(I+1)*GAM(I,J)+
1 1.E-30)*ARXJ(J)
 GMM=GAM(I,J-1)*GAM(I+1,J-1)/(XCV(I)*GAM(I+1,J-1)+XCV(I+1)*
1 GAM(I,J-1)+1.0E-30)*ARXJP(J-1)
 DIFF=2.*(GM+GMM)/SXMN(J)
 ENDIF
 FLOW=FL+FLM
 CALL DIFLOW
 AIM(I+1,J)=ACOF+AMAX1(0.,FLOW)      ! a_W
 AIP(I,J)=AIM(I+1,J)-FLOW!Relationship between coefficients
 IF (J= =M2) THEN
 AREA=R(M1)*XCV(I)
 FLOW=AREA*V(I,M1)*RHO(I,M1)
```

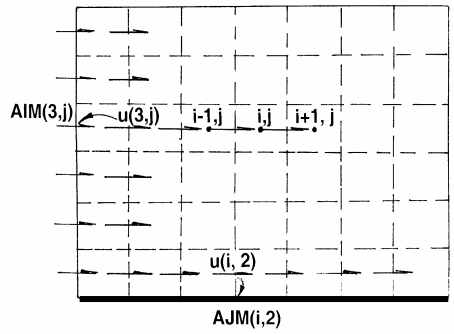
```
DIFF=AREA*GAM(I,M1)/YCV(M2)
ELSE
AREA=R(J)*XCV(I)
FL=V(I,J)*(FY(J)*RHO(I,J)+FYM(J)*RHO(I,J-1))*RMN(J)
FLP=V(I,J+1)*(FY(J+1)*RHO(I,J+1)+FYM(J+1)*RHO(I,J))*RMN(J+1)
FLOW=(FV(J)*FL+FVP(J)*FLP)*XCV(I)
DIFF=AREA*GAM(I,J)/YCV(J)
ENDIF
CALL DIFLOW
AJM(I,J+1)=ACOF+AMAX1(0.,FLOW) ! a_S
AJP(I,J)=AJM(I,J+1)-FLOW         !Relationship
VOL=YCVRS(J)*XCV(I)        !Volume of V- CV
SXT=SX(J)
```

```
   APT=(ARXJ(J)*RHO(I,J)*0.5*(SXT+SXMN(J))+ARXJP(J-1)*RHO(I,J-1)*
  10.5*(SXB+SXMN(J)))/(YCVRS(J)*DT)
   AP(I,J)=AP(I,J)-APT
   CON(I,J)=CON(I,J)+APT*V(I,J)
   AP(I,J)=(-AP(I,J)*VOL+AIP(I,J)+AIM(I,J)+AJP(I,J)+AJM(I,J))
  1/RELAX(NF)
   CON(I,J)=CON(I,J)*VOL+REL*AP(I,J)*V(I,J)
   DV(I,J)=VOL/YDIF(J)
   DV(I,J)=DV(I,J)/AP(I,J)
204 ENDDO
203 ENDDO
   COFV(IST:L2,JST:M2,1:6)=COF(IST:L2,JST:M2,1,6) ! Store
   coefficients of V-eq. to compute coefficients of P-equation
 CALCULATE UHAT AND VHAT !
   DO 150 J=2,M2
   DO 151 I=3,L2
   UHAT(I,J)=(COFU(I,J,2)*U(I+1,J)+COFU(I,J,3)*U(I-1,J)+COFU(I,J,4)
  1 *U(I,J+1)+COFU(I,J,5)*U(I,J-1)+COFU(I,J,1))/COFU(I,J,6)
```

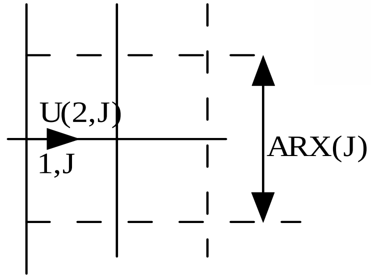
! Compute $\tilde{u}, \tilde{v}$

$$\widetilde{u_e} = \sum \frac{a_{nb} u_{nb} + b}{a_e}$$

```
151 ENDDO
150 ENDDO
    DO 250 J=3,M2
    DO 251 I=2,L2
    VHAT(I,J)=(COFV(I,J,2)*V(I+1,J)+COFV(I,J,3)*V(I-1,J)+COFV(I,J,4)
   1 *V(I,J+1)+COFV(I,J,5)*V(I,J-1)+COFV(I,J,1))/COFV(I,J,6)
251 ENDDO\
250 ENDDO
COEFFICIENTS FOR THE PRESSURE EQUATION----------------------------
    NF=3
    CALL RESET
    IST=2
    JST=2
    CALL GAMSOR  !In pressure equation no source term for the generality
    DO 410 J=2,M2   ! source term is still computed.
    DO 411 I=2,L2
    VOL=YCVR(J)*XCV(I)      !Volume of main CV.
    CON(I,J)=CON(I,J)*VOL
411 ENDDO
410 ENDDO
```




```
DO 402 I=2,L2
ARHO=R(1)*XCV(I)*RHO(I,1)
CON(I,2)=CON(I,2)+ARHO*V(I,2) ! Accumulative add
AJM(I,2)=0  !a_S =0， Adiabatic boundary
402 ENDDO
DO 403 J=2,M2
ARHO=ARX(J)*RHO(1,J)
CON(2,J)=CON(2,J)+ARHO*U(2,J) ! Accumulative addition
AIM(2,J)=0. ! a_W =0， Adiabatic  boundary
DO 404 I=2,L2
IF(I= =L2) THEN
ARHO=ARX(J)*RHO(L1,J)
CON(I,J)=CON(I,J)-ARHO*U(L1,J) ! Accumulative addition
AIP(I,J)=0.  !a_E=0
ELSE
ARHO=ARX(J)*（FX(I+1)*RHO(I+1,J)+FXM(I+1)*RHO(I,J))
```



$$\begin{cases} \Delta X \cdot 1 \quad r=1 \quad \text{直角} \\ r\cdot\theta(\theta=1)\cdot\Delta x \ \text{圆柱} \\ r\Delta\theta\cdot 1 \ \text{极坐标} \end{cases}$$

```
FLOW=ARHO*UHAT(I+1,J) !
CON(I,J)=CON(I,J)-FLOW
CON(I+1,J)=CON(I+1,J)+FLOW !
AIP(I,J)=ARHO*DU(I+1,J)   ! a_E
AIM(I+1,J)=AIP(I,J) !Relation ship between（a_W） and (a_E)_i+1
ENDIF
IF(J= =M2) THEN
 ARHO=RMN(M1)*XCV(I)*RHO(I,M1)
 CON(I,J)=CON(I,J)-ARHO*V(I,M1) ! Accumulative addition
 AJP(I,J)=0. !  North coefficient of M2
 ELSE
ARHO=RMN(J+1)*XCV(I)*(FY(J+1)*RHO(I,J+1)+FYM(J+1)*RHO(I,J))
FLOW=ARHO*VHAT(I,J+1)
CON(I,J)=CON(I,J)-FLOW
CON(I,J+1)=CON(I,J+1)+FLOW
AJP(I,J)=ARHO*DV(I,J+1)
AJM(I,J+1)=AJP(I,J) !Relationship between coefficients
ENDIF
```

```
      AP(I,J)=AIP(I,J)+AIM(I,J)+AJP(I,J)+AJM(I,J)
404 ENDDO
403 ENDDO
      DO 421 J=2,M2
      DO 422 I=2,L2
      AP(I,J)=AP(I,J)/RELAX(NP) ! Pressure underrelaxation
      CON(I,J)=CON(I,J)+(1.0-RELAX(NP))*AP(I,J)*P(I,J)
422 ENDDO
421 ENDDO
      COFP(IST:L2,JST:M2,2:5)=COF(IST:L2,JST:M2,2:5)
```

!Store a_E,a_W,a_N,a_S for p-correction equation

! while CON（b）and AP (aP) are not stored; Because AP has been
!underelaxed, and the veloity in p-correction eq. is different.

```
    NF=NP !NFMAX+1; P(I,J) is one member of F(I,J,NF)
    CALL SOLVE  ! Solving P-equation
```

COMPUTE U AND V ! Pressure has been solved

```
      NF=1
      IST=3
      JST=2
      COF(IST:L2,JST:M2,1:6)=COFU(IST:L2,JST:M2,1:6) ! Coefficients of U
      DO 551 J=JST,M2
      DO 552 I=IST,L2
      CON(I,J)=CON(I,J)+DU(I,J)*AP(I,J)*(P(I-1,J)-P(I,J))
522 ENDDO
521 ENDDO
      CALL SOLVE !Solving U equation
C-----------------------------------------------------------------------------------------
      NF=2
      IST=2
      JST=3
      COF(IST:L2,JST:M2,1:6)=COFV(IST:L2,JST:M2,1:6) !Coefficients of V
      DO 553 J=JST,M2
      DO 554 I=IST,L2
      CON(I,J)=CON(I,J)+DV(I,J)*AP(I,J)*(P(I,J-1)-P(I,J))
```

```
    CON(I,J)=CON(I,J)+DV(I,J)*AP(I,J)*(P(I,J-1)-P(I,J))
554 ENDDO
553 ENDDO
    CALL SOLVE ! Solving V-equation. Such U V are temporary, need to be
  ! improved
COEFFICIENTS FOR THE PRESSURE CORRECTION EQUATION
    NF=3      ! P-correction equation
    CALL RESET    ! Zero of CON(I,j)  and AP(i,j)
    IST=2
    JST=2
    COF(IST:L2,JST:M2,2:5)=COFP(IST:L2,JST:M2,2:5)
  ! Transfer coefficients of P-eq. to P-correction equation.
    CALL GAMSOR
    SMAX=0.
    SSUM=0.
```

```
      DO 510 J=2,M2
      DO 511 I=2,L2
      VOL=YCVR(J)*XCV(I)        ! Volume of PCV
      CON(I,J)=CON(I,J)*VOL
511 ENDDO
510 ENDDO
      DO 502 I=2,L2
      ARHO=R(1)*XCV(I)*RHO(I,1)
      CON(I,2)=CON(I,2)+ARHO*V(I,2)  ! Source term b
502 ENDDO
      DO 503 J=2,M2
      ARHO=ARX(J)*RHO(1,J)
      CON(2,J)=CON(2,J)+ARHO*U(2,J)
      DO 504 I=2,L2
      IF(I= =L2) THEN
      ARHO=ARX(J)*RHO(L1,J)
      CON(I,J)=CON(I,J)-ARHO*U(L1,J)  ! Calculate b-term
      ELSE
      ARHO=ARX(J)*(FX(I+1)*RHO(I+1,J)+FXM(I+1)*RHO(I,J))
      FLOW=ARHO*U(I+1,J)  ! Adopt U*,V* to solve P'
      CON(I,J)=CON(I,J)-FLOW
      CON(I+1,J)=CON(I+1,J)+FLOW
```

Do loop 502—504 for mass source of each CV

```
 ENDIF
IF(J= =M2) THEN
ARHO=RMN(M1)*XCV(I)*RHO(I,M1)
CON(I,J)=CON(I,J)-ARHO*V(I,M1
ELSE
ARHO=RMN(J+1)*XCV(I)*(FY(J+1)*RHO(I,J+1)+FYM(J+1)*RHO(I,J))
FLOW=ARHO*V(I,J+1)
CON(I,J)=CON(I,J)-FLOW
CON(I,J+1)=CON(I,J+1)+FLOW
ENDIF
AP(I,J)=AIP(I,J)+AIM(I,J)+AJP(I,J)+AJM(I,J)      <-- 主对角元
PC(I,J)=0.  ！ Initial field
SMAX=AMAX1(SMAX,ABS(CON(I,J)))  ！ Take the maximum
SSUM=SSUM+CON(I,J)  ！ Summation of b
504 ENDDO
503 ENDDO
CALL SOLVE ！ Solving p-correction equation
```

```
COME HERE TO CORRECT THE VELOCITIES
    DO 521 J=2,M2
    DO 522 I=2,L2
    IF(I/=2) U(I,J)=U(I,J)+DU(I,J)*(PC(I-1,J)-PC(I,J)) ! Correcting velocity u
    IF(J/=2) V(I,J)=V(I,J)+DV(I,J)*(PC(I,J-1)-PC(I,J)) ! Correcting velocity v
522 ENDDO
521 ENDDO
500 ENDIF
COEFFICIENTS FOR OTHER EQUATIONS----------------------------------------
    IST=2
    JST=2
    DO 600 N=4,NFMAX  !NF>=4
    NF=N
    IF(LSOLVE(NF)) THEN
    CALL GAMSOR
    IF(LSOLE(4)) THEN
    DO I=1,L1
    DO J=1,M1
    RHO(I,J)=RHO(I,J)*CP(I,J)
    ENDDO
    ENDDO
    REL=1.-RELAX(NF)
```

```
      DO 602 I=2,L2
      AREA=R(1)*XCV(I)
      FLOW=AREA*V(I,2)*RHO(I,1)
      DIFF=AREA*GAM(I,1)/YDIF(2)
      CALL DIFLOW
      AJM(I,2)=ACOF+AMAX1(0.,FLOW)
  602 ENDDO
      DO 603 J=2,M2
      FLOW=ARX(J)*U(2,J)*RHO(1,J)
      DIFF=ARX(J)*GAM(1,J)/(XDIF(2)*SX(J))
      CALL DIFLOW
      AIM(2,J)=ACOF+AMAX1(0.,FLOW)
      DO 604 I=2,L2
      IF(I= =L2) THEN
      FLOW=ARX(J)*U(L1,J)*RHO(L1,J)
      DIFF=ARX(J)*GAM(L1,J)/(XDIF(L1)*SX(J))
      ELSE
      FLOW=ARX(J)*U(I+1,J)*(FX(I+1)*RHO(I+1,J)+FXM(I+1)*RHO(I,J))
      DIFF=ARX(J)*2.*GAM(I,J)*GAM(I+1,J)/((XCV(I)*GAM(I+1,J)+
```

```
1 XCV(I+1)*GAM(I,J)+1.0E-30)*SX(J))
  ENDIF
  CALL DIFLOW
  AIM(I+1,J)=ACOF+AMAX1(0.,FLOW)
  AIP(I,J)=AIM(I+1,J)-FLOW
  AREA=RMN(J+1)*XCV(I)
   IF(J= = M2) THEN
  FLOW=AREA*V(I,M1)*RHO(I,M1)
  DIFF=AREA*GAM(I,M1)/YDIF(M1)
   ELSE
   FLOW=AREA*V(I,J+1)*(FY(J+1)*RHO(I,J+1)+FYM(J+1)*RHO(I,J))
   DIFF=AREA*2.*GAM(I,J)*GAM(I,J+1)/(YCV(J)*GAM(I,J+1)+
 1 YCV(J+1)*GAM(I,J)+1.0E-30)
   ENDIF
   CALL DIFLOW
```

```
    AJM(I,J+1)=ACOF+AMAX1(0.,FLOW)
    AJP(I,J)=AJM(I,J+1)-FLOW
    VOL=YCVR(J)*XCV(I)
    APT=RHO(I,J)/DT  ! Transient term ρ/△t without volume
    AP(I,J)=AP(I,J)-APT
    CON(I,J)=CON(I,J)+APT*F(I,J,NF)
    AP(I,J)=(-AP(I,J)*VOL+AIP(I,J)+AIM(I,J)+AJP(I,J)+AJM(I,J))
   1/RELAX(NF)
    CON(I,J)=CON(I,J)*VOL+REL*AP(I,J)*F(I,J,NF)
604 ENDO
603 ENDO
    CALL SOLVE !
    IF（LSLVE(4)) THEN
    DO I=I,L1
    DO J=1,M1
    RHO(I,J)=RHO(I,J)/CP(I,J)
    ENDDO
    ENDDO
    ENDIF
    ENDIF
600 ENDDO（End of the solving process）
    TIME=TIME+DT  !  Forward time
    ITER=ITER+1   !Increase the indicator
    IF(ITER>= LAST) LSTOP=.TRUE. RETURN
    END
```

$$b = S_C \Delta V + a_P^0 \phi_P^0 \qquad a_P = a_E + a_W + a_N + a_S + a_P^0 - S_P \Delta V$$

Transient, Linear----
Steady, nonlinear

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

```
      SUBROUTINE SUPPLY
C**********************************************************************
      USE START_L
      IMPLICIT NONE
      REAL*8 DX,DY,RHOM,PREF
      INTEGER*4 I,J,N,JJ,IEND,JEND,IBEG,JBEG,IFST,JFST,JFL
C**********************************************************************
```

```
C*************************************************************************
 10 FORMAT(1X,26(1H*),3X,A10,3X,26(1H*))
 20 FORMAT(1X,4H I =,I6,6I9)
 30 FORMAT(1X,' J')
 40 FORMAT(1X,I3,2X,1P7E9.2)
 50 FORMAT(1X,1H )   !
 51 FORMAT(2X,'I =',2X,7(I4,5X))
 52 FORMAT(2X,'X =',1P7E9.2)
 53 FORMAT(1X,' TH =',1P7E9.2)
 54 FORMAT(2X,'J =',2X,7(I4,5X))
 55 FORMAT(2X,'Y =',1P7E9.2)
C*************************************************************************
     ENTRY UGRID
     XU(2)=0.
     DX=XL/FLOAT(L1-2)
     DO 1 I=3,L1
     XU(I)=XU(I-1)+DX
   1 ENDDO
     YV(2)=0.
     DY=YL/FLOAT(M1-2)
     DO 2 J=3,M1
      YV(J)=YV(J-1)+DY
   2 ENDDO
     RETURN
```

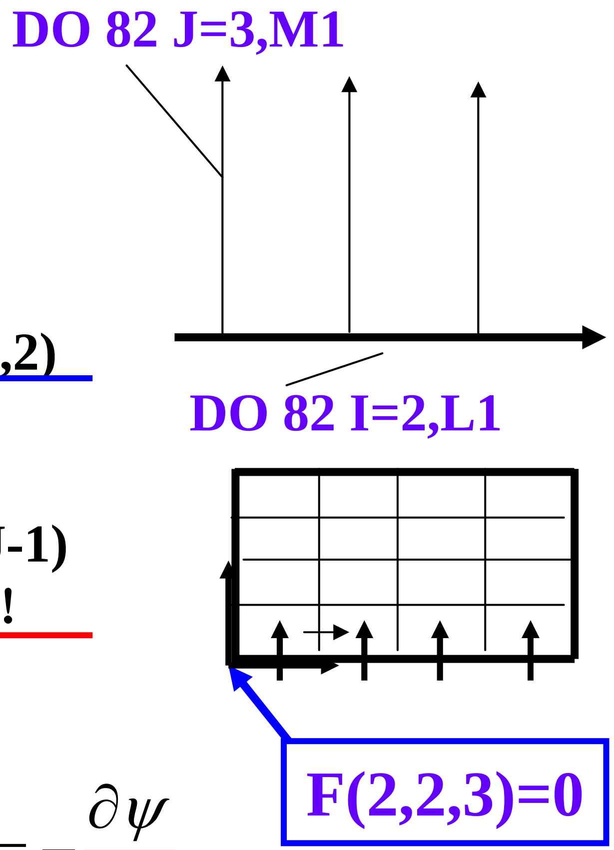
1P7E9.2

1P---1 integral digit of each data;

7E---7 data in scientific expression

9.2---Each data contains 9 places, and there are two decimal places (小数2位)

```
C*****************************************************
      ENTRY PRINT
      IF(LPRINT(3)) THEN
C     CALCULATE THE STREAM FUNCTION
      F(2,2,3)=0.
      DO 81 I=2,L1
      IF(I.NE.2) F(I,2,3)=F(I-1,2,3)-RHO(I-1,1)*V(I-1,2)
     1*R(1)*XCV(I-1)  ! I＝2，F(2,2,3)=0；
      DO 82 J=3,M1
      RHOM=FX(I)*RHO(I,J-1)+FXM(I)*RHO(I-1,J-1)
      F(I,J,3)=F(I,J-1,3)+RHOM*U(I,J-1)*ARX(J-1) !
   82 ENDDO
   81 ENDDO
```



$$\psi = \int \rho u r dy \quad \psi = -\int \rho v r dx \quad \rho u r = \frac{\partial \psi}{\partial y}; \rho v r = -\frac{\partial \psi}{\partial x}$$

For bottom, from left to right $\psi_{i,2} = \psi_{i-1,2} - \sum_{i=3} \rho_{i-1,1} v_{i-1,2} r(1) \Delta x_i$

For vertical, from bottom to top $\psi_{i,j} = \psi_{i,j-1} + \rho_m u_{i,j-1} r(j) \Delta y_j$

```
    IF(LPRINT(NP)) THEN
 CONSTRUCT BOUNDARY PRESSURES BY EXTRAPOLATION
    DO 91 J=2,M2
    P(1,J)=(P(2,J)*XCVS(3)-P(3,J)*XDIF(2))/XDIF(3)
    P(L1,J)=(P(L2,J)*XCVS(L2)-P(L3,J)*XDIF(L1))/XDIF(L2)
 91 ENDDO
    DO 92 I=2,L2
    P(I,1)=(P(I,2)*YCVS(3)-P(I,3)*YDIF(2))/YDIF(3)
    P(I,M1)=(P(I,M2)*YCVS(M2)-P(I,M3)*YDIF(M1))/YDIF(M2)
 92 ENDDO
    P(1,1)=P(2,1)+P(1,2)-P(2,2)
    P(L1,1)=P(L2,1)+P(L1,2)-P(L2,2)
    P(1,M1)=P(2,M1)+P(1,M2)-P(2,M2)
    P(L1,M1)=P(L2,M1)+P(L1,M2)-P(L2,M2)
    PREF=P(IPREF,JPREF) ! Reference point of pressure
    DO 93 J=1,M1
    DO 93 I=1,L1
    P(I,J)=P(I,J)-PREF  ! Relative pressure
  94ENDDO
  93ENDDO
    ENDIF
```

```
PRINT 50 ! Print out to screen
WRITE(8,50) ! Output into file
IEND=0
DO WHILE (IEND/=L1)
IBEG=IEND+1
IEND=IEND+7  ! !7 data in each line
IEND=MIN0(IEND,L1) ! Take minimum
PRINT 50
WRITE(8,50)
PRINT 51,(I,I=IBEG,IEND) !From IBEG too IEND for printing
WRITE(8,51) (I,I=IBEG,IEND)
IF(MODE/=3) THEN
PRINT 52,(X(I),I=IBEG,IEND)
WRITE(8,52) (X(I),I=IBEG,IEND)
ELSE
PRINT 53,(X(I),I=IBEG,IEND)
WRITE(8,53) (X(I),I=IBEG,IEND)
ENDIF
ENDDO
IF(IEND= =L1) THEN
```

```
JEND=0
PRINT 50
WRITE(8,50)
DO WHILE(JEND/=M1) THEN
JBEG=JEND+1
JEND=JEND+7
JEND=MIN0(JEND,M1)
PRINT 50
WRITE(8,50)
PRINT 54,(J,J=JBEG,JEND)
WRITE(8,54) (J,J=JBEG,JEND)
PRINT 55,(Y(J),J=JBEG,JEND)
WRITE(8,55) (Y(J),J=JBEG,JEND) GO TO 311
ENDDO
ENDIF
```

```
DO 999 N=1,NCP
NF=N
IF(LPRINT(NF)) THEN
PRINT 50
WRITE(8,50)
PRINT 10,TITLE(NF)
WRITE(8,10) TITLE(NF)
IFST=1
JFST=1
IF(NF==1.OR.NF==3) IFST=2
IF(NF==2.OR.NF==3) JFST=2
IBEG=IFST-7
DO WHILE（IEND<L1.OR.IBEG== -5.OR.IBRG== -6)
IBEG=IBEG+7  ！ Starting point for each line (7data)
IEND=IBEG+6  ！ Ending point of the line
IEND=MIN0(IEND,L1)
PRINT 50 WRITE(8,50)
```

```
   PRINT 20,(I,I=IBEG,IEND)
   WRITE(8,20) (I,I=IBEG,IEND)
   PRINT 30
   WRITE(8,30)
   JFL=JFST+M1  .
   DO 115 JJ=JFST,M1
   J=JFL-JJ
   PRINT 40, J, (F(I,J,NF),I=IBEG,IEND)
   WRITE(8,40) J,(F(I,J,NF),I=IBEG,IEND)
115 ENDDO
   ENDDO
   ENDIF
 999 END  （End of print do-loop）
```

Transformation of data format

```
OPEN(9,FILE="RESULT.DAT")
        WRITE(9,'("VARIABLES=X,Y",$)')
         DO NF=1,NCP
         IF(LPRINT(NF)) WRITE(9,'(",",A7,$)') TITLE(NF)
         ENDDO
        WRITE(9,'(/,"ZONE I=",I4,",J=",I4,",T=T",$)') L1,M1
        DO J=1,M1
        DO I=1,L1
         WRITE(9,'(/,E11.3,E11.3,$)') X(I),Y(J)
        DO NF=1,NCP
         IF(LPRINT(NF)) THEN
        FSHOW=F(I,J,NF)
        IF(NF==1) THEN
          IF(I==1) FSHOW=U(2,J)
          IF(I>=2.AND.I<=L2)  FSHOW=(U(I,J)+U(I+1,J))/2
          IF(I==L1) FSHOW=U(L1,J)
        ENDIF
```

Data format of TECPLOT

Data format of TECPLOT

For u

```
IF(NF==2) THEN
   IF(J==1) FSHOW=V(I,2)
   IF(J>=2.AND.J<=M2) FSHOW=(V(I,J)+V(I,J+1))/2
   IF(J==M1) FSHOW=V(I,M1)
ENDIF
WRITE(9,'(E11.3,$)') FSHOW
ENDIF
ENDDO
 ENDDO
ENDDO
CLOSE(9)
RETURN
END
```

For v

************************** .TEMP. **************************

J \ I =	1	2	3	4	5	6	7
7	2.00E+00	2.30E+00	2.90E+00	3.50E+00	4.10E+00	4.70E+00	5.00E+00
6	1.80E+00	2.08E+00	2.64E+00	3.20E+00	3.76E+00	4.32E+00	4.60E+00
5	1.40E+00	1.64E+00	2.12E+00	2.60E+00	3.08E+00	3.56E+00	3.80E+00
4	1.00E+00	1.20E+00	1.60E+00	2.00E+00	2.40E+00	2.80E+00	3.00E+00
3	6.00E -01	7.60E- 01	1.08E+00	1.40E+00	1.72E+00	2.04E+00	2.20E+00
2	2.00E -01	3.20E- 01	5.60E- 01	8.00E- 01	1.04E+00	1.28E+00	1.40E+00
1	0.00E+00	1.00E- 01	3.00E- 01	5.00E- 01	7.00E- 01	9.00E- 01	1.00E+00

1P7E9.2

- **1P---1 integral digit of each data;**
- **7E---7 data in scientific expression**
- **9.2---Each data contains 9 places, and there are two decimal places (小数2位)**

同舟共济
渡彼岸！