Numerical Heat Transfer

(数值传热学)

Chapter 10 General Code for 2D Elliptical Fluid Flow and Heat Transfer (2)

Instructor：Fang, Wen-Zhen

Email: fangwenzhen@xjtu.edu.cn

Key Laboratory of Thermo-Fluid Science & Engineering
Xi’an Jiaotong University

2024-Nov-26

Chapter 10 General Code for 2D Elliptical Fluid Flow and Heat Transfer Problems (2)

10.6 Methods of application and explanation of Main Program

10.6.1 Methods of Code application

10.6.2 Explanation of Main Program

10.6.2.1 MODULE START_L

10.6.2.2 PROGRAM MAIN

10.6.2.3 SUBROUTINE DIFLOW

10.6.2.4 SUBROUTINE SOLVE

10.6.2.5 SUBROUTINE SETUP

10.6.2.6 SUBROUTINE SUPPLY

10. 6 Methods of Application and Explanation of Main Program

10.6.1 Methods of Code 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(will be taught in Chapter 11) similar to the problem studied**

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.

4. Making correspondent modifications for the six-Module in USER, according to the problem studied, especially for following parts:

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

.TRUE.

(2) LAST—Specify iteration number, default value is 5.

(3) NTIMES(NF)—Default value equals 1; for steady nonlinear one, setting: 1 to 2; unsteady linear: 5 to 6

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

For fully implicit scheme, in the a_p-term there is a term of $a_P^0 = \rho \Delta V / \Delta t$, if $\Delta t \to \infty, a_P^0 \to 0$, leading to steady state results. Default value is for steady case.

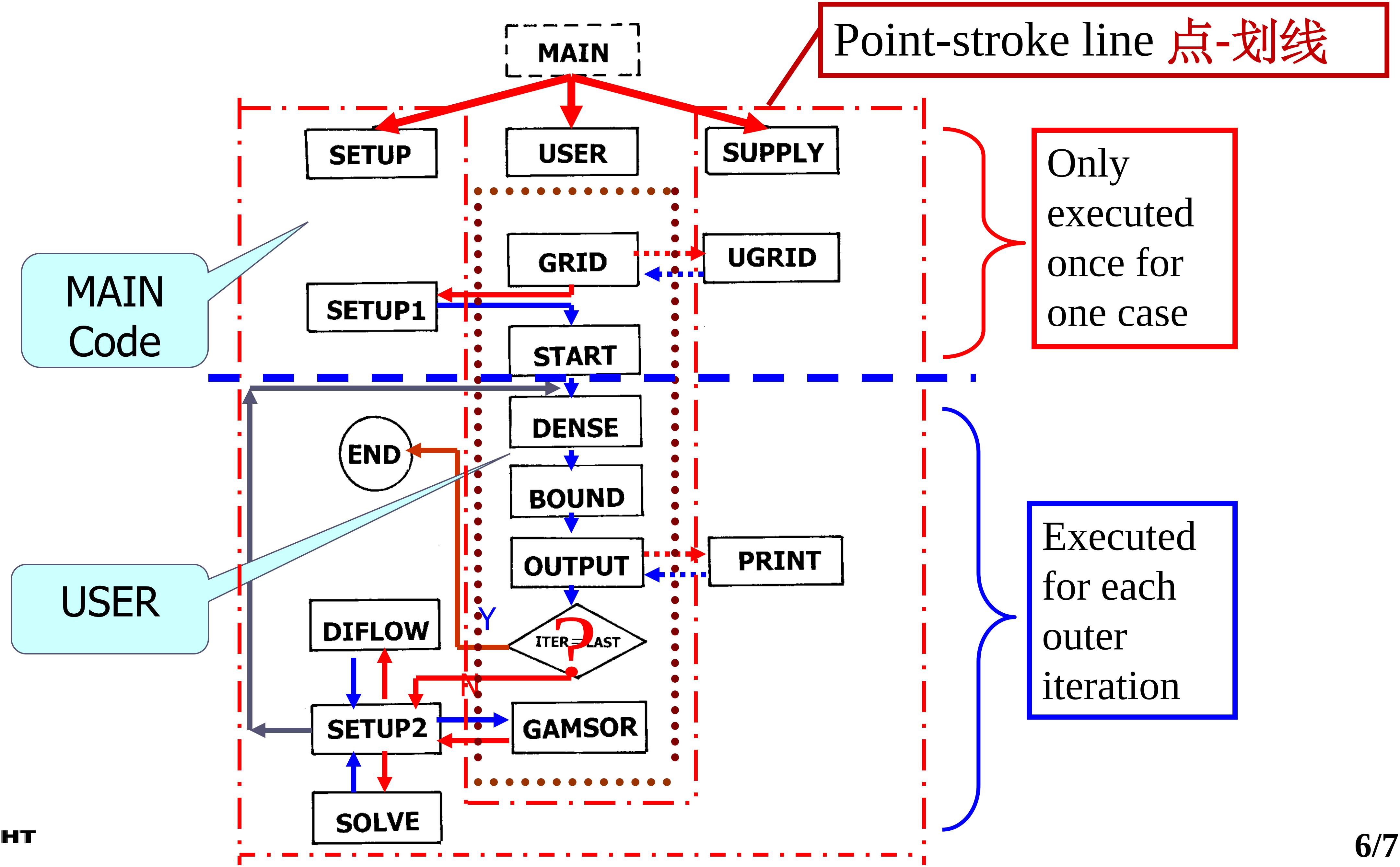
(5) RELAX(NF)—Default value is 1.

5 Defining a new dependent variable, say *C*(*i*,*j*), as follows:

First defining C(NI,NJ),

then using EQUIVALENCE:

EQUIVALENCE (F(1,1,5), C(1,1)).



Point-stroke line 点-划线

Only executed once for one case

Executed for each outer iteration

For the **Main Program**, these parts will be explained in detail.

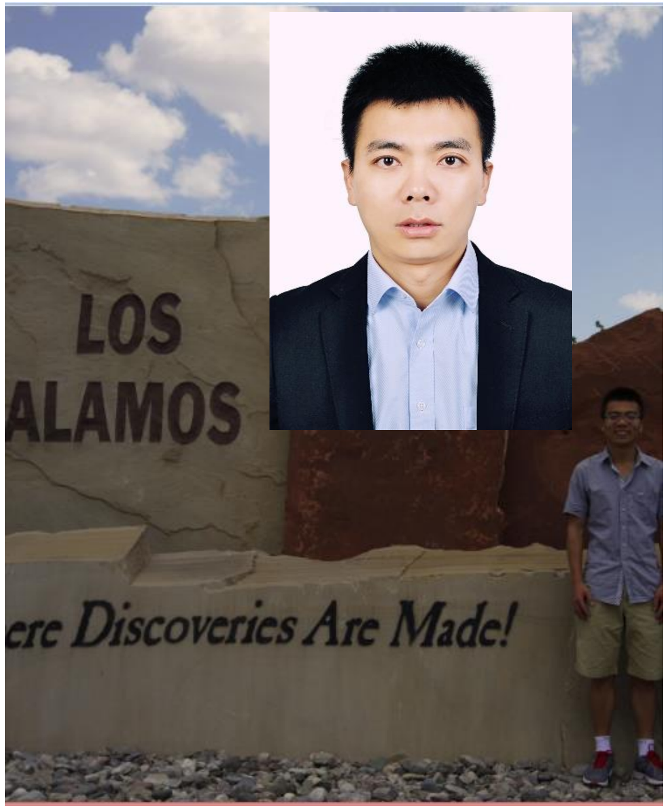
1. MODULE START_L
2.--------------------MAIN ----------------
3. SUBROUTINE DIFLOW
4. Structure of SOLVE
5. Block correction
6. Structure of SETUP
7. MODE execution
8. Determination of neighbor coefficients
9. Determination of AP coefficients
10. Structure of SIMPLER
11. Temporal storage of coefficients for SIMPLER
12. Accumulated addition
13. Storage of coefficients of *p*-equation
14. Nominal density for temperature
15. Iteration=Marching forward
16. Data Format for print out

10-6-2 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 local computational 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 as a
C  frame to re-develop your own code for research purpose.
C --------Instructor of Numerical Heat Transfer, XJTU,2013.---------------
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C  The current version of the program was updated from Fortran 77 to
C  Fortran 95  by Dr. Yu-Tong Mu , Dr. Li Chen and  Dr.Kong Ling of NHT
C  group of XJTU during 2013.01-04
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C****************************************************************
```

母玉同

凌空



陈黎

10.6.2.1 MODULE START_L

(1)-Explained in detail

```
      MODULE START_L       ! Name of Module
      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
      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,
     &   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,
     &  IST,JST,ITER,LAST,MODE,NTIMES(NFX4),IPREF,JPREF
       REAL*8 SMAX,SSUM
       REAL*8 FLOW,DIFF,ACOF
```

Sc or b

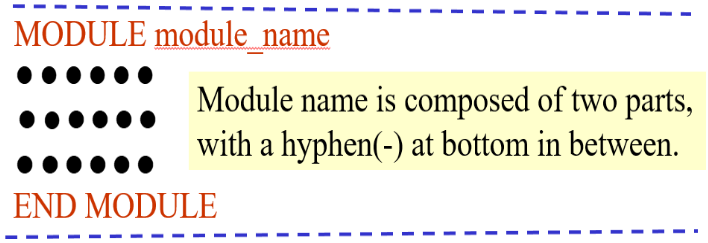
a_e, a_w, a_n, a_s, a_p

(1) Packaging data (封装数据);
(2) Initializing data (数据初始化);
(3) Declaring type of data (声明数据类型).

```
C****************************************
  EQUIVALENCE(F(1,1,1),U(1,1)),(F(1,1,2),V(1,1)),(F(1,1,3),PC(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)
 &,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)),
 &(COF(1,1,3),AIM(1,1)),(COF(1,1,4),AJP(1,1)),
 &(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),
 &(XCVS,THCVS),(XL,THL)
```

Default value!!

```
  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
```



```
MODULE module_name
●●●●●●
●●●●●●
●●●●●●
END MODULE
```

Module name is composed of two parts, with a hyphen(-) at bottom in between.

(1) Packaging data (封装数据);

(2) Initializing data (数据初始化);

(3) Declaring type of data (声明数据类型).

Some explains to this most important module

```
REAL*8,DIMENSION(NI,NJ,NFX4)::F
```

Real variable 3-D array, array title F， F(NI,NJ,NFX4);
Variable number in three coordinates are NI,NJ and NFX4 respectively;

```
REAL*8 SMAX,SSUM
```

Real variable of SMAX and SSUM, with length of eight digits;

```
INTEGER*4 NF,NP,NRHO
```

Integer variable of NF,NP,NRHO, with length of four digits;

```
EQUIVALENCE(F(1,1,1),U(1,1)),(F(1,1,2),V(1,1))
```

Making the 1st variable of the 3D array F identical to the 2D array U; the same for (F(1,1,2), V(1,1)))

10.6.2.2 PROGRAM MAIN

(2)-Explained in detail

```
C***********************************************************
C-------------------------------------MAIN ------------------------------------
C***********************************************************
```

Calling Module

```
PROGRAM MAIN  ! Set up entire flow chart
USE START_L      Share the variables defined in the MODULE
IMPLICIT NONE
C***********************************************************
OPEN(8,FILE='RESULT.txt')  ! Result file for output
```

Only Executed once

```
CALL GRID      !Grid generation (setup interface positions)
CALL SETUP1    !Set up 1-D array of geometric parameters
CALL START     !Set up initial field
DO WHILE (.NOT.LSTOP）!  If LSTOP is .F., then do loop
```

Executed Many times

```
CALL DENSE     !Set up fluid density
CALL BOUND     !Set up boundary condition
CALL OUTPUT    !Print out representative results
CALL SETUP2    !Key module: set coefficients and solve ABEqs.
ENDDO
CALL OUTPUT!Print out some results
CLOSE(8)    !Simulation completed  close file RESULT.TXT in Channel 8
STOP        !Terminate computation
END       !End of main program
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

For ABEqs, we determine coefficients using **Subroutine DIFLOW**

For all other scalar variables (including *T*, etc)

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

$$a_P\phi_P=a_E\phi_E+a_W\phi_W+a_N\phi_N+a_S\phi_S+b$$

$$\boxed{a_E=D_eA(|P_{\Delta e}|)+[\![-F_e,0}\qquad a_W=D_wA(|P_{\Delta w}|)+[\![F_w,0$$

a_E / D_e :

Scheme	Central difference	Upwind difference
Definition	$1\text{-}0.5\ P_{\Delta e}$	$1+\ \|\!\|-P_{\Delta e},0\|\!\|$
Hybrid	Power-law	Exponential
$\|\!\|-P_{\Delta e},1-\frac{1}{2}P_{\Delta e},0\|\!\|$	$\|\!\|0,\ (1-0.1P_{\Delta e})^5\|\!\|+\|\!\|0,\ \text{-}P_{\Delta e}\|\!\|$	$\frac{P_{\Delta e}}{\exp(P_{\Delta e})-1}$

$$P_{\Delta e}=\frac{F_e}{D_e}$$

10.6.2.3 SUBROUTINE DIFLOW

(3)-Explained in detail

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

SUBROUTINE DIFLOW ! **Determine** $D \cdot A(|P_\Delta|)$ **of power law scheme**
!The input variables are DIFF and FLOW

USE START_L ! **Share the variables defined in the MODULE START_L**
IMPLICIT NONE
REAL*8 TEMP ! **temporal variable**

C**

ACOF=DIFF ! $D \cdot A(|P_\Delta|) = D$ （ACOF represents $D \cdot A(|P_\Delta|)$）

! 1st return for diffusion case

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

! 2nd return for $|P_\Delta| > 10$

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

TEMP=TEMP/DIFF ! $1-0.1|P_\Delta|$

ACOF=DIFF*TEMP5** ! $D \cdot (1-0.1|P_\Delta|)^5 = D \cdot A(|P_\Delta|)$

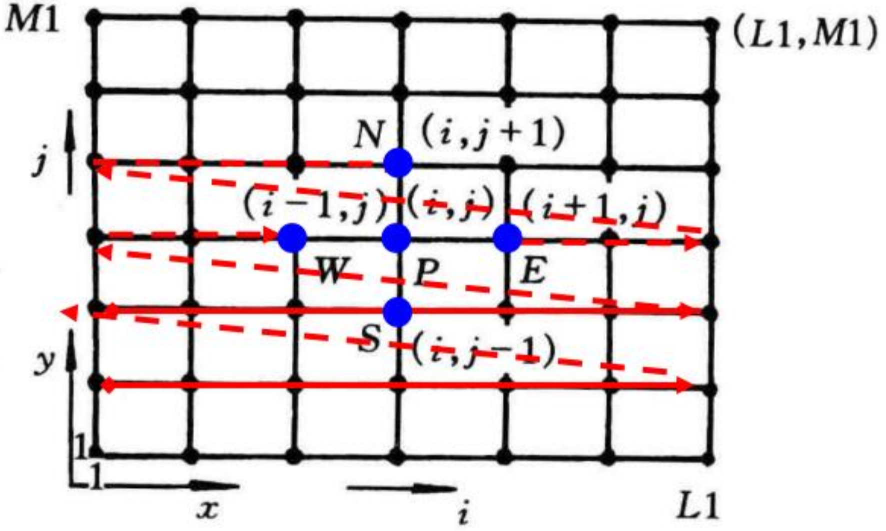
! 3rd return for $|P_\Delta| < 10$

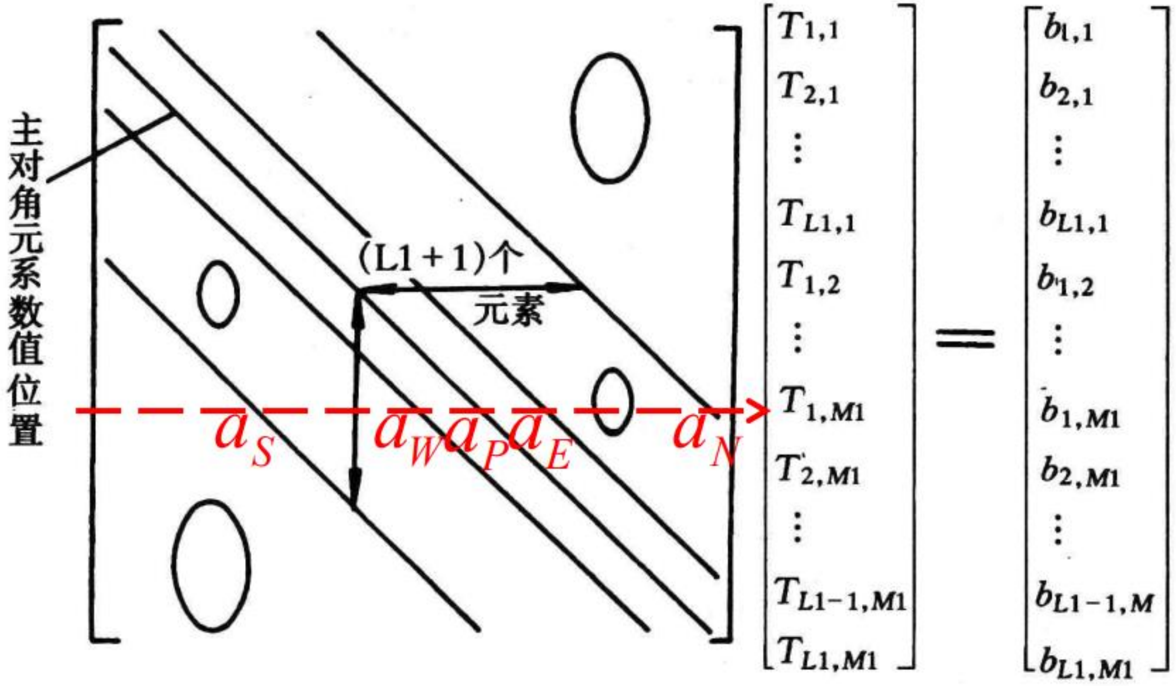
RETURN

END **!In SETUP2:** $a_E = D_e A(|P_\Delta|) + [0, -F_e]$

10.6.2.4 SUBROUTINE SOLVE

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE SOLVE       ! alternative direction line iteration
      USE START_L                 ＋ Block correction
      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**********************************************************************
```



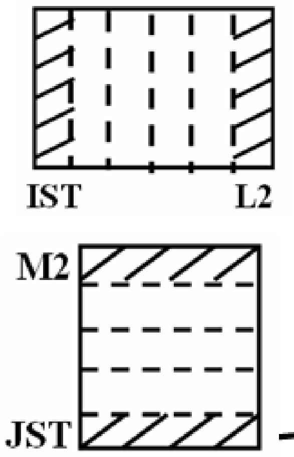


Structure of SOLVE

AD---alternative direction

S O L V E

```
DO 999 NT=1， NTIMES（NF）
N=NF
IF (LBLK(NF)) THEN
PT(ISTF)=0.
••••••
13 ENDDO
 PT(JSTF)=0.
 ••••••
23 ENDDO
10 ENDIF
```



Two times of block corrections

AD Block Correction

Upward line iteration

downward line iteration

Left to right line iteration

Right to left line iteration

```
999 ENDDO
```

Four times of line iterations

AD line Iteration

(4)-Explained in detail

Review on block correction

1.Equation for correction：

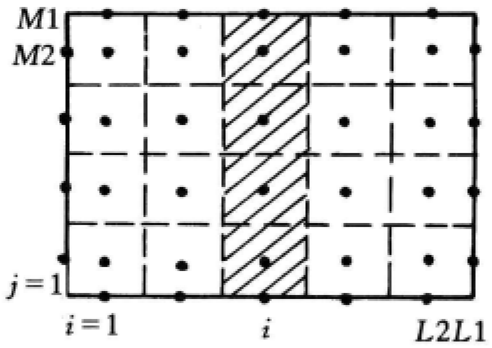
It is required that： $(\phi^*_{i,j} + \bar{\phi}'_i)$ satisfy following eq.

$$\sum_j \underline{AP}(\phi^*_{i,j} + \bar{\phi}'_i) = \sum_j \underline{AIP}(\phi^*_{i+1,j} + \bar{\phi}'_{i+1}) + \sum_j \underline{AIM}(\phi^*_{i-1,j} + \bar{\phi}'_{i-1})$$

$$+ \sum_j (\underline{AJM})(\phi^*_{i,j-1} + \bar{\phi}'_i)$$

$$+ \sum_j (\underline{AJP})(\phi^*_{i,j+1} + \bar{\phi}'_i) + \sum_j CON$$

$$(i = IST, \ldots L2)$$



IST-solution starting subscript in X-direction； L2-last but one.

Here *AP*,*AIP*,*AIM*, etc. are the symbles adopted in teaching code

Review on block correction

(5)-Explained in detail

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

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

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

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

$$\boxed{\begin{gathered} BL = A, BLP = B, \\ BLM = C \end{gathered}}$$

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

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

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

DENOM

- **TDMA**

$$A_iT_i = B_iT_{i+1} + C_iT_{i-1} + D_i,\ i = 1,2,\ldots..M1 \qquad \textbf{(a)}$$

(1) Elimination (消元)－Reducing the unknowns at each line from 3 to 2

$$T_{i-1} = P_{i-1}T_i + Q_{i-1} \qquad \textbf{（b）}$$

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

(2) Back substitution (回代）－Starting from M1 via Eq.(b) to get T_i sequentially

$$T_{M1} = Q_{M1} \qquad T_{i-1} = P_{i-1}T_i + Q_{i-1}$$

● Implementation of TDMA for 1st kind B.C.

For 1st kind B.C., the solution region is from i=2...to M1-1=M2, because T_1 and T_{M1} are known.

Applying Eq.(b) to i=1 with given $T_{1,\text{given}}$:

$$T_1 = P_1 T_2 + Q_1 \longrightarrow P_1 = 0\,;\ \ Q_1 = T_{1,given}$$

Because T_{M1} is known，back substitution should be started from M_2:

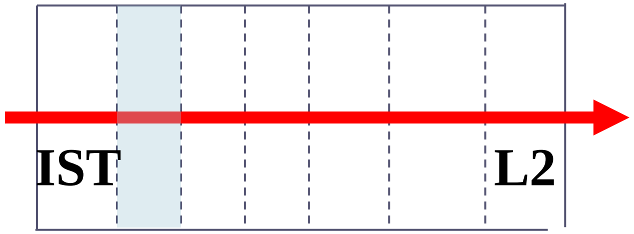
$$T_{M2} = P_{M2} T_{M1} + Q_2$$

When the ASTM is adopted to deal with B.C. of 2nd and 3rd kind, the numerical B.C. for all cases is regarded as 1st kind, and the above treatment should be adopted.

```
C*************************************************************************
      ISTF=IST-1
      JSTF=JST-1
      IT1=L2+IST          !Temporal variables for starting
      IT2=L3+IST           points of DO-loop
      JT1=M2+JST
      JT2=M3+JST
C*************************************************************************
      DO 999  NT=1,NTIMES(NF) ! Solution of algebraic equation
      N=NF  !  NF: 1＝U， 2＝V， 3＝P， 4=T……….
C-------------------------------------------------------------------------

     IF(LBLK(NF)) THEN !When LBLK is true, execute Block-correction
     PT(ISTF)=0.    !  Coefficient in TDMA    P_{IST-1}
     QT(ISTF)=0.    !  Constant in TDMA       Q_{IST-1}
     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
```

I –direction B. Correction.



(5)-Explained in detail

In discussion of TDMA: A B C D

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

Coefficients calculation

```
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)
& +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
```

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

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

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

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

$$A_i\bar{\phi}'_i = B_i\bar{\phi}'_{i+1} + C_i\bar{\phi}'_{i-1} + D_i$$

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

$$P_i = \frac{B_i}{A_i - C_iP_{i-1}}; \quad Q_i = \frac{D_i + C_iQ_{i-1}}{\underline{A_i - C_iP_{i-1}}};$$

DENOM

Elimination (消元)

```
DENOM=BL-PT(I-1)*BLM
IF(ABS(DENOM/BL) <1.E-10) DENOM=1.E25
PT(I)=BLP/DENOM
QT(I)=(BLC+BLM*QT(I-1))/DENOM
11 ENDDO
```

!Ensure a meaningful correction

Back substitution (回代)

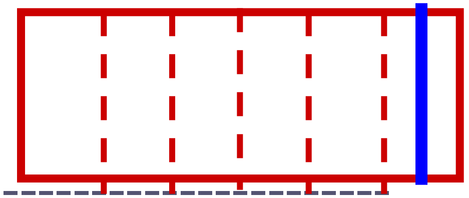
```
      BL=0.   （Initial set up)
      DO 13 II=IST,L2
      I=IT1-II
      BL=BL*PT(I)+QT(I)
      DO 14 J=JST,M2
      F(I,J,N)=F(I,J,N)+BL!
   14 ENDDO
   13 ENDDO
C----------------------------------------------------------------------
      PT(JSTF)=0.
      QT(JSTF)=0.
      DO 21 J=JST,M2
      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)
```

IT1=L2+IST

I=IT1-II＝L2＋IST-IST＝L2-Begin

I=IT1-II＝L2＋IST-L2＝IST-End

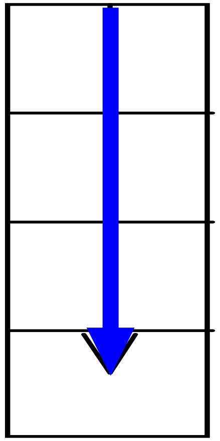
Correcting by BL for the same column



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

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

TDMA: from L2 to IST



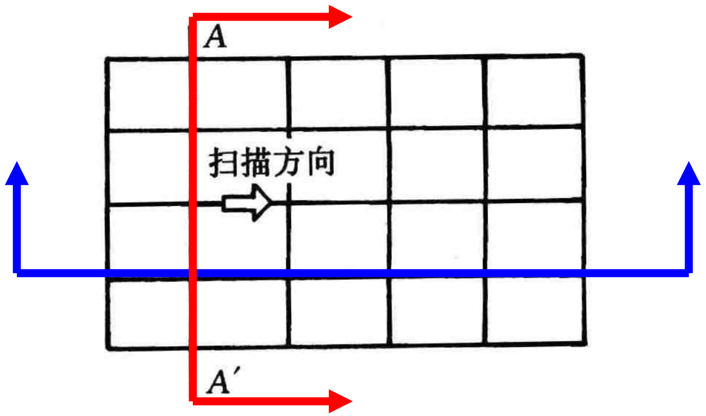
$$(BL)\bar{\phi}'_j = (BLP)\bar{\phi}'_{j+1} + (BLM)\bar{\phi}'_{j-1} + BLC, J = JST,....M2$$

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)
 & +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 block
 24 ENDDO
 23 ENDDO
 10 ENDIF
C— — — — — — — — — — — — — — — — — — — — — — — — — — — — —
!  Above is block correction, following is AD line iteration
```

line iteration：



Alternative direction iteration (ADI)

Solving in I-direction, scanning in J direction

$$a_P T_P^{(k+1)} = a_E T_E^{(k+1)} + a_W T_W^{(k+1)} + [\underline{a_N T_N^{(k)} + a_S T_S^{(k)} + b}]$$

! b'

At the same line, TDMA is used for direct solution, from line to line, iterative method is used.

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

Solving in I-direction, scanning in J direction, from bottom to top

$$AP\phi_{i,j}^{n}=AIP\phi_{i+1,j}^{n}+AIM\phi_{i-1,j}^{n}+b+AJP\phi_{i,j+1}^{n-1}+AJM\phi_{i,j-1}^{n-1};\quad i=IST\ldots L2$$

```
C-------------------------------------------------------------------------
      DO 90 J=JST,M2
        PT(ISTF)=0.      ! PT=0， QT=given boundary value, 1st kind boundary condition
        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-------------------------------------------------------------------------
```

Elimination
(消元)

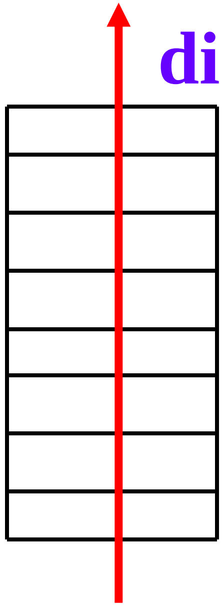
Back substitution
(回代)

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

$$Q_i=\frac{D_i+C_iQ_{i-1}}{A_i-C_iP_{i-1}};$$

$$b+AJP\phi_{i,j+1}^{n-1}+AJM\phi_{i,j-1}^{n-1}$$

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



Scanning direction

```
C----------------------------------------------------------------------------
   DO 190 JJ=JST,M3 ！ Solving in I-direction， scanning from top to bottom
   J=JT2-JJ  !Starting from M3 ,rather than from M2
   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----------------------------------------------------------------------------
```

For executing 1st kind B.C.

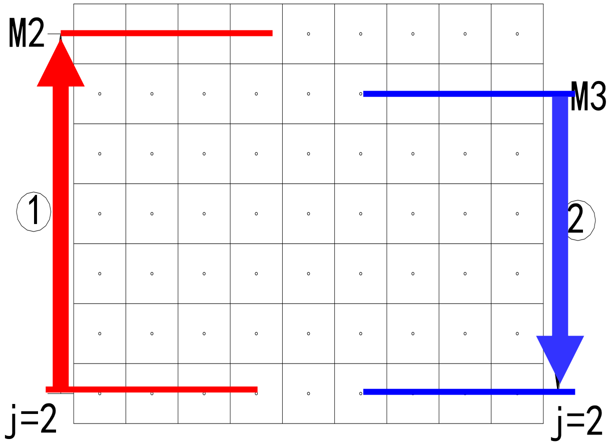
Elimination (消元)

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

$$b + AJP\phi^{n-1}_{i,j+1} + AJM\phi^{n-1}_{i,j-1}$$

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

Back substitution (回代)



```
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)
 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)
 380 ENDDO
 390 ENDDO
C************************************************************************
```

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

  ENTRY RESET  !（CON， AP are accumulatively used, should be reset）
  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
```

S_c or b

S_p or a_p

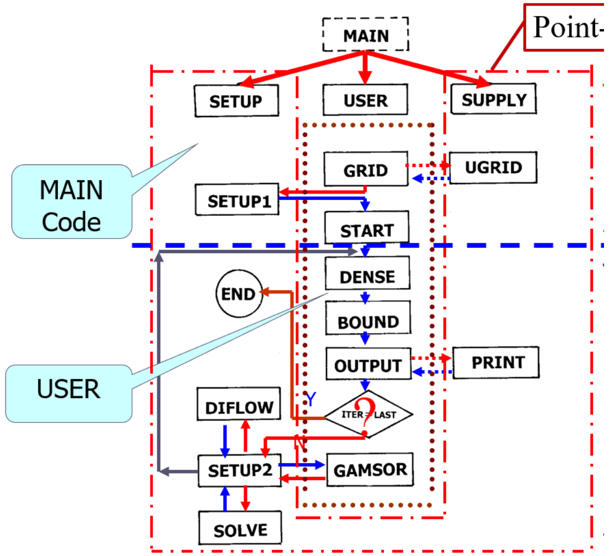
10.6.2.5 SUBROUTINE SETUP

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
  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***********************************************************************************

 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------------------------------------------------------------------------------------------
```

Structure of SETUP

(6)-Explained in detail



ENTRY SETUP1

Setup 28 one dimensional geometric parameters;

Setup initial values

RETURN

$$a_e u_e = \sum a_{nb} u_{nb} + b + A_e (p_P - p_E)$$

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

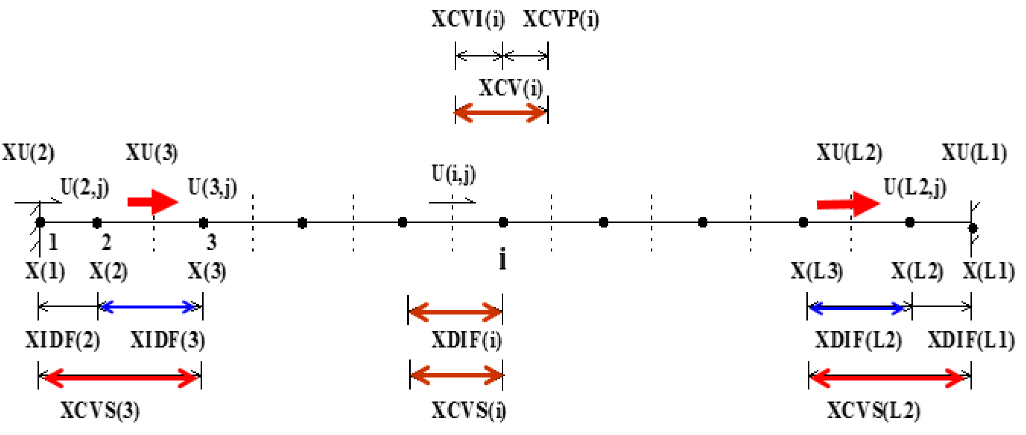
SIMPLER

Coefficient for other equation and solve it (from NF=4 to 10 in order)

RETURN

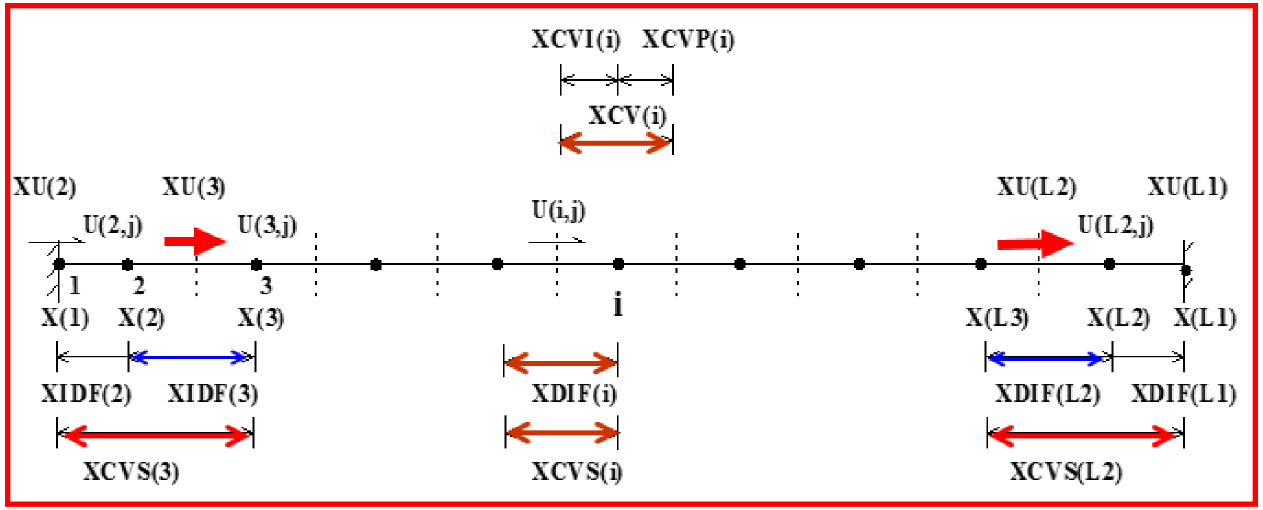
S
E
T
U
P

```
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))
    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
```

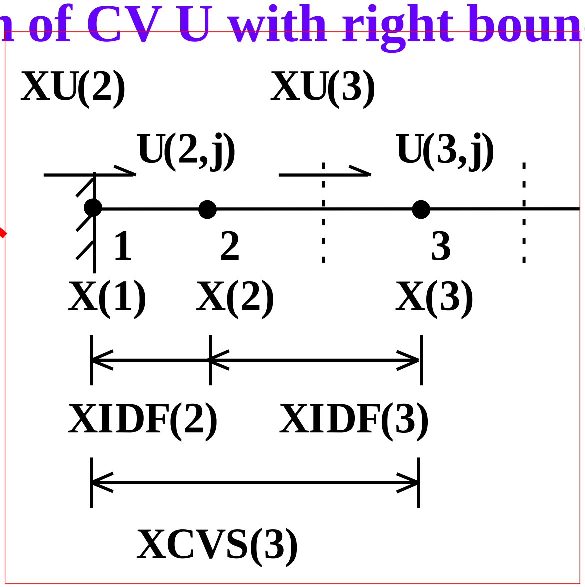


Similarly in Y-direction.

! Practice B:
XU(I) has been
set in GRID



```
      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)    !  $(\delta x)_{e^-}$
      XCVIP(I)=XCVI(I)       !  $(\delta x)_{e^+}$
22 ENDDO
      XCVIP(2)=XCV(2)
      XCVI(L2)=XCV(L2)
      DO 35 J=2,M1
      YDIF(J)=Y(J)-Y(J-1)
35 ENDDO
```



(7a)---
Explained in detail

```
      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 both nodes and interfaces in Cartesian coordinate

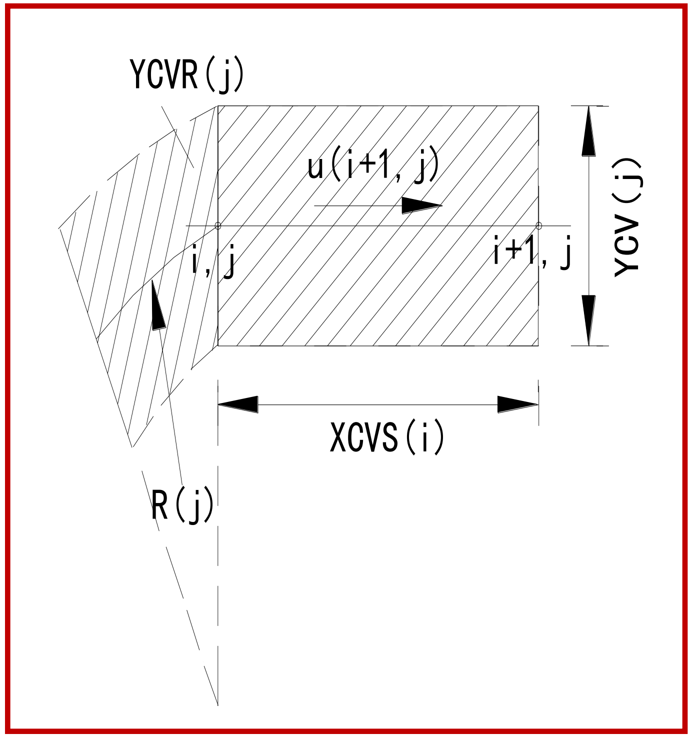
(7b)---Explained in detail

```
     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)
     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

!E-W conduction area of CV for three cases, for Cartesian R=1



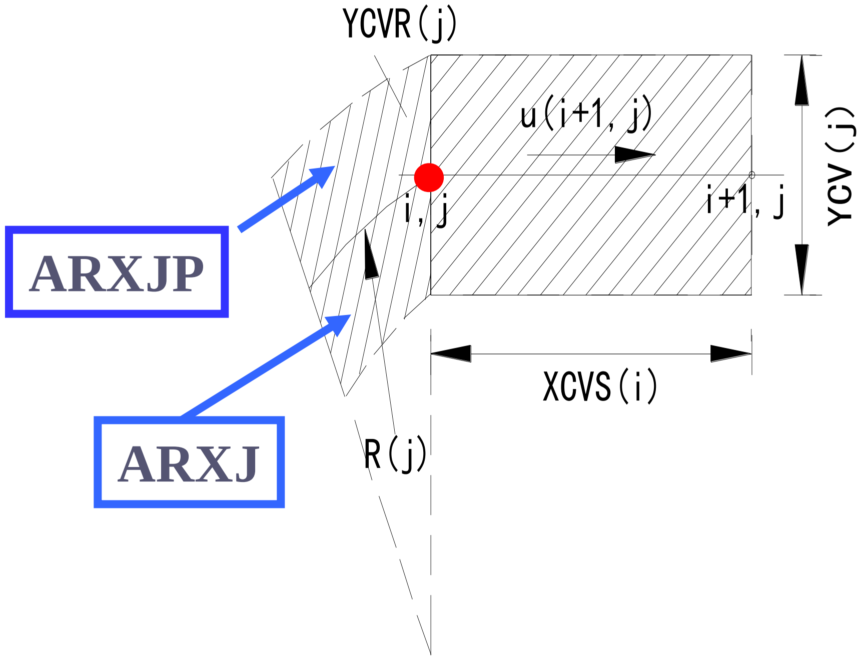
(7c)--- Explained in detail

```
      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)
```

$$\text{ARXJ(J)}=\frac{1}{2}(\text{R(j)}+\text{RMN(j)})\bullet\frac{\text{YCV(j)}}{2}=$$

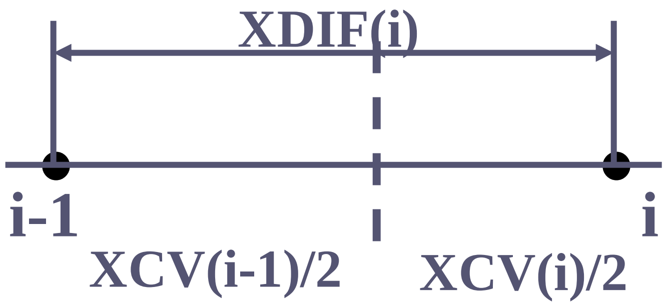
$$0.25[1+\frac{\text{RMN(j)}}{\text{R(j)}}]\bullet\underline{\text{R(j)}\bullet\text{YCV(j)}}=$$

$$0.25[1+\frac{\text{RMN(j)}}{\text{R(j)}}]\bullet\underline{\text{ARX(j)}}$$



ARXJP

ARXJ



```
   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.
CON,AP,U,V,RHO,PC AND P ARRAYS ARE INITIALIZED HERE
```

$$\boxed{\begin{aligned}\phi_{i-1/2} &= \phi_{i-1}\frac{\text{XCV(i)/2}}{\text{XDIF(i)}} + \phi_i\frac{\text{XCV(i-1)/2}}{\text{XDIF(i)}} \\ &= \phi_{i-1}FXM(i) \quad + \phi_i FX(i)\end{aligned}}$$

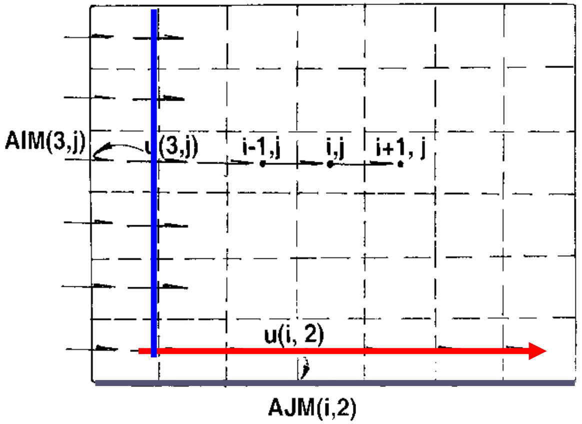
The first letter C is also used to indicate that this is an explanation line

```
      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)
      RETURN
```

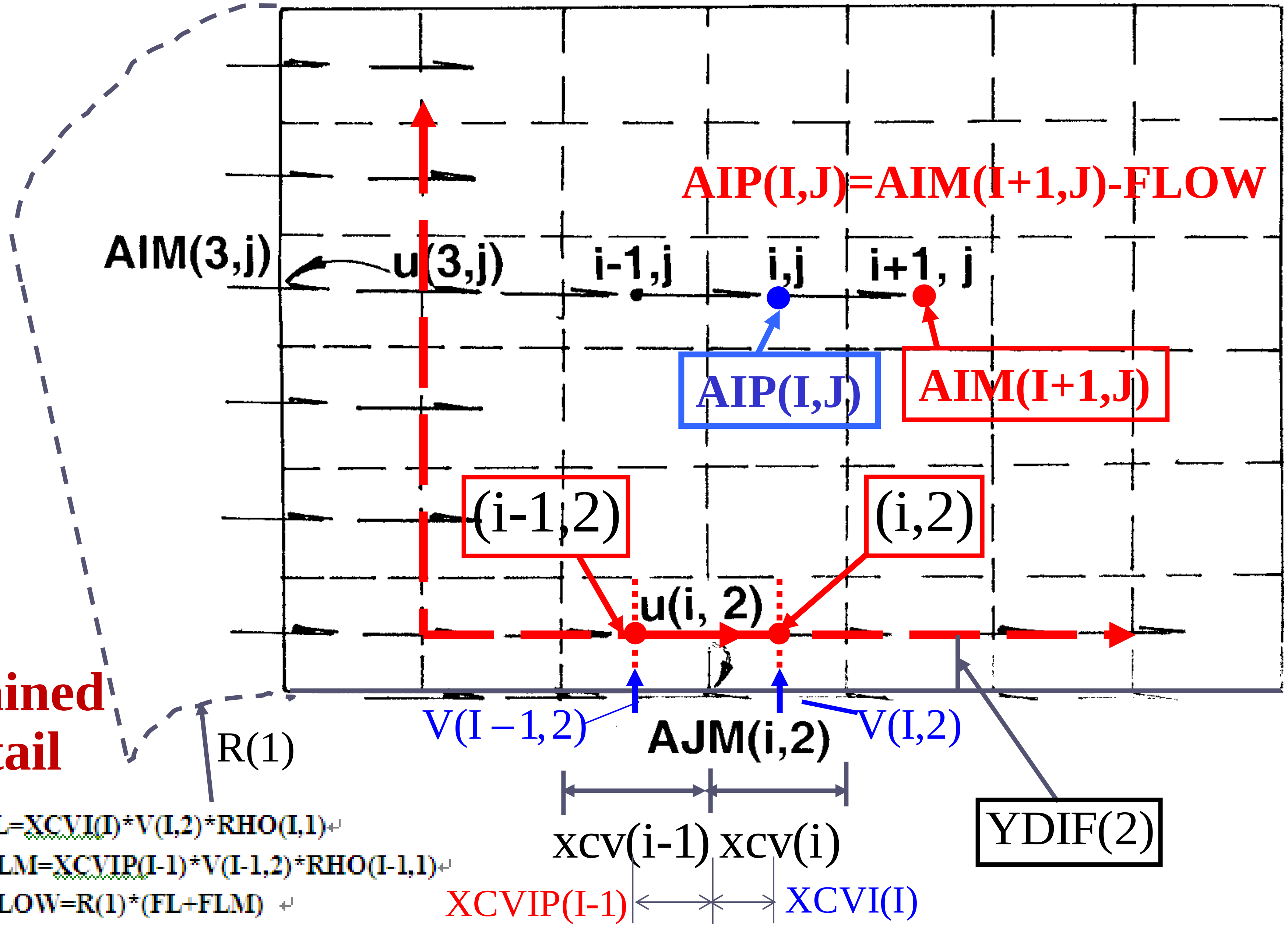
Set up initial fields for iteration

Print out coordinate title of output data

```
C-----------------------------------------------------------------------------
   ENTRY SETUP2
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
COEFFICIENTS FOR THE U EQUATION
      NF=1  ! NF=1：U；NF=2：V；NF=3：P’, P；NF=NP：P
      IF(LSOLVE(NF)) THEN       !
      IST=3
      JST=2
      CALL GAMSOR
      REL=1.-RELAX(NF) !（U）under-relaxation
      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 south interface
      DIFF=R(1)*(XCVI(I)*GAM(I,1)+XCVIP(I-1)*GAM(I-1,1))/YDIF(2)
      CALL DIFLOW !With DIFF and FLOW at hand, CALL DIFLOW to get D·A(|P|);
      AJM(I,2)=ACOF+AMAX1(0.,FLOW)   Coefficient a_S
102 ENDDO
```



$$a_S = D_s A(|P_\Delta|) + [0, -F_s]$$



(8)---Explained in detail

```
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)
```

```
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 a_W
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
```

$$D \cdot A(|P_{\Delta}|) + \ 0, F$$

```
  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)*
& RHO(I-1,J))
   GM=GAM(I,J)*GAM(I,J+1)/(YCV(J)*GAM(I,J+1)+YCV(J+1)*GAM(I,J)+
& 1.0E-30)*XCVI(I)
   GMM=GAM(I-1,J)*GAM(I-1,J+1)/(YCV(J)*GAM(I-1,J+1)+YCV(J+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)     ! Coefficient a_s
  AJP(I,J)=AJM(I,J+1)-FLOW   !Relationship between coefficients
```

(9)--- Explained in detail

```
  VOL=YCVR(J)*XCVS(I)        !Volume of velocity CV
  APT=(RHO(I,J)*XCVI(I)+RHO(I-1,J)*XCVIP(I-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))
&/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))  !  To get flow area
  DU(I,J)=DU(I,J)/AP(I,J)  !  de in velocity correction
104 ENDDO
103 ENDDO
```

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

$$!\, d_e = A_e / a_e$$

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

$$\boxed{a_p = (\sum a_{nb} + \rho_P\Delta V/\Delta t - S_p\Delta V)/\alpha}$$

! Come here we have finished the coefficients calculation for *u* velocity and should store them temporary to leave COF empty to calculate coefficients for velocity *v*.

----------Review of SIMPLER algorithm------------

1. **Assuming initial fields，determine coefficients of discretized *u, v* eqs.;**

2. **Calculating pseudo-velocity** $u,\tilde{v}$;

(10)---Explained in detail

$$\boxed{a_e u_e = \sum a_{nb}u_{nb} + b + A_e(p_P - p_E)}$$

$$\boxed{u_e = \sum \frac{a_{nb}u_{nb} + b}{a_e} + \frac{A_e}{a_e}(p_P - p_E) \longrightarrow} \quad u_e = \tilde{u}_e + \frac{A_e}{a_e}(p_P - p_E)$$

and Solving pressure equation，obtaining p^* ;

$$\boxed{a_P p_P = a_E p_E + a_W p_W + a_N p_N + a_S p_S + b}$$

$$a_P = a_E + a_W + a_N + a_S$$

$$a_E = d_e A_e \rho_e \quad a_W = d_w A_w \rho_w \quad a_n = d_n A_n \rho_n \quad a_S = d_s A_s \rho_s$$

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

Coefficients of *u*, *v* momentum equations are needed for determining coefficients of pressure equation. $d_e = \frac{A_e}{a_e}$

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

$$\boxed{a_e u_e = \sum a_{nb} u_{nb} + b + A_e(p_P - p_E)}$$

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

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

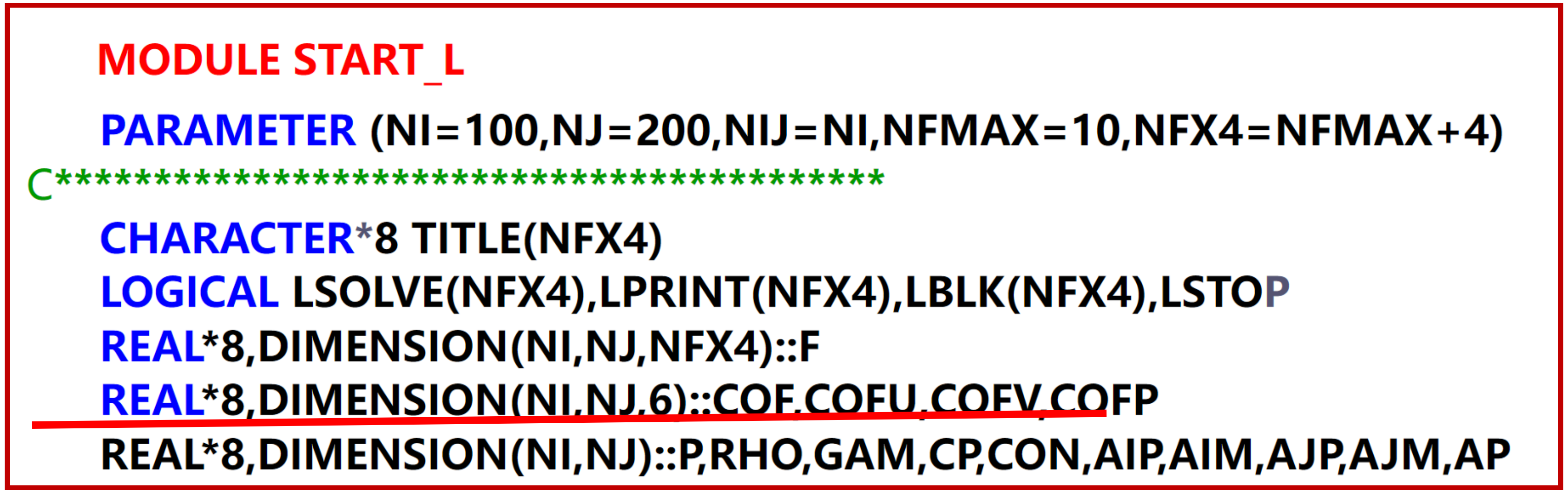
In pressure correction equation: $b = [(\rho u^*)_w - (\rho u^*)_s]A_e + [(\rho v^*)_s - (\rho v^*)_n]A_n$

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

$$u_e^{'} = \frac{A_e}{a_e}(p_P^{'} - p_E^{'}) \quad = d_e(p_P^{'} - p_E^{'})$$

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

----------End of Review of SIMPLER algorithm------------



```
    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
    REAL*8,DIMENSION(NI,NJ,6)::COF,COFU,COFV,COFP
    REAL*8,DIMENSION(NI,NJ)::P,RHO,GAM,CP,CON,AIP,AIM,AJP,AJM,AP
```

```
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
```

```
COFU(IST:L2, JST:M2, 1:6)=COF(IST:L2,JST:M2,1:6) ! Transfer the coefficients
```

Explain

! Store coefficients of *U* temporary as follows:

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)

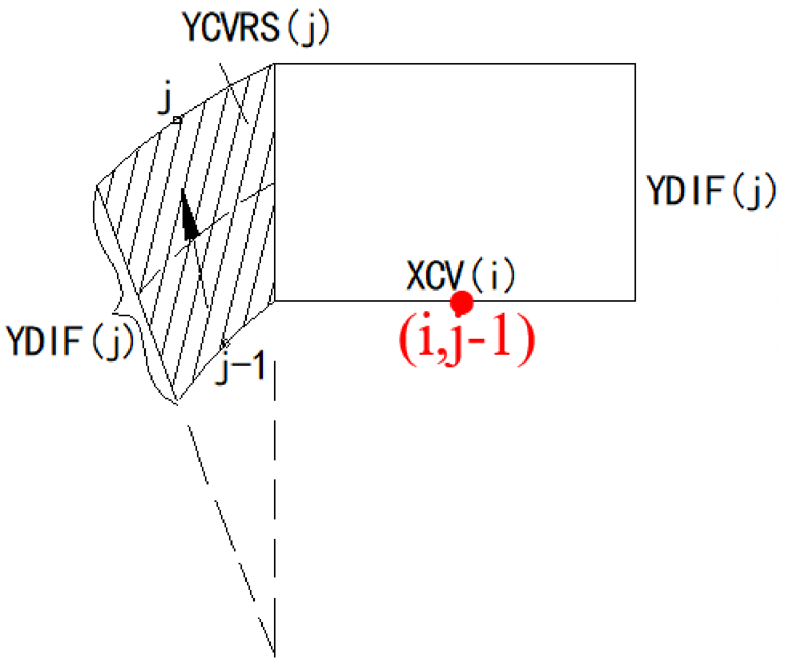
! In SIMPLER to solve pressure eq., coefficients of both *u*-eq. and
! *v*-eq. are needed. Only *u*-coefficients are not enough. Thus,
! *u*-coefficients are temporary stored, and *v*-eq. coefficients
! are computed by using array COF(I,J)

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)
```

(11)---Explained in detail

```
    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= = 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))/(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.E-30)*ARXJ(J)
  GMM=GAM(I,J-1)*GAM(I+1,J-1)/(XCV(I)*GAM(I+1,J-1)+XCV(I+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)*
   &0.5*(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))
  &/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)
   & *U(I,J+1)+COFU(I,J,5)*U(I,J-1)+COFU(I,J,1))/COFU(I,J,6)
```

! Compute $u, \tilde{v}$

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

```
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)
      & *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                    !In the discretized pressure equation, the source term is
       CALL RESET
```

$$! \quad b=[(\rho u)_w-(\rho u)_e]A_e+[(\rho\tilde{v})_s-(\rho\tilde{v})_n]A_n$$

```
       IST=2                   !This term has to be computed for every interface of a CV!
       JST=2
       CALL GAMSOR
       DO 410 J=2,M2,
       DO 411 I=2,L2
       VOL=YCVR(J)*XCV(I)      !Volume of main CV.
       CON(I,J)=CON(I,J)*VOL   !Pressure has no inherent source term, here setting this
411 ENDDO                      !operation just for general purpose .Usually CON(I,J)=0
410 ENDDO
```

(12) Explained in detail

! For boundary CV, actual velocity is used.

DO 402 I=2,L2

ARHO=R(1)*XCV(I)*RHO(I,1)

累加 ! $b=[(\rho u)_w-(\rho u)_e]A_e+[(\rho\tilde{v})_s-(\rho\tilde{v})_n]A_n$

CON(I,2)=CON(I,2)+ARHO*V(I,2) ! Accumulative add

AJM(I,2)=0 !a_S =0， Adiabatic boundary

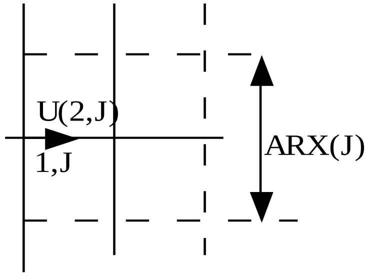
402 ENDDO

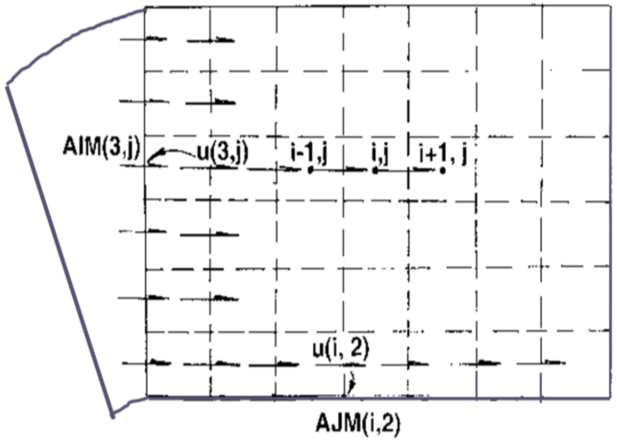
DO 403 J=2,M2

ARHO=ARX(J)*RHO(1,J)

CON(2,J)=CON(2,J)+ARHO*U(2,J) ! Accumulative additio

AIM(2,J)=0. ! a_W =0， Adiabatic boundary





DO 404 I=2,L2

IF(I= =L2) THEN ! For boundary CV, actual velocity is used.

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

! $b=[(\rho u)_w-(\rho u)_e]A_e+[(\rho\tilde{v})_s-(\rho\tilde{v})_n]A_n$

ELSE

ARHO=ARX(J)*(FX(I+1)*RHO(I+1,J)+FXM(I+1)*RHO(I,J))

```
FLOW=ARHO*UHAT(I+1,J) !   ! For inner CV, UHAT is used.
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) !Relationship 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)    ! For inner CV, VHAT is used.
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)
```

(13) Explained in detail

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

! while CON（b） and AP (a_P) are not stored; Because AP has been

! underrelaxed, and the velocity in b term of *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))
```

$$a_e u_e = \sum a_{nb} u_{nb} + b + (p_P - p_E) A_e$$

```
      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 do not satisfy mass
                           ! conservation, 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.
```

！ $$b=[(\rho u^*)_w-(\rho u^*)_e]A_e+[(\rho v^*)_s-(\rho v^*)_n]A_n$$

！ The velocities just solved are u* and v*

```
      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
```

! $$b=[(\rho u^{*})_{w}-(\rho u^{*})_{e}]A_{e}+[(\rho v^{*})_{s}-(\rho v^{*})_{n}]A_{n}$$

```
      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)
       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
```

For AP

```
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)    ！ Nominal density for temperature
      ENDDO
      ENDDO
      REL=1.-RELAX(NF)
```

(14) Explain in detail

$$\rho^{*}=\rho c_{p}$$

```
      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)+
 & 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)+
& 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))
     &/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 ! If the temp. eq. is solved ,then Reset density back to rho
       DO I=I,L1
       DO J=1,M1
       RHO(I,J)=RHO(I,J)/CP(I,J)  ! Reset density back to rho
       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
```

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

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

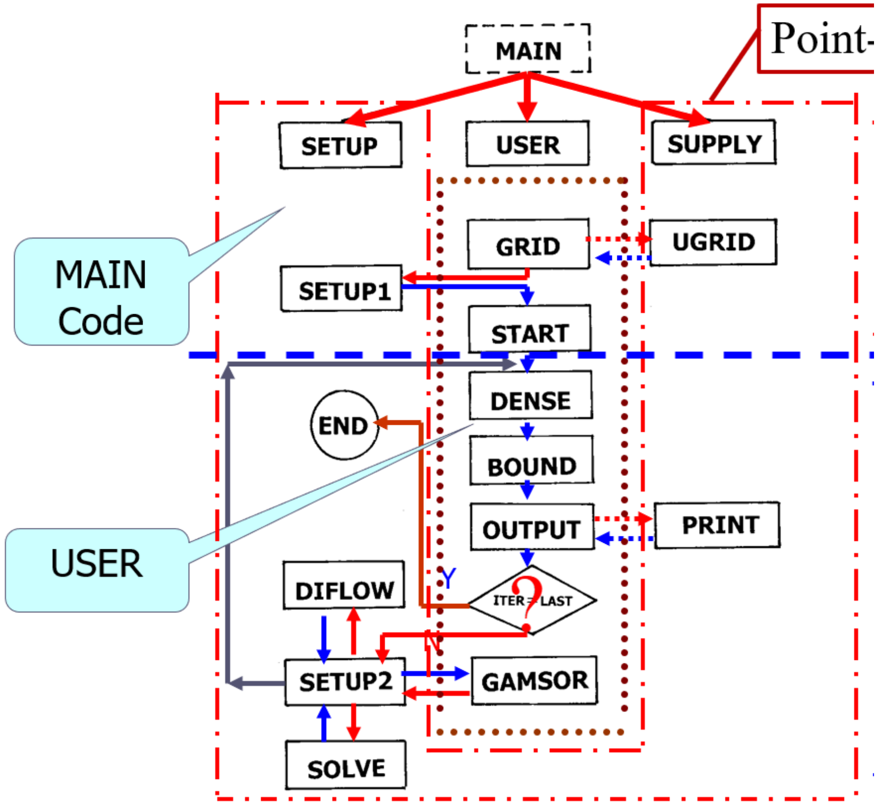
$$\left.\right\}$$

Transient,
Linear----
Steady,
nonlinear

(15)---Explained in detail

10.6.2.6 SUBROUTINE SUPPLY

```
      SUBROUTINE SUPPLY        ! main function: for printing
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 integer digit of each data;

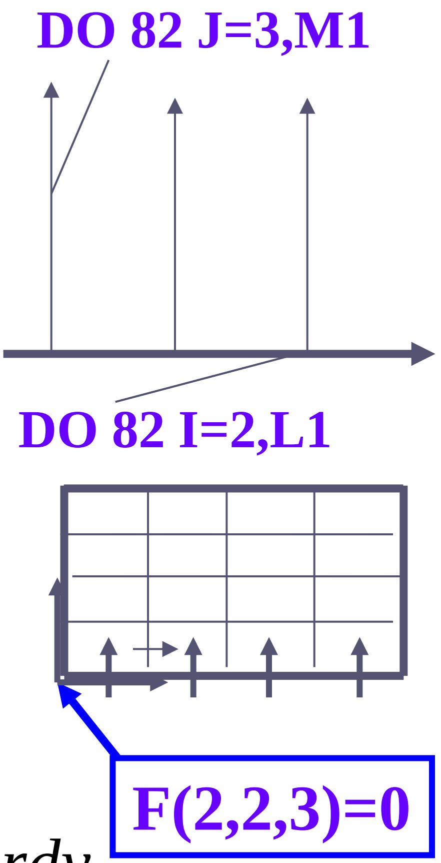
!7E---7 data in scientific expression

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

```
2.00E+00 2.30E+00 2.90E+00 3.50E+00 4.10E+00 4.70E+00 5.00E+00
1.80E+00 2.08E+00 2.64E+00 3.20E+00 3.76E+00 4.32E+00 4.60E+00
1.40E+00 1.64E+00 2.12E+00 2.60E+00 3.08E+00 3.56E+00 3.80E+00
1.00E+00 1.20E+00 1.60E+00 2.00E+00 2.40E+00 2.80E+00 3.00E+00
6.00E-01  7.60E-01 1.08E+00 1.40E+00  1.72E+00 2.04E+00 2.20E+00
2.00E-01  3.20E-01 5.60E-01  8.00E-01   1.04E+00 1.28E+00 1.40E+00
0.00E+00 1.00E-01 3.00E-01  5.00E-01   7.00E-01  9.00E-01  1.00E+00
```

(16)---Explained in detail

```
C****************************************************
      ENTRY PRINT            ! For print out，NF=3
                             represents stream function
      IF(LPRINT(3)) THEN
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)
     &*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
```



$$\rho ur = \frac{\partial \psi}{\partial y}; \rho vr = -\frac{\partial \psi}{\partial x} \quad \psi = -\int \rho vrdx \quad \psi = \int \rho urdy$$

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

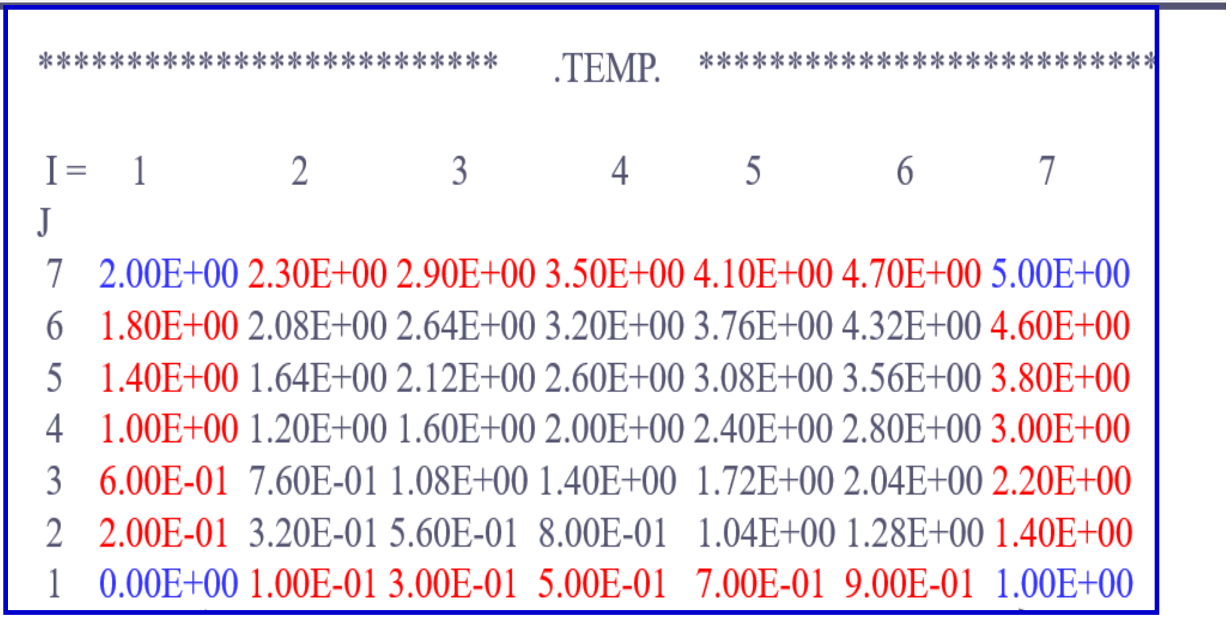
For vertical, from bottom to top $\psi_{i,j} = \psi_{i,j-1} + \rho_m u_{i,j-1} r(j) \Delta y_j$

```
      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 to 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 out x-coordinates
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)  ! Print out y-coordinates
WRITE(8,55) (Y(J),J=JBEG,JEND) GO TO 311
ENDDO
ENDIF
```

```
DO 999 N=1,NCP          ! NCP has been defined as 14 in SETUP1
NF=N
IF(LPRINT(NF)) THEN          ! Print out F(I,J,NF) field
PRINT 50
WRITE(8,50)
PRINT 10,TITLE(NF)
WRITE(8,10) TITLE(NF)          ! Print out title of variable F(I,J,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)
```



```
*************************    .TEMP.    *************************

 I =   1        2        3        4        5        6        7
 J
 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
```

```
      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）
```

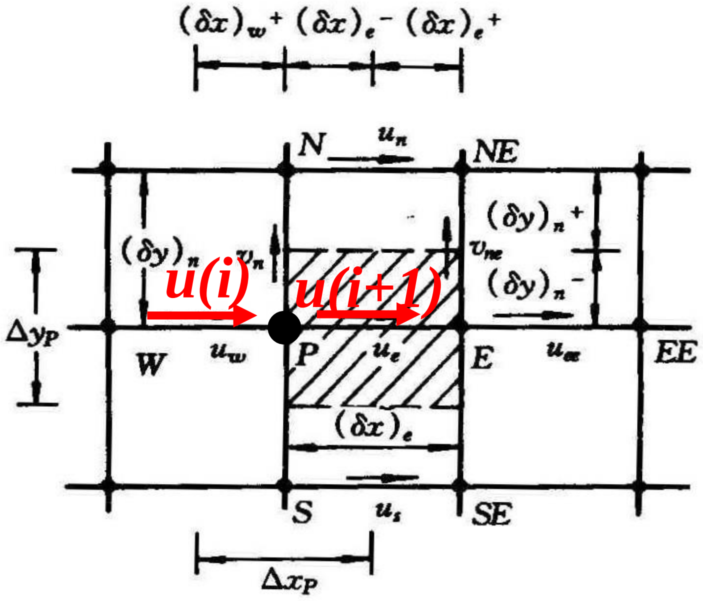
Transformation of data format for Tecplot

```
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

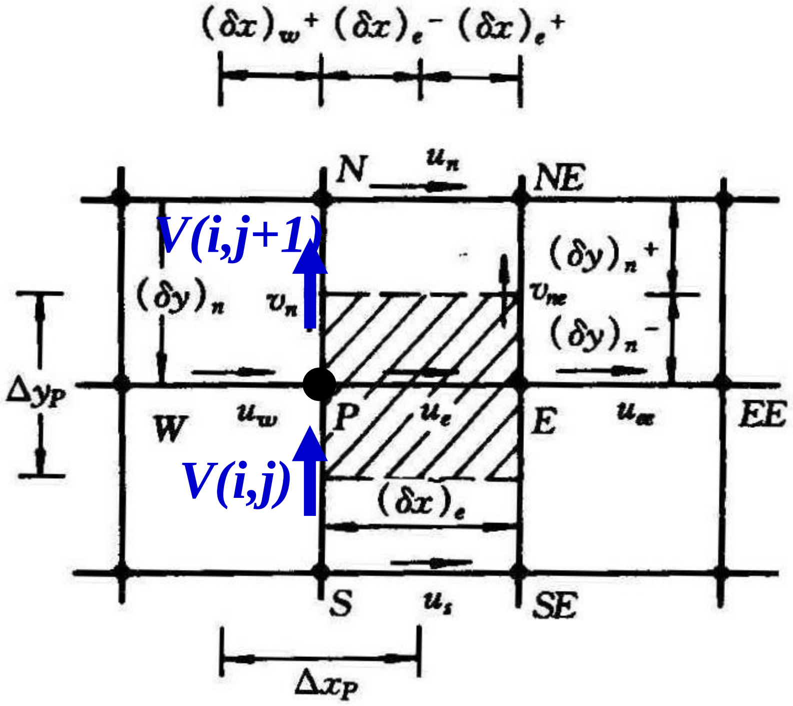
Data format of TECPLOT

$\Big\}$ 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



Comments and Recommendations for Teaching Code Study

1. We should study the code line by line to completely understanding the function of each line and the numerical techniques included.

You should understand every detail included in each line, for example:

```
IF(MODE.== 3) THEN
SX(J)=R(J)
IF(J /= 1) SXMN(J)=RMN(J)
ENDIF
```

why here J=1 should not be included?

2.You can understand a numerical algorithm, say SIMPLER, completely only when you know how to implementing the algorithm by code.

3.If you meet some difficulty in understanding the teaching code you may contact me by email (fangwenzhen@mail.xjtu.edu.cn) at any time.

4. Our teaching assistants will give you instruction on how to run the code.

Announcement

The lessons On Dec. 2 (Monday) and Dec. 9 (Monday), the class will be cancelled Since the class time is conflicted with another course. Next class will be on Dec. 3 (Thursday) .

下周一（12月2日）和下下周一（12月9日）停课两次，下周二（ 12月3日）和下下周二的（ 12月10日）课不停课，谢谢大家！

Announcement

In the study of application of FLUENT, our class will be divided into two teaching groups: Fundamental and Intermediate. They are presented at the same time. Every student should make your choice. Please send your choice to the teaching assistance group in this week. We have to arrange an additional classroom from the graduate school.

Fill the table

群聊：NHT中级班

群聊：NHT基础班

Following students are invited for the office hour of this afternoon （2024.11.26）

Tuesday, Venue: 1-5080, 2:30 pm - 4:00 pm

3124101202	王百川
3124103037	宋岳轩
3124103039	王基惠
3124103042	徐昊
3124103072	杨泽峰
3124103073	李鸿鹏
3124103075	马继军
3124103146	王楠
3124103147	董梦芸
3124103148	王林业

3124103149	范志泽楷
3124103150	吴诗帆
3124103151	全帅宇
3124103233	虎登科
3124103234	余顺杰
3124103235	武文浩
3124103236	左梦成
3124103237	黄文玥
3124103238	李家乐
3124103239	卢堉浩

本组网页地址：http://nht.xjtu.edu.cn　欢迎访问！

Teaching PPT will be loaded on our website

同舟共济

渡彼岸！

People in the same boat help each other to cross to the other bank, where....