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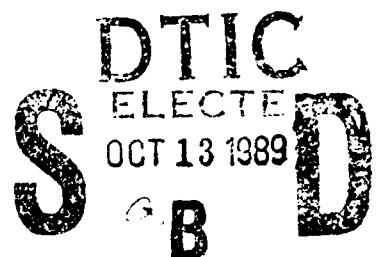
AD:



Final Report  
for the Period  
July 1988 to  
March 1989

# Gas Flows in Rocket Motors

## Volume 3. Appendix D. Computer Code Listings



August 1989

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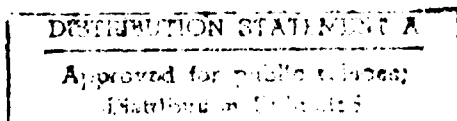
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*Prepared for the*

**Astronautics Laboratory (AFSC)**

Air Force Space Technology Center  
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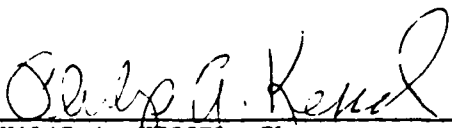
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## FOREWORD

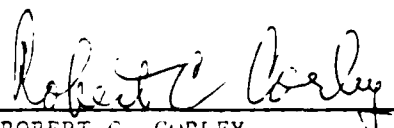
This is the final report for Task 1, Navier Stokes Analysis of Rocket Nozzles, for SETA contract F04611-88-C-0014 with the Astronautics Laboratory (AFSC), Edwards AFB CA. This work was performed by Pennsylvania State University as a subcontractor to Science Applications International Corporation (the SETA contractor). Dr Philip A. Kessel was the project manager for this analysis task.

This report has been reviewed and is approved for release and distribution in accordance with the distribution statement on the cover and on the DD Form 1473.

  
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## REPORT DOCUMENTATION PAGE

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| 1a. REPORT SECURITY CLASSIFICATION<br>UNCLASSIFIED                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |                                          | 1b. RESTRICTIVE MARKINGS                                                                          |                                                                       |                               |
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| 6c. ADDRESS (City, State, and ZIP Code)<br>Mechanical Engineering Department<br>University Park PA 16802                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |       |                                          | 7b. ADDRESS (City, State, and ZIP Code)<br>AL/LSCF<br>Edwards AFB CA 93523-5000                   |                                                                       |                               |
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| 16. SUPPLEMENTARY NOTATION<br>This is volume 3 of a 3 volume report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |       |                                          |                                                                                                   |                                                                       |                               |
| 17. COSATI CODES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |       |                                          | 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)                 |                                                                       |                               |
| FIELD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | GROUP | SUB-GROUP                                |                                                                                                   |                                                                       |                               |
| 20                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 04    |                                          | nozzle analysis, Navier-Stokes, turbulent flow, equilibrium chemistry                             |                                                                       |                               |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |       |                                          |                                                                                                   |                                                                       |                               |
| 19. ABSTRACT (Continue on reverse if necessary and identify by block number)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |       |                                          |                                                                                                   |                                                                       |                               |
| <p>Detailed descriptions of the governing equations, the method of solution, and the computer code for calculating perfect gas or real gas flow in axisymmetric nozzles are given. The codes permit calculation of a perfect gas or a real gas for inviscid flow by solving the Euler equations, and for viscous flow by solving the thin layer Navier-Stokes equations. These equations are written in a conservative form and solved implicitly in body-fitted coordinates. The solution obtained by the conservative variables is expressed in terms of the density, <math>\rho</math>, the momentum parallel to the axis of symmetry (<math>u</math>), the momentum perpendicular to the axis (<math>v</math>), and the total internal energy, <math>e_0</math>. These variables are then used to calculate the nonconservative primitive variables, the velocity components, <math>u</math> and <math>v</math>, the pressure, <math>p</math>, and the temperature, <math>T</math>. The nozzle performance including the rate of mass flow, <math>\dot{m}</math>, the thrust, <math>T</math>, and the specific impulse are also computed.</p> <p>The codes were written in FORTRAN V and ran on the CYBER 180/840, NOS/BE system which limited the number of grid points to 20 x 44 for solving the Euler equations and 60 x 40 for</p> |       |                                          |                                                                                                   |                                                                       |                               |
| 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT<br><input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |       |                                          | 21. ABSTRACT SECURITY CLASSIFICATION<br>UNCLASSIFIED                                              |                                                                       |                               |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL<br>Dr Philip A. Kessel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |       |                                          | 22b. TELEPHONE (Include Area Code)<br>(805) 275-5591                                              |                                                                       | 22c. OFFICE SYMBOL<br>AL/LSCF |

Block 19.

the TLNS equations. The results obtained for the nozzle flowfield showed maximum global mass flux errors of less than  $\pm 1\%$  for the Euler equations and less than  $\pm 2\%$  for the TLNS equations. Solutions with more dense grids (typically  $100 \times 50$  or higher) consistently showed global mass conservation of better than one percent.

VENKATESWARAN SANKA (V19)

AXI2DV FOR

X14140

USERID: V19 ORIGIN: PSUVM CREATED: 06/20/89 15:36:06  
FILENAME: AXI2DV FOR CLASS: A FORMAT: J  
SPOOLID: 2820 RECS: 2633 COPY: 1 DUPLICATE: 1

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| Availability Codes |                                            |
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VENKATESWARAN SANKA (V19)

AXI2DV FOR

```
STIXXXXX JOB
```

```
*JP T=500, L=10000
```

```
EXEC PGM=IEFBR14
```

```
DD VOL=REF=STU.I19500.MYH100.LIB,DISP=(OLD,DELETE),
```

```
DSN=STU.I19500.MYH100.HERMES.CONV.SOLU.VIS
```

```
DD VOL=REF=STU.I19500.MYH100.LIB,DISP=(OLD,DELETE),
```

```
DSN=STU.I19500.MYH100.HERMES.CONV.LINE.VIS
```

```
DD VOL=REF=STU.I19500.MYH100.LIB,DISP=(OLD,DELETE),
```

```
DSN=STU.I19500.MYH100.HERMES.CONV.MASS.VIS
```

```
EXEC FVCG,PARM.SOURCE='OPT(3)'
```

```
SYSIN DD *
```

```
C*****
```

```
C+ PROGRAM NAME: AXI2DV.FOR *
```

```
C+ AXISYMMETRIC TRANSONIC NOZZLE FLOW *
```

```
C+ IN GENERAL COORDINATE SYSTEM *
```

```
C+ USING TIME ITERATIVE CD/CD SCHEME *
```

```
C+ WITH THIN-LAYER APPROXIMATED NAVIER-STOKE'S EQ. *
```

```
C*****
```

```
C+
```

```
C+ MAIN PROGRAM
```

```
C+
```

```
C*****
```

```
IMPLICIT REAL*8(A-H,O-Z)
```

```
PARAMETER (IZ=150,JZ=100)
```

```
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
```

```
P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
```

```
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
```

```
,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
```

```
,ZMUT(IZ,JZ)
```

```
,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
```

```
COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
```

```
PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
```

```
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
```

```
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
```

```
DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
```

```
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),
```

```
(Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
```

```
C*****
```

```
CALL ERRSET(208,256,-1,0,0,0)
```

```
CALL INITIA
```

```
DO 10 NADV=NBEG,NEND
```

```
C WRITE(6,*) NADV
```

```
CALL SOLVE
```

```
CALL CHECK
```

```
10 CONTINUE
```

```
CALL MASS
```

```
CALL OUTPUT
```

```
STOP
```

```
END
```

```
C*
```

```
C* SET UP INITIAL CONDITION
```

```
C*
```

```
SUBROUTINE INITIA
```

```
C*****
```

```
IMPLICIT REAL*8(A-H,O-Z)
```

```

PARAMETER (IZ=150,JZ=100)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
ZMUT(IZ,JZ)
AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
COMMON/CFCOEF/CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
CPA8,CPA9,CPA10,ENE(101)
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
(Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
DIMENSION SS(3500,4)
NAMELIST/INPUT/IL,JL,NEND,PO,TO,CFL,OMEGAX,OMEGAY,RM1,AIN,EST,
NITER,ATH,RL,THETA,CPO,GAMMAO,NBEG,ITIME,ISUP,IVISC,IWALL,RM2
IREAD,PRN,REN,TREF,ZMUO,TWALL,ESTY,PB,PRNT,COND
C... ISUP = 0 FOR PURE SUBSONIC FLOW
C      1 FOR TRANSONIC FLOW
C      3 FOR PURE SUPERSONIC FLOW
C... NOT SUITABLE FOR PURE SUPERSONIC FLOW CALCULATION
C... EP = BACK PRESSURE FOR ISUP=0
C
C ** READ INPUT DATA
READ(5,INPUT)
WRITE(22,INPUT)
C ** SET UP GEOMETRY
IL1=IL-1
JL1=JL-1
C
CALL CFCOEF
C WRITE(6,*) CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7,CPA8,CPA9,CPA10
C
PI=8.0868
C1=(AIN-ATH)/2.
C2=(AIN+ATH)/2.
DO 10 I=1,IL
IF(ISUP.EQ.3)THEN
AREA(I)=AIN+(ATH-AIN)*DFLOAT(I-1)/DFLOAT(IL1)
ELSE
C AREA(I)=(C1*DCOS(DFLOAT(I-1)*2.*PI/DFLOAT(IL1))+C2)*0.5
ARR=ATH/AIN
XX=DFLOAT(I-1)/DFLOAT(IL1)*RL
C AREA(I)=-2.0*(ARR-1.)*XX**3+3.0*(ARR-1.)*XX**2+1.0
AREA(I)=(ARR-1.)*(XX**2-4.*XX+4.)*XX**2+1.0
END IF
10 CONTINUE
IF(IREAD.EQ.2)THEN
DO 18 I=1,IL
READ(38,*) X(1,1),AREA(I)
18 CONTINUE

```

```

        ENDIF
        DO 20 I=1, IL
        DO 20 J=1, JL
        IF (IREAD.EQ.2) THEN
            X(I,J)=X(I,1)
        ELSE
            X(I,J)=DFLOAT(I-1)/DFLOAT(IL1)*RL
        ENDIF
20    Y(I,J)=DFLOAT(J-1)/DFLOAT(JL1)*AREA(I)
        IF (FST.NE.0.DO.AND.ISUP.EQ.3) THEN
            DO=(FST-1.0)/(FST**IL1-1.)*RL
            DO 15 I=1, IL
            XL=DO*(FST** (I-1)-1.)/(FST-1.)
            AREA(I)=AIN+XL/RL*(ATH-AIN)
            DO 15 J=1, JL
            X(I,J)=XL
            Y(I,J)=DFLOAT(J-1)/DFLOAT(JL1)*AREA(I)
15    CONTINUE
        ELSE
            ENDIF
C * STRETCH THE GRID ALONG Y-DIRECETION IN VISCOUS CASE
        IF (IVISC.EQ.1.AND.FSTY.NE.0.DO) THEN
            DO 17 I=1, IL
            Y(I,1)=0.
            DAO=(1.-FSTY)/(1.-FSTY**JL1)*AREA(I)
            DO 17 J=2, JL
            Y(I,J)=Y(I,J-1)+DAO*FSTY**(J-2)
17    CONTINUE
        ELSE
            ENDIF
C * READ GRID FROM DATA FILE
        IF (IREAD.EQ.1) THEN
            DO 25 I=1, IL
            DO 25 J=1, JL
            READ(38) II, JJ, X(I,J), Y(I,J)
25    CONTINUE
        ELSE
            END IF
            ATH=Y(1, JL)
            DO 125 I=2, IL
            IF (Y(I, JL).LT.ATH) THEN
                ATH=Y(I, JL)
                XTH=X(I, JL)
            ELSE
                ENDIF
125    CONTINUE
C ** COORDINATE TRANSFORMATION
            EXI=1.0
            EYI=1.0
            DO 30 I=1, IL
            IP1=I+1
            IM1=I-1
            IF (I.EQ.1) IM1=1
            IF (I.EQ.IL) IP1=IL
            DSAI=2.*EXI

```

```

      IF(I.EQ.1.OR.I.EQ.IL)DSAI=EXI
      DO 30 J=1,JL
      JP1=J+1
      JM1=J-1
      IF(J.EQ.1)JM1=1
      IF(J.EQ.JL)JP1=JL
      DETA=2.*EYI
      IF(J.EQ.1.OR.J.EQ.JL)DETA=EYI
      XSAI=(X(IP1,J)-X(IM1,J))/DSAI
      YSAI=(Y(IP1,J)-Y(IM1,J))/DSAI
      XETA=(X(I,JP1)-X(I,JM1))/DETA
      YETA=(Y(I,JP1)-Y(I,JM1))/DETA
      IF(J.EQ.1)THEN
        XETA=XETA-0.5*(X(I,J)-2.*X(I,J+1)+X(I,J+2))
        YETA=YETA-0.5*(Y(I,J)-2.*Y(I,J+1)+Y(I,J+2))
      ELSE
      ENDIF
      IF(J.EQ.JL) THEN
        XETA=(3.DO*X(I,JL)-4.DO*X(I,JL-1)+X(I,JL-2))*0.5DO
        YETA=(3.DO*Y(I,JL)-4.DO*Y(I,JL-1)+Y(I,JL-2))*0.5DO
      ELSE
      ENDIF
      RJP=XSAI*YETA-XETA*YSAI
      RJ(I,J)=1./RJP
      SAIX(I,J)=YETA/RJP
      SAIX(I,J)=-XETA/RJP
      ETAX(I,J)=-YSAI/RJP
      ETAY(I,J)=XSAI/RJP
30
C ** INITIALIZATION
      RGAS=8314.3/20.405
      R=RGAS
      DO 991 I=1,IL
      DO 991 J=1,JL
      TTT=3061.1DO
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
      > RHO(I,J),RHOI(I,J),RHOV(I,J),E(I,J),TTT)
991 CONTINUE
C* GIVE THE INITIAL VALUE OF VISCOSTY
C      TIN=TO*(1.+0.5*GM10*RM1**2)
C      UIN=RM1*DSQRT(GAMMA0*R*TIN)
C      PIN=PO*(TIN/TO)**(GAMMA0/GM10)
C      RIN=PIN/(R*TIN)
C      ZMU0=(RIN*UIN*AREA(1)*2.)/REN
C* CALCULATE METRIC TERMS AT MID POINTS
C*
      CALL MCONST
C ** SKIF TO RERUN THE CODE
      IF(NBEG.NE.1)GOTO 300
      RM=0.04
      DO 50 I=1,IL
C#      IF(ISUP.EQ.0)THEN
C#          RMTH=RM2
C#          RM=RM1+X(I,1)/RL*2.*(RMTH-RM1)
C#          IF(X(I,1).GT.(0.5*RL))RM=RMTH-(X(I,1)-0.5*RL)/RL*2.
C#          *(RMTH-RM1)

```

```

C# ELSE
C# RM=RM1+DFLOAT(I-1)/DFLOAT(IL1)*(RM2-RM1)
C# END IF
CALL ISENMA(I,ATH,XTH,RM)
TS=TO/(1.+0.5*GM1(I,1)*RM**2)
UU=RM*DSQRT(GAMMA(I,1)*R*TS)
DO 50 J=1,JL
IF(I.EQ.1.OR.I.EQ.IL)THEN
    IF(I.EQ.1)SLOPE=(Y(I+1,J)-Y(I,J))/(X(I+1,J)-X(I,J))
    IF(I.EQ.IL)SLOPE=(Y(I,J)-Y(I-1,J))/(X(I,J)-X(I-1,J))
ELSE
    SLOPE=(Y(I+1,J)-Y(I-1,J))/(X(I+1,J)-X(I-1,J))
END IF
DENOM=DSQRT(1.+SLOPE*SLOPE)
U(I,J)=UU/DENOM
V(I,J)=UU*SLOPE/DENOM
VN(I,J)=ETAX(I,J)*U(I,J)+ETAY(I,J)*V(I,J)
UN(I,J)=SAIX(I,J)*U(I,J)+SAIY(I,J)*V(I,J)
IF(J.EQ.JL)THEN
    VN(I,J)=0.
    U(I,J)=UU/DENOM
    V(I,J)=-ETAX(I,J)/ETAY(I,J)*U(I,J)
    UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
ELSE
    END IF
50 CONTINUE
C* NO-SLIP INITIAL CONDITION
IF(IVISC.EQ.1)THEN
    DO 60 I=1,IL
        U(I,JL)=0.
        V(I,JL)=0.
        UN(I,JL)=0.
        VN(I,JL)=0.
60 CONTINUE
ELSE
    ENDIF
EIGMAX=0.0
DO 80 I=1,IL
    DO 80 J=1,JL
        TS=TO-(U(I,J)**2+V(I,J)**2)/CP(I,J)*0.5
        PS=FO/(TO/TS)**(GAMMA(I,J)/GM1(I,J))
        IF(J.EQ.JL.AND.IVISC.EQ.1)THEN
            IF(IWALL.EQ.1)TS=TWALL
            PS=P(I,J-1)
        ELSE
            ENDIF
        RHOO=PS/R/TS
        RHO(I,J)=RHOO
        RHOU(I,J)=RHO(I,J)*U(I,J)
        RHOV(I,J)=RHO(I,J)*V(I,J)
        E(I,J)=RHO(I,J)*(CV(I,J)*TS+0.5*(U(I,J)**2+V(I,J)**2))
80 P(I,J)=PS
DO 90 I=1,IL
    DO 90 J=1,JL
        CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))

```

```

      ZM=DSQRT(U(I,J)**2+V(I,J)**2)/CO
      IF(COND.GT.0.0.AND.ZM.LT.1.0) GOTO 210
      CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CY=DSQRT(ETAX(I,J)**2+ETAY(I,J)**2)
      CX=(UN(I,J)+CX*CO)/EXI
      CY=(VN(I,J)+CY*CO)/EYI
C      EIGNN=CX
C      IF(DABS(CY).GT.EIGNN)EIGNN=DABS(CY)
      EIGNN=DSQRT(CX**2+CY**2)
      IF(ETIME.EQ.1)GO TO 85
      IF(CX.GE.EIGMAX)EIGMAX=CX
      IF(CY.GT.EIGMAX)EIGMAX=CY
85    DELTAU(I,J)=CFL/EIGNN
      GOTO 90
210  CONTINUE
C    ZM=DSQRT((U(I,J)**2+V(I,J)**2)/C(I,J)**2)
      SX=UN(I,J)**2*(1.DO-ZM**2)**2+4.DO*(U(I,J)**2+V(I,J)**2)
      SY=VN(I,J)**2*(1.DO-ZM**2)**2+4.DO*(U(I,J)**2+V(I,J)**2)
      EIGVX=0.5DO*(UN(I,J)*(1.DO+ZM**2)+DSQRT(SX))
      EIGVY=0.5DO*(VN(I,J)*(1.DO+ZM**2)+DSQRT(SY))
      DELTAU(I,J)=CFL/DSQRT(EIGVX**2+EIGVY**2)
90    CONTINUE
      IF(ETIME.EQ.1)RETURN
      DO 100 I=1,IL
      DO 100 J=1,JL
100   DELTAU(I,J)=CFL/EIGMAX
      RETURN
300   CONTINUE
310   READ(19,720,END=1000)NDUM,(SS(NDUM,K),K=1,4)
      GOTO 310
1000  CONTINUE
      REWIND 19
      NBEG=NDUM+1
      NEND=NBEG+NITER-1
      DO 320 N=1,NDUM
320   WRITE(19,720)N,(SS(N,K),K=1,4)
720   FORMAT(I5,3X,4(1X,E14.7))
      DO 330 I=1,IL
      DO 330 J=1,JL
      READ(66) (Q(I,J,K),K=1,4),DELTAU(I,J)
      TCP=0.DO
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
      RHO(I,J),RHOI(I,J),RHOV(I,J),E(I,J),TCP)
      U(I,J)=RHOI(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
330  CONTINUE
      REWIND 66
      RETURN
      END)
C*****

```

```

SUBROUTINE ISENMA(I,ATH,XTH,RM)
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=100)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
, RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),LELTAU(IZ,JZ)
, ZMUT(IZ,JZ)
, AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
=====
ARR=(Y(1,JL)/ATH)**2
RM1=RM*1.05
RM2=RM*0.95
IF(X(1,JL).GT.XTH)THEN
    RM1=RM*1.05
    RM2=RM*1.01
ELSE
ENDIF
GP1=GAMMA(I,JL)+1.0
GEXP=GP1/(2.0-2.0*GAMMA(I,JL))
GSQRT=DSQRT(GAMMA(I,JL))
CNUM=GSQRT*(GP1/2.0)**GEXP
ZM=RM1
F01=ZM*GSQRT*(1.0+0.5*GM1(I,JL)*ZM*ZM)**GEXP
F1=CNUM/F01
ZM=RM2
F01=ZM*GSQRT*(1.0+0.5*GM1(I,JL)*ZM*ZM)**GEXP
F2=CNUM/F01
10 RM3=RM1+(RM2-RM1)*(ARR-F1)/(F2-F1)
ZM=RM3
F01=ZM*GSQRT*(1.0+0.5*GM1(I,JL)*ZM*ZM)**GEXP
F3=CNUM/F01
ERR=DABS(ARR-F3)
IF(ERR.LT.1.0D-4) GO TO 20
RM1=RM2
F1=F2
RM2=RM3
F2=F3
GO TO 10
20 RM=RM3
WRITE(6,*) I,ARR,RM
RETURN
END

```

```

C-----
SUBROUTINE SOLVE
C*
C* SOLVE SUBROUTINE
C*
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=100)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)

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```

      ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
      ,ZMUT(IZ,JZ)
      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,FO,TC
      PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
C  RHS CALCULATION
      IF(IVISC.EQ.1)CALL MULAM
      IF(PRNT.NF.0.DO) CALL MUTUR
      CALL RHS
      IF(IVISC.EQ.1)CALL VFHS
C** CALCULATE RESIDUAL
      DO 40 I=1,IL
      DO 40 J=1,JL
      DO 40 K=1,4
40    DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
C*
C* ADX-SAI-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
C*
      IF(OMEGAX.NE.0.ODO)CALL ADDX
C*
C* ADY-ETA-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
C*
      IF(OMEGAY.NE.0.ODO)CALL ADDY
C*
C* SOLVE SAI-OPERATOR
C*
      JEND=JL
      IF(IVISC.EQ.1)JEND=JL1
      DO 50 J=2,JEND
50    CALL COEFX(J)
C*
C* SOLVE ETA-OPERATOR
C*
      IEND=IL1
      IF(ISUP.EQ.1.OR.ISUP.EQ.3)IEND=IL
      DO 55 I=2,IEND
55    CALL COEFY(I)
C*
C* UPDATING VARIABLES
C*
      EIGMAX=0.
      IBEG=1
      IF(ISUP.EQ.3)IBEG=2
      DO 70 I=IBEG,IL
      DO 70 J=2,JEND
      RJJ=RJ(I,J)/Y(I,J)
      DO 60 K=1,4
60    Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
      TCP=0.DO

```

```

CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
> RHO(I,J),RHOI(I,J),RHOV(I,J),E(I,J),TCP)
U(I,J)=RHOI(I,J)/RHO(I,J)
V(I,J)=RHOV(I,J)/RHO(I,J)
UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
ZM=DSQRT(U(I,J)**2+V(I,J)**2)/CO
IF(COND.GT.0.0.AND.ZM.LT.1.0) GOTO 210
CX=DSQRT(SAIX(I,J)*SAIX(I,J)+SAIY(I,J)*SAIY(I,J))
CY=DSQRT(ETAX(I,J)*ETAX(I,J)+ETAY(I,J)*ETAY(I,J))
CX=(UN(I,J)+CX*CO)/EXI
CY=(VN(I,J)+CY*CO)/EYI
C   EIGNN=DABS(CX)
C   IF(DABS(CY).GT.EIGNN) EIGNN=DABS(CY)
EIGNN=DSQRT(CX**2+CY**2)
IF(EIGNN.GT.EIGMAX)EIGMAX=EIGNN
DELTAU(I,J)=ITIME*CFL/EIGNN+(1-ITIME)*DELTAU(I,J)
GOTO 70
210 CONTINUE
SX=UN(I,J)**2*(1.DO-ZM**2)**2+4.DO*(U(I,J)**2+V(I,J)**2)
> *(SAIX(I,J)**2+SAIY(I,J)**2)
SY=VN(I,J)**2*(1.DO-ZM**2)**2+4.DO*(U(I,J)**2+V(I,J)**2)
> *(ETAX(I,J)**2+ETAY(I,J)**2)
EIGVX=0.5DO*(UN(I,J)*(1.DO+ZM**2)+DSQRT(SX))
EIGVY=0.5DO*(VN(I,J)*(1.DO+ZM**2)+DSQRT(SY))
DELTAU(I,J)=CFL/DSQRT(EIGVX**2+EIGVY**2)
70 CONTINUE
C *
C * CENTERLINE BOUNDARY CONDITIONS
CALL CLBC
IF(IVISC.EQ.1)CALL WALLBC
RETURN
END
C*
C* SUBROUTINE FOR CALCULATING METRIC TERMS
C* AT THE MIDPOINT
SUBROUTINE MCONST
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=100)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,ZMUT(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
DIMENSION RHO(IZ,JZ),RHOI(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOI(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))

```

C\*\*\*\*\*

```

DATA FD3,OD3/1.333333333333,0.333333333333/
DO 20 I=2,IL
DO 20 J=1,JL1
IF(I.EQ.IL)THEN
XSAI=0.5*(X(I,J)+X(I,J+1)-X(I-1,J)-X(I-1,J+1))
YSAI=0.5*(Y(I,J)+Y(I,J+1)-Y(I-1,J)-Y(I-1,J+1))
ELSE
YSAI=0.25*(Y(I+1,J+1)+Y(I+1,J)-Y(I-1,J+1)-Y(I-1,J))
XSAI=0.25*(X(I+1,J+1)+X(I+1,J)-X(I-1,J+1)-X(I-1,J))
END IF
YETA=Y(I,J+1)-Y(I,J)
XETA=X(I,J+1)-X(I,J)
RJJ=1./(XSAI*YETA-XETA*YSAI)
A1(I,J)=RJJ*(FD3*YSAI**2+XSAI**2)
A2(I,J)=-RJJ*OD3*XSAI*YSAI
A3(I,J)=RJJ*(YSAI**2+FD3*XSAI**2)
A4(I,J)=RJJ*(XSAI**2+YSAI**2)
20 CONTINUE
RETURN
END

```

C-----  
SUBROUTINE SMOOTH

C\*

C\* ADD ARTIFICIAL DISSIPATIONAL TERM FOR SAI,ETA-DIRECTION

C\*

C\*\*\*\*\*

```

IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=100)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,ZMUT(IZ,JZ)
> ,ARBA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))

```

C\*\*\*\*\*

```

DIMENSION ADD(4)
DIMENSION PRE(4,4),PADD(4)

```

C \*\* SAI-DIRECTION

```

ENTRY ADDX
COEF=0.125DO*OMEGAX
DO 70 J=1,JL
DO 70 I=1,IL
IF(I.EQ.1) GO TO 10
IF(I.EQ.2) GO TO 20
IF(I.EQ.IL1) GO TO 30
IF(I.EQ.IL) GO TO 40
DO 5 K=1,4

```

```

5  ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
  +6.*Q(I,J,K)-4.*Q(I-1,J,K)
  +Q(I-2,J,K))
  GO TO 50
10  DO 15 K=1,4
    QM=2.*Q(1,J,K)-Q(2,J,K)
    QMM=2.*QM-Q(1,J,K)
15  ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
  +6.*Q(I,J,K)-4.*QM+QMM)
  GO TO 50
20  DO 25 K=1,4
    QMM=2.*Q(1,J,K)-Q(2,J,K)
25  ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
  +6.*Q(I,J,K)-4.*Q(I-1,J,K)
  +QMM)
  GO TO 50
30  DO 35 K=1,4
    QFP=2.*Q(I+1,J,K)-Q(I,J,K)
35  ADD(K)=COEF*(QFP-4.*Q(I+1,J,K)+6.*Q(I,J,K)
  -4.*Q(I-1,J,K)+Q(I-2,J,K)
  )
  GO TO 50
40  DO 45 K=1,4
    QP=2.*Q(I,J,K)-Q(I-1,J,K)
    QPP=2.*QP-Q(I,J,K)
45  ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
  Q(I-1,J,K)+Q(I-2,J,K))
50  CONTINUE
    CALL PRECON(I,J,PRE)
    CALL MMV(4,PRE,ADD,PADD)
    DO 60 K=1,4
60  DQ(I,J,K)=DQ(I,J,K)-PADD(K)/RJ(I,J)*Y(I,J)
70  CONTINUE
    RETURN
C **
C  ADD ETA-DIRECTON 4TH ORDER ARTLEFLCLAL VLSCOSLTY
C **
    ENTRY ADDY
    COEF=0.125DO*OMEGAY
    DO 170 I=1,IL
    DO 170 J=1,JL
    IF(J.EQ.1) GO TO 110
    IF(J.EQ.2) GO TO 120
    IF(J.EQ.JL1) GO TO 130
    IF(J.EQ.JL) GO TO 140
    DO 95 K=1,4
95  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
  +6.*Q(I,J,K)-4.*Q(I,J-1,K)
  +Q(I,J-2,K))
    GO TO 150
110  DO 115 K=1,4
    QM=2.*Q(I,1,K)-Q(I,2,K)
    QMM=2.*QM-Q(I,1,K)
115  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
  +6.*Q(I,J,K)-4.*QM+QMM)

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```

      GO TO 150
120   DO 125 K=1,4
      QMM=2.*Q(I,1,K)-Q(I,2,K)
125   ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
      > +6.*Q(I,J,K)-4.*Q(I,J-1,K)
      > +QMM)
      GO TO 150
130   DO 135 K=1,4
      QPP=2.*Q(I,J+1,K)-Q(I,J,K)
135   ADD(K)=COEF*(QPP-4.*Q(I,J+1,K)+6.*Q(I,J,K)
      > -4.*Q(I,J-1,K)+Q(I,J-2,K)
      > )
      GO TO 150
140   DO 145 K=1,4
      QP=2.*Q(I,J,K)-Q(I,J-1,K)
      QPP=2.*QP-Q(I,J,K)
145   ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
      > Q(I,J-1,K)+Q(I,J-2,K))
150   CONTINUE
      CALL PRECON(I,J,PRE)
      CALL MMV(4,PRE,ADD,PADD)
      DO 160 K=1,4
160   DQ(I,J,K)=DQ(I,J,K)-PADD(K)/RJ(I,J)*Y(I,J)
170   CONTINUE
      RETURN
      END

C
C ** SUBROUTINE FOR CENTER LINE BOUNDARY CONDITIONS
      SUBROUTINE BC
C-----
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
      > P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
      > ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
      > ,ZMUT(IZ,JZ)
      > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
      > PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
      > (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
      DIMENSION AM(IZ),BM(IZ),CM(IZ),DM(IZ),PTEMP(IZ)
      DATA SCONST/110./
      ENTRY CLBC
C * THE QUANTITIES EXTRAPOLATED ARE U,P,T AND LET V=0
C
      IF (ISUP.EQ.3) THEN
        I1=2
      ELSE
        I1=1

```

```

END IF
DO 20 I=11, IL
  SY=SAIY(I, 1)
  EY=ETAY(I, 1)
  DENOM=SY-1.5*EY
  IF(I.EQ.1) THEN
    UIM1=0.
    PIM1=0.
    RIM1=1.0
  ELSE
    UIM1=U(I-1, 1)
    PIM1=P(I-1, 1)
    RIM1=RHO(I-1, 1)
  END IF
  V(I, 1)=0.
  U(I, 1)=(SY*UIM1-0.5*EY*(4.*U(I, 2)-U(I, 3)))/DENOM
  UN(I, 1)=SAIX(I, 1)*U(I, 1)
  VN(I, 1)=ETAX(I, 1)*U(I, 1)
  P(I, 1)=(SY*PIM1-0.5*EY*(4.*P(I, 2)-P(I, 3)))/DENOM
  RIV=1./RGAS
  TIM1=PIM1/RIM1*RIV
  T2=P(I, 2)/RHO(I, 2)*RIV
  T3=P(I, 3)/RHO(I, 3)*RIV
  T1=(SY*TIM1-0.5*EY*(4.*T2-T3))/DENOM
  CALL CPGAM(CP(I, 1), CV(I, 1), GAMMA(I, 1), GM1(I, 1), RGAS, I, 1,
  > RHO(I, 1), RHOU(I, 1), RHOV(I, 1), E(I, 1), T1)
  RHO(I, 1)=P(I, 1)/T1*RIV
  RHOU(I, 1)=RHO(I, 1)*U(I, 1)
  RHOV(I, 1)=RHO(I, 1)*V(I, 1)
  E(I, 1)=P(I, 1)/GM1(I, 1)+0.5*RHO(I, 1)*(U(I, 1)**2+V(I, 1)**2)
20 CONTINUE
RETURN

C*
ENTRY WALLBC
J=JL
IBEG=1
IF(ISUP.EQ.3) IBEG=2
C* SOLVE THE PRESSURE EQUATION
IF(ISUP.NE.3) THEN
  AM(1)=0.
  BM(1)=1.5*(ETAX(1, J)**2+ETAY(1, J)**2)-(SAIX(1, J)*
  > ETAX(1, J)+SAIY(1, J)*ETAY(1, J))
  CM(1)=SAIX(1, J)*ETAX(1, J)+SAIY(1, J)*ETAY(1, J)
  DM(1)=(ETAX(1, J)**2+ETAY(1, J)**2)*(2.*P(1, J-1)-0.5*P(1, J-2))
  ELSE
    AM(1)=0.
    BM(1)=1.
    CM(1)=0.
    DM(1)=P(1, J)
  ENDIF
  DO 30 I=2, IL1
    CC1=SAIX(I, J)*ETAX(I, J)+SAIY(I, J)*ETAY(I, J)
    CC2=ETAX(I, J)**2+ETAY(I, J)**2
    AM(I)=-0.5*CC1
    BM(I)=1.5*CC2

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```

      CM(I)=0.5*CC1
      DM(I)=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
30  CONTINUE
      CC1=SAIX(IL,J)*ETAX(IL,J)+SAIY(IL,J)*ETAY(IL,J)
      CC2=ETAX(IL,J)**2+ETAY(IL,J)**2
      AM(IL)=-CC1
      BM(IL)=CC1+1.5*CC2
      CM(IL)=C.
      DM(IL)=CC2*(2.*P(IL,J-1)-0.5*P(IL,J-2))
      CALL SYH(1,IL,AM,BM,CM,DM)
      DO 32 I=1,IL
32  PTEMP(I)=DM(I)
      RIV=1./RGAS
      IF(IWALL.EQ.0)THEN
        IF(ISUP.EQ.3)THEN
          DM(1)=P(1,J)*RIV/RHO(1,J)
        ELSE
          T1=P(1,J-1)*RIV/RHO(1,J-1)
          T2=P(1,J-2)*RIV/RHO(1,J-2)
          CC2=ETAX(1,J)**2+ETAY(1,J)**2
          DM(1)=CC2*(2.*T1-0.5*T2)
        END IF
      DO 34 I=2,IL
        CC2=ETAX(I,J)**2+ETAY(I,J)**2
        T1=P(I,J-1)*RIV/RHO(I,J-1)
        T2=P(I,J-2)*RIV/RHO(I,J-2)
34  DM(I)=CC2*(2.*T1-0.5*T2)
      CALL SYH(1,IL,AM,BM,CM,DM)
      ELSE
      ENDIF
      DO 40 I=IBEG,IL
      IF(IWALL.EQ.0)THEN
        TT=DM(I)
      ELSE
        TT=TWALL
      ENDIF
      PP=PTEMP(I)
      U(I,JL)=0.
      V(I,JL)=0.
      RHOU(I,JL)=0.
      RHOV(I,JL)=0.
      RHOO=PP*RIV/TT
      RHO(I,JL)=RHOO
      CALL CPCAM(CP(I,JL),CV(I,JL),GAMMA(I,JL),GM1(I,JL),RGAS,I,JL,
> RHO(I,JL),RHOU(I,JL),RHOV(I,JL),E(I,JL),TT)
      E(I,JL)=PP/GM1(I,JL)
      P(I,JL)=PP
      UN(I,JL)=0.
      VN(I,JL)=0.
40  CONTINUE
      RETURN
C*
C*  LAMINAR VISCOSITY CALCULATION
C*
C  ENTRY MULAM

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C* USE SUTHERLAND LAW
C DO 60 I=1, IL
C DO 60 J=1, JL
C TOS=TREF+SCONST
C TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
C TTS=TT+SCONST
C ZMU(I,J)=ZMUO*TOS/TTS*(TT/TREF)**1.5
C ZMU(I,J)=ZMUO
C ZMU(I,J)=ZMUO*(TT/TREF)**0.67
C 60 CONTINUE
C RETURN
C END

C*****
SUBROUTINE MULAM
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=100)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,ZMUT(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
B1=4.3222557667160623D-06
B2=3.8885996244952953D-08
B3=-3.7263546610032919D-12
DO 50 NN=1, IL
DO 50 MM=1, JL
TT=(E(NN,MM)/RHO(NN,MM)-0.5*(U(NN,MM)**2+V(NN,MM)**2))/CV(NN,MM)
ZMU(NN,MM)=B1+B2*TT+B3*TT*TT
50 CONTINUE
C RETURN
C END

C
C BOLDWIN & LOMAX TURBULENCE MODEL
C
SUBROUTINE MUTUR
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=100)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,ZMUT(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,

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      PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHO(1,1)),
      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
DIMENSION YVERT(JZ),ZMUI(JZ)
DATA AP,CCP,CKLEB,CWK,VKCON,XK/26., 1.6, .3, .25, .4, .0168/
DATA ZMUI/JZ*0.0/
DO 991 II=1,IL
  I=II
  FYMAX = 0.0
  YMAX = 0.0
  UDIF=0.
  YVERT(JL) = 0.0
  TAUW = ZMU(I,JL)*DABS(ETAY(I,JL)*(U(I,JL)-U(I,JL-1))-
      ETAX(I,JL)*(V(I,JL)-V(I,JL-1)))
  CYP = DSQRT(RHO(I,JL)*TAUW)/ZMU(I,JL)
C
DO 10 KK = 2,JL1
  K = JL+1-KK
  YVER = YVERT(K+1) + 1.0/DSQRT(ETAX(I,K)**2 + ETAY(I,K)**2)
  OMG = DABS( ETAY(I,K)*(U(I,K+1)-U(I,K-1))*0.5
      +SAIY(I,K)*(U(I,K) -U(I-1,K))
      -ETAX(I,K)*(V(I,K+1)-V(I,K-1))*0.5
      -SAIX(I,K)*(V(I,K) -V(I-1,K)) )
  YPLUS = CYP*YVER
  TURLEN = VKCON*YVER*(1.0DO -DEXP(-YPLUS/AP))
  ZMUI(K) = RHO(I,K)*OMG*TURLEN**2
  FY = TURLEN/VKCON*OMG
  UTOTAL= DSQRT(U(I,K)**2+V(I,K)**2)
  IF(UTOTAL.GE.UDIF) UDIF=UTOTAL
  IF(FY .LT. FYMAX) GO TO 10
  FYMAX = FY
  YMAX = YVER
10 YVERT(K) = YVER
C
VXDIF = UDIF
C
WRITE(6,*) II,K,TURLEN,YVER,OMG,FY,FYMAX
FWAKE1=YMAX*FYMAX
FWAKE2=CWK*YMAX*VXDIF**2/FYMAX
FWAKE =DMIN1(FWAKE1,FWAKE2)
C
DO 20 KK = 2, JL1
  K = JL+1-KK
  FKLEB = (CKLEB*YVERT(K)/YMAX)**6
  FKLEB = 1./(1.0 + 5.5*FKLEB)
  ZMUO = XK*CCP*RHO(I,K)*FWAKE*FKLEB
  IF(ZMUI(K).GT.ZMUO) THEN
    ZMUTUR = ZMUO
  ELSE
    ZMUTUR = ZMUI(K)
  END IF
  ZMUT(I,K)= ZMUTUR

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      ZMU(I,K) = ZMU(I,K) + ZMUTUR
C      WRITE(77,119)K,Y(I,K),YVERT(K),U(I,K),ZMUI(K),ZMUO,ZMU(I,K)
C119  FORMAT(2X,I3,6(2X,D13.6))
20    CONTINUE
C
      ZMUT(I,1)=0.
      ZMUT(I,JL)=0.
991  CONTINUE
      RETURN
      END
C* SOURCE TERM JACOBIAN MATRIX
      SUBROUTINE DHDQ(D,I,J)
C-----
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
      >      P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
      >      ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
      >      ,ZMUT(IZ,JZ)
      >      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
      >      PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),
      >      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
      DIMENSION D(4,4)
      CALL SZERO(4,D)
      IF(IVISC.EQ.0)THEN
        R2MY=0.
      ELSE
        R2MY=4./3.*ZMU(I,J)/(Y(I,J)*Y(I,J)*RHO(I,J))
      END IF
      D(3,1)=.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/Y(I,J)+IVISC*V(I,J)*R2MY
      D(3,2)=-GM1(I,J)*U(I,J)/Y(I,J)
      D(3,3)=-GM1(I,J)*V(I,J)/Y(I,J)-IVISC*R2MY
      D(3,4)=GM1(I,J)/Y(I,J)
      RETURN
      END
      SUBROUTINE JACCAL
C*
C* SUBROUTINE FOR JACOBIAN METRIX
C* IF IA=1, ACAP MATRIX
C* IF IA=2, BCAP MATRIX
C*
C*****
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
      >      P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
      >      ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)

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~ ,ZMUT(IZ,JZ)
~ ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
~ PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
~ (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
DIMENSION A(4,4),B(4,4),C(4,4)
C*****
ENTRY JACOB(IA,A,I,J)
IF(IA.EQ.2)GO TO 10
CX=SAIX(I,J)
CY=SAIY(I,J)
CONTRA=UN(I,J)
GO TO 20
10 CX=ETAX(I,J)
CY=ETAY(I,J)
CONTRA=VN(I,J)
20 CONTINUE
PHI2=0.5DO*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
A(1,1)=0.0DO
A(1,2)=CX
A(1,3)=CY
A(1,4)=0.DO
A(2,1)=CX*PHI2-U(I,J)*CONTRA
A(2,2)=CONTRA-(GAMMA(I,J)-2.)*CX*U(I,J)
A(2,3)=CY*U(I,J)-GM1(I,J)*CX*V(I,J)
A(2,4)=GM1(I,J)*CX
A(3,1)=CY*PHI2-V(I,J)*CONTRA
A(3,2)=CX*V(I,J)-GM1(I,J)*CY*U(I,J)
A(3,3)=CONTRA-CY*V(I,J)*(GAMMA(I,J)-2.)
A(3,4)=GM1(I,J)*CY
A(4,1)=CONTRA*(2.DO*PHI2-GAMMA(I,J)*E(I,J)/RHO(I,J))
A(4,2)=CX*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA*U(I,J)
A(4,3)=CY*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA*V(I,J)
A(4,4)=GAMMA(I,J)*CONTRA
RETURN
C* VISCOUS TERM JACOBIAN MATRIX
C*
ENTRY VJACOB(A,B,C,I,J)
JP1=J+1
JM1=J-1
ZMUP=0.5*(ZMU(I,J)+ZMU(I,JP1))
ZMUM=0.5*(ZMU(I,J)+ZMU(I,JM1))
YYP=0.5*(Y(I,J)+Y(I,JP1))
YYM=0.5*(Y(I,J)+Y(I,JM1))
YJP=RJ(I,JP1)/Y(I,JP1)
IF(JM1.EQ.1)THEN
YJM=0.
ELSE
YJM=RJ(I,JM1)/Y(I,JM1)
ENDIF

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IF (PRNT.EQ.0.DO) THEN
  GAMP=0.5*(GAMMA(I,J)+GAMMA(I,J+1))
  GAMM=0.5*(GAMMA(I,J)+GAMMA(I,J-1))
  GKCPP=ZMUP*GAMP/PRN
  GKCPM=ZMUM*GAMM/PRN
ELSE
  ZMUTP = 0.5*(ZMUT(I,JP1)+ZMUT(I,J))
  ZMUTM = 0.5*(ZMUT(I,JM1)+ZMUT(I,J))
  ZMULP = ZMUP - ZMUTP
  ZMULM = ZMUM - ZMUTM
  GAMP=0.5*(GAMMA(I,J)+GAMMA(I,J+1))
  GAMM=0.5*(GAMMA(I,J)+GAMMA(I,J-1))
  GKCPP = GAMP*(ZMULP/PRN+ZMUTP/PRNT)
  GKCPM = GAMM*(ZMULM/PRN+ZMUTM/PRNT)
ENDIF
EXJ=ETAX(I,J)/RJ(I,J)
EYJ=ETAY(I,J)/RJ(I,J)
ZMUU=ZMU(I,J)
OR=1./RHO(I,J)
ORP=1./RHO(I,JP1)
ORM=1./RHO(I,JM1)
ZMURP=ZMU(I,JP1)*ORP
ZMURM=ZMU(I,JM1)*ORM
UR =U(I,J)*OR
URP=U(I,JP1)*ORP
URM=U(I,JM1)*ORM
VR =V(I,J)*OR
VRM=V(I,JM1)*ORM
VRP=V(I,JP1)*ORP
UMRP=URP*ZMU(I,JP1)
UMRM=URM*ZMU(I,JM1)
VMRP=VRP*ZMU(I,JP1)
VMRM=VRM*ZMU(I,JM1)
U2R =UR*U(I,J)
U2RP=URP*U(I,JP1)
U2RM=URM*U(I,JM1)
V2R =VR*V(I,J)
V2RP=VRP*V(I,JP1)
V2RM=VRM*V(I,JM1)
UVR =UR*V(I,J)
UVRP=URP*V(I,JP1)
UVRM=URM*V(I,JM1)
ER2 =E(I,J)*OR**2
ER2P=E(I,JP1)*ORP**2
ER2M=E(I,JM1)*ORM**2
ZRYJP=ZMURP*YJP
ZRYJM=ZMURM*YJM
ORYJP=ORP*YJP
ORYJM=ORM*YJM
VMRP=-ZMURP*V(I,JP1)*YJP
VMRM=-ZMURM*V(I,JM1)*YJM
URYJP=-URP*YJP
URYJM=-URM*YJM
VYJP=2.*ZMU(I,JP1)*VRP*YJP
VYJM=2.*ZMU(I,JM1)*VRM*YJM

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V2YJF=-V2RP*2.*ZMU(I,JP1)*YJP
V2YJM=-V2RM*2.*ZMU(I,JM1)*YJM
UVYJF=-2.*ZMU(I,JP1)*UVRP*YJP
UVYJM=-2.*ZMU(I,JM1)*UVRM*YJM
VYJP2=VYJP*0.5
VYJM2=0.5*VYJM
UYJP=ZMU(I,JP1)*URP*YJP
UYJM=ZMU(I,JM1)*URM*YJM
AAP1= ZMUP*A1(I,J)*YYP
AAP2= ZMUP*A2(I,J)*YYP
AAP3= ZMUP*A3(I,J)*YYP
AAP4= GKCPP*A4(I,J)*YYP
AAM1= ZMUM*A1(I,JM1)*YYM
AAM2= ZMUM*A2(I,JM1)*YYM
AAM3 =ZMUM*A3(I,JM1)*YYM
AAM4 =GKCPM*A4(I,JM1)*YYM
IF(JM1.EQ.1)THEN
CALL SZERO(1,A)
ELSE
A(1,1) =0.
A(1,2) =0.
A(1,3) =0.
A(1,4) =0.
A21=(AAM1*URM+AAM2*VRM)*RJ(I,JM1)/Y(I,JM1)
A(2,1) =A21-1./3.*EXJ*VMRM
A(2,2) =-AAM1*ORM*RJ(I,JM1)/Y(I,JM1)
A(2,3) =-AAM2*ORM*RJ(I,JM1)/Y(I,JM1)-1./3.*EXJ*ZRYJM
A(2,4) =0.
A31=(AAM2*URM+AAM3*VRM)*RJ(I,JM1)/Y(I,JM1)
A(3,1) =A31+1./3.*ZMU(I,J)
*      *EXJ*URYJM
A(3,2) =-AAM2*ORM*RJ(I,JM1)/Y(I,JM1)+1./3.*ZMU(I,J)*EXJ*ORYJM
A(3,3) =-AAM3*ORM*RJ(I,JM1)/Y(I,JM1)
A(3,4) =0.
A(4,1) =(-AAM4*(-ER2M+U2RM+V2RM)+AAM1*U2RM+AAM3*V2RM+
+      2.*AAM2*UVRM)*RJ(I,JM1)/Y(I,JM1)-
+      1./3.*EYJ*V2YJM-1./3.*EXJ*UVYJM
A(4,2) =AAM4*URM*RJ(I,JM1)/Y(I,JM1)-A21-1./3.*EXJ*VYJM2
A(4,3) =AAM4*VRM*RJ(I,JM1)/Y(I,JM1)-A31-1./3.*EYJ*VYJM-
*      1./3.*EXJ*UYJM
A(4,4) =-AAM4*ORM*RJ(I,JM1)/Y(I,JM1)
ENDIF
C(1,1) =0.
C(1,2) =0.
C(1,3) =0.
C(1,4) =0.
C21=(AAP1*URP+AAP2*VRP)*RJ(I,JP1)/Y(I,JP1)
C(2,1) =C21+1./3.*EXJ*VMRP
C(2,2) =-AAP1*ORP*RJ(I,JP1)/Y(I,JP1)
C(2,3) =-AAP2*ORP*RJ(I,JP1)/Y(I,JP1)+1./3.*EXJ*ZRYJP
C(2,4) =0.
C31=(AAP2*URP+AAP3*VRP)*RJ(I,JP1)/Y(I,JP1)
C(3,1) =C31-1./3.*ZMU(I,J)
*      *EXJ*URYJP
C(3,2) =-AAP2*ORP*RJ(I,JP1)/Y(I,JP1)-1./3.*ZMU(I,J)*EXJ*ORYJP

```

```

C(3,3) = -AAP3*ORP*RJ(I,JP1)/Y(I,JP1)
C(3,4) = 0.
C(4,1) = (-AAP4*(-ER2P+U2RP+V2RP)+AAP1*U2RP+AAP3*V2RP+
2.*AAP2*UVRP)*RJ(I,JP1)/Y(I,JP1)+
1./3.*EYJ*V2YJP+1./3.*EXJ*UVYJP
C(4,2) = AAP4*URP*RJ(I,JP1)/Y(I,JP1)-C21+1./3.*EXJ*VYJP2
C(4,3) = AAP4*VRP*RJ(I,JP1)/Y(I,JP1)-C31+1./3.*EYJ*VYJP+
1./3.*EXJ*UYJP
C(4,4) = -AAP4*ORP*RJ(I,JP1)/Y(I,JP1)
AA1 = AAP1+AAM1
AA2 = AAP2+AAM2
AA3 = AAP3+AAM3
AA4 = AAP4+AAM4
B(1,1) = 0.
B(1,2) = 0.
B(1,3) = 0.
B(1,4) = 0.
B(2,1) = (-AA1*UR-AA2*VR)*RJ(I,J)/Y(I,J)
B(2,2) = AA1*OR*RJ(I,J)/Y(I,J)
B(2,3) = -AA2*OR*RJ(I,J)/Y(I,J)
B(2,4) = 0.
B(3,1) = (-AA2*UR-AA3*VR)*RJ(I,J)/Y(I,J)
B(3,2) = AA2*OR*RJ(I,J)/Y(I,J)
B(3,3) = AA3*OR*RJ(I,J)/Y(I,J)
B(3,4) = 0.
B(4,1) = (AA4*(-ER2+U2R+V2R)-AA1*U2R-AA3*V2R-
2.*AA2*UVR)*RJ(I,J)/Y(I,J)
B(4,2) = -AA4*UR*RJ(I,J)/Y(I,J)-B(2,1)
B(4,3) = -AA4*VR*RJ(I,J)/Y(I,J)-B(3,1)
B(4,4) = AA4*OR*RJ(I,J)/Y(I,J)
RETURN
END

```

```

C*****
SUBROUTINE FOR COMPUTING PRECONDITIONER
C*****

```

```

SUBROUTINE PRECON(I,J,A)

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```

C*****

```

```

IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=100)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ),
RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
ZMUT(IZ,JZ)
AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
FRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
(Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
DIMENSION A(4,4)
C*****
CALL SZERO(4,A)

```

```

      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      ZM=DSQRT(U(I,J)**2+V(I,J)**2)/CO
      IF(COND.GT.0.0.AND.ZM.LT.1.0) GO TO 100
      DO 1 MM=1,4
1    A(MM,MM)=1.0DO
      RETURN
100 CONTINUE
      ALPHA=U(I,J)*U(I,J)+V(I,J)*V(I,J)
      CON=CO*CO/ALPHA
      CONM1=CON-1.0DO
      A(1,1)=1.0DO
      A(2,2)=1.0DO
      A(3,3)=1.0DO
      A(4,1)=0.5DO*ALPHA*CONM1
      A(4,2)=-U(I,J)*CONM1
      A(4,3)=-V(I,J)*CONM1
      A(4,4)=CON
      RETURN
      END

```

```

C-----
      SUBROUTINE EIGEN(IA,A,I,J)
C*
C* SUBROUTINE FOR EIGENVECTOR MATRIX CALCULATION
C* IF IA=1 L FOR ACAP
C* IF IA=2 L FOR BCAP
C*
C*****
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
      > P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
      > ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
      > ,ZMUT(IZ,JZ)
      > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
      > PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),
      > (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
      DIMENSION A(4,4),C(IZ,JZ)
C*****
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      C(I,J)=CO
      ZM=DSQRT(U(I,J)**2+V(I,J)**2)/CO
C*
      IF(COND.GT.0.0.AND.ZM.LT.1.0) GO TO 500
C*
C* EIGENVECTOR FOR ORIGINAL EULER EQN
C*
      IF(IA.EQ.2)GO TO 10
      CX=SAIX(I,J)

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        CY=SAIY(I,J)
        GO TO 20
10    CX=ETAX(I,J)
        CY=ETAY(I,J)
20    CONTINUE
        SQ2=DSQRT(2.DO)
C      C=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
        C1=CX/DSQRT(CX**2+CY**2)
        C2=CY/DSQRT(CX**2+CY**2)
        A(1,1)=1.-0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/CO**2
        A(1,2)=GM1(I,J)*U(I,J)/CO**2
        A(1,3)=GM1(I,J)*V(I,J)/CO**2
        A(1,4)=-GM1(I,J)/CO**2
        A(2,1)=(-C2*U(I,J)+C1*V(I,J))/RHO(I,J)
        A(2,2)=C2/RHO(I,J)
        A(2,3)=-C1/RHO(I,J)
        A(2,4)=0.
        A(3,1)=- (C1*U(I,J)+C2*V(I,J))/SQ2/RHO(I,J)+
>      0.5/SQ2*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/RHO(I,J)/CO
        A(3,2)=C1/SQ2/RHO(I,J)-GM1(I,J)/SQ2*U(I,J)/RHO(I,J)/CO
        A(3,3)=C2/SQ2/RHO(I,J)-GM1(I,J)/SQ2*V(I,J)/RHO(I,J)/CO
        A(3,4)=GM1(I,J)/SQ2/RHO(I,J)/CO
        A(4,1)=(C1*U(I,J)+C2*V(I,J))/SQ2/RHO(I,J)+0.5/SQ2*GM1(I,J)*
>      (U(I,J)**2+V(I,J)**2)/RHO(I,J)/CO
        A(4,2)=-C1/SQ2/RHO(I,J)-GM1(I,J)/SQ2*U(I,J)/RHO(I,J)/CO
        A(4,3)=-C2/SQ2/RHO(I,J)-GM1(I,J)/SQ2*V(I,J)/RHO(I,J)/CO
        A(4,4)=GM1(I,J)/SQ2/RHO(I,J)/CO
        GOTO 600

C
C
500 CONTINUE

C*
C* EIGENVECTOR FOR PRECONDITIONED EULER EQN
C*
        IF(IA.EQ.2) GO TO 50
        IF(IA.NE.1) STOP 999
        CX=SAIX(I,J)
        CY=SAIY(I,J)
        CONTRA=UN(I,J)
        GO TO 60
50    CX=ETAX(I,J)
        CY=ETAY(I,J)
        CONTRA=VN(I,J)
60    CONTINUE
        UU=U(I,J)**2+V(I,J)**2
        XM=DSQRT(UU/C(I,J)**2)
        QM=1.DO-XM**2
        XMM=QM**2
        AC=DSQRT(CONTRA**2*XMM+4.DO*C(I,J)**2*XM**2
>      *(CX**2+CY**2))
        A(1,1)=0.5DO+0.5DO*(V(I,J)*CX-U(I,J)*CY)/(RHO(I,J)*
>      (CX**2+CY**2))-2.DO*QM*CONTRA**2/(XMM*CONTRA**2-AC**2)
>      +GM1(I,J)*UU*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
        A(1,2)=0.5DO*CY/(RHO(I,J)*(CX**2+CY**2))+2.DO*
>      CX*QM*CONTRA/(XMM*CONTRA**2-AC**2)

```

```

> -GM1(I,J)*U(I,J)*2.DO*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
  A(1,3)=-0.5DO*CX/(RHO(I,J)*(CX**2+CY**2))+2.DO*CY*QM*CONTRA
> /(XMM*CONTRA**2-AC**2)
> -GM1(I,J)*V(I,J)*2.DO*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
  A(1,4)=2.DO*GM1(I,J)*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
  A(2,1)=0.5DO+0.5DO*(U(I,J)*CY-V(I,J)*CX)/(RHO(I,J)
> *(CX**2+CY**2))
> -2.DO*QM*CONTRA**2/(XMM*CONTRA**2-AC**2)
> +GM1(I,J)*UU*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
  A(2,2)=-0.5DO*CY/(RHO(I,J)*(CX**2+CY**2))+2.DO*CX*QM*CONTRA/
> (XMM*CONTRA**2-AC**2)
> -GM1(I,J)*U(I,J)*2.DO*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
  A(2,3)=0.5DO*CX/(RHO(I,J)*(CX**2+CY**2))+2.DO*CY*QM*CONTRA/
> (XMM*CONTRA**2-AC**2)
> -GM1(I,J)*V(I,J)*2.DO*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
  A(2,4)=2.DO*GM1(I,J)*(CX**2+CY**2)/(XMM*CONTRA**2-AC**2)
  A(3,1)=(QM*CONTRA+AC)*CONTRA-GM1(I,J)*UU*(CX**2+CY**2))
> /(AC*(QM*CONTRA-AC))
  A(3,2)=(-CX*(QM*CONTRA+AC)+2.DO*GM1(I,J)*U(I,J)*(CX**2+CY**2))
> /(AC*(QM*CONTRA-AC))
  A(3,3)=(-CY*(QM*CONTRA+AC)+2.DO*GM1(I,J)*V(I,J)*(CX**2+CY**2))
> /(AC*(QM*CONTRA-AC))
  A(3,4)=-2.DO*GM1(I,J)*(CX**2+CY**2)/(AC*(QM*CONTRA-AC))
  A(4,1)=(CONTRA*(QM*CONTRA-AC)-GM1(I,J)*UU*(CX**2+CY**2))
> /(AC*(QM*CONTRA+AC))
  A(4,2)=(-CX*(QM*CONTRA-AC)+2.DO*GM1(I,J)*U(I,J)*(CX**2+CY**2))
> /(AC*(QM*CONTRA+AC))
  A(4,3)=-((QM*CONTRA-AC)*CY+2.DO*GM1(I,J)*V(I,J)*(CX**2+CY**2))
> /(AC*(QM*CONTRA+AC))
  A(4,4)=-2.DO*GM1(I,J)*(CX**2+CY**2)/(AC*(QM*CONTRA+AC))
600 CONTINUE
  RETURN
  END

```

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C-----
  SUBROUTINE COEFX(J)
C*
C*  SETTING COEFFICIENTS FOR LX-OPERATOR
C*
C*****
  IMPLICIT REAL*8(A-H,O-Z)
  PARAMETER (IZ=150,JZ=100)
  COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
  COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,ZMUT(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
  COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
  COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
  COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
  DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
  EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHO(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****

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```

    DIMENSION IN(4),EE(4,4,IZ),EL(4,IZ),W(4,IZ)
    DIMENSION AM(4,4),BM(4,4),CM(4,4),DM(4)
    DIMENSION AL(4,4),BE(4)
    DIMENSION A(4,4),AL1(4,4),D(4,4)

C
    DIMENSION PA(4,4),PPD(4,4),PINV(4,4),PRE(4,4),AL2(4,4)
    DIMENSION AM1(4,4),BM1(4,4),CM1(4,4),DM1(4),PIA(4,4)
    DIMENSION E1(4,4),EINV(4,4),AA(4,4),GA(4,4),GA1(4,4),EG(4,4)
    > ,AINV(4,4)
C*****
C*
C* UPSTREAM BOUNDARY CONDITION AT I=1
C*
    I=1
    TAUD=DELTAU(I,J)*THETA/EXI
    IF(ISUP.EQ.3)GOTO 45
    CALL SZERO(4,AM)
    CALL JACOB(1,A,I,J)
    CALL DHDQ(D,I,J)
    CALL PRECON(I,J,PRE)
    CALL EIGEN(1,AL1,I,J)
    DO 951 M=1,3
    DO 951 N=1,4
951 AL1(M,N)=0.DO
    DO 901 MM=1,4
    DO 901 NN=1,4
    PPD(MM,NN)=PRE(MM,NN)-TAUD*D(MM,NN)
901 CONTINUE
    CALL INVER(4,PPD,PINV)
    CALL MMM(4,PINV,A,PA)
    CALL MMM(4,AL1,PA,PIA)
    CALL SZERO(4,BM)
    DO 10 M=1,4
    DO 10 N=1,4
    BM(M,N)=AL1(M,N)-TAUD*PIA(M,N)
10 CONTINUE
    RJYY=RJ(I,J)/Y(I,J)
    RCV=RHO(I,J)*CV(I,J)
    RJRCV=RJYY/RCV
    BM(1,1)=(-E(I,J)/RHO(I,J)+GM1(I,J)/GAMMA(I,J)*(U(I,J)**2
    > +V(I,J)**2))*RJRCV
    BM(1,2)=-GM1(I,J)/GAMMA(I,J)*U(I,J)*RJRCV
    BM(1,3)=-GM1(I,J)/GAMMA(I,J)*V(I,J)*RJRCV
    BM(1,4)=RJRCV
C    BM(2,1)=-GAMMA(I,J)*E(I,J)/RHO(I,J)+(GAMMA(I,J)+1.)*AAA
C    BM(2,2)=-U(I,J)
C    BM(2,3)=-V(I,J)
C    BM(2,4)=1.DO
    C1=(RHO(I,J)*E(I,J)-0.5*RHO(I,J)**2*(U(I,J)**2+V(I,J)**2))
    C2=(RHO(I,J)*E(I,J)-0.5*GM1(I,J)/GAMMA(I,J)*RHO(I,J)**2*(U(I,J)**2
    > +V(I,J)**2))
    C3=(C2/C1)**(GAMMA(I,J)/GM1(I,J))
    C4=GAMMA(I,J)/GM1(I,J)/C1*(C2/C1)**(1.DO/GM1(I,J))
    BM(2,1)=(0.5*(U(I,J)**2+V(I,J)**2)*C3+C4*E(I,J)*(C1-C2)/RHO(I,J)
    > )*GM1(I,J)*RJYY

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      BM(2,2)=(-U(I,J)*C3+C4*U(I,J)*(C2-GM1(I,J)/GAMMA(I,J)*C1))
> *GM1(I,J)*RJYY
      BM(2,3)=(-V(I,J)*C3+C4*V(I,J)*(C2-GM1(I,J)/GAMMA(I,J)*C1))
> *GM1(I,J)*RJYY
      BM(2,4)=(C3+C4*(C1-C2))*GM1(I,J)*RJYY
      EM(3,1)=-VN(I,J)*RJYY/RHO(I,J)
      BM(3,2)=ETAX(I,J)*RJYY/RHO(I,J)
      BM(3,3)=ETAY(I,J)*RJYY/RHO(I,J)
      BM(3,4)=0.
      CALL SZERO(4,CM)
      CALL JACOB(1,A,I+1,J)
      CALL MMM(4,PINV,A,PA)
      CALL MMM(4,AL1,PA,PIA)
      DO 20 M=1,4
      DO 20 N=1,4
      CM(M,N)=-TAUD*PIA(M,N)
20  CONTINUE
      DO 971 M=1,3
      DO 971 N=1,4
971  CM(M,N)=0.DO
C*
      CALL MMM(4,AL1,PINV,AL2)
      DO 952 M=1,4
952  DM1(M)=DQ(I,J,M)
      CALL MMV(4,AL2,DM1,DM)
C*
      TON=(E(I,J)/RHO(I,J)-0.5*GM1(I,J)/GAMMA(I,J)*(U(I,J)**2
> +V(I,J)**2))/CV(I,J)
      TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
      PON=P(I,J)*(TON/TT)**(GAMMA(I,J)/GM1(I,J))
      DM(1)=(TO-TON)
      DM(2)=(PO-PON)
      DM(3)=-VN(I,J)
      GOTO 49
45  CONTINUE
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      CALL SZERO(4,CM)
      DO 46 M=1,4
      DM(M)=0.
      BM(M,M)=1.0
46  CONTINUE
49  CONTINUE
      CALL EEL(I,4,IL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
C*
C* INTERIOR NODES
C*
      DO 70 I=2,IL1
      TAUD=0.5DO*DELTAU(I,J)*THETA/EXI
      TAUD2=2.*TAUD
      IM1=I-1
      IP1=I+1
      CALL PRECON(I,J,PRE)
      CALL JACOB(1,A,IM1,J)
      CALL DHDQ(D,I,J)

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DO 902 MM=1,4
DO 902 NN=1,4
PPD(MM,NN)=PRE(MM,NN)-TAUD2*D(MM,NN)
902 CONTINUE
CALL INVER(4,PPD,PINV)
CALL MMM(4,PINV,A,PA)
CALL SMM(4,TAUD,PA,AM)
CALL SZERO(4,BM)
DO 50 M=1,4
50 BM(M,M)=BM(M,M)+1.
CALL JACOB(1,A,IP1,J)
CALL MMM(4,PINV,A,PA)
CALL SMM(4,-TAUD,PA,CM)
DO 961 M=1,4
961 DM1(M)=DQ(I,J,M)
CALL MMV(4,PINV,DM1,DM)
C
C
CALL EEL(I,4,IL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
70 CONTINUE
C*
C* DOWNSTREAM BOUDARY CONDITION AT I=IL
C*
I=IL
TAUD=DELTAU(I,J)*THETA/EXI
CALL JACOB(1,A,I-1,J)
CALL DHDQ(D,I,J)
CALL PRECON(I,J,PRE)
DO 903 MM=1,4
DO 903 NN=1,4
PPD(MM,NN)=PRE(MM,NN)-TAUD*D(MM,NN)
903 CONTINUE
CALL INVER(4,PPD,PINV)
IF(ISUP.EQ.1.OR.ISUP.EQ.3) GO TO 75
CALL EIGEN(1,AL1,I,J)
DO 71 N=1,4
71 AL1(4,N)=0.0DO
CALL MMM(4,AL1,PA,AM1)
CALL SMM(4,TAUD,AM1,AM)
CALL JACOB(1,A,I,J)
CALL MMM(4,PINV,A,PA)
C DO 78 M=1,4
C DO 78 N=1,4
C 78 A(M,N)=A(M,N)-D(M,N)
CALL MMM(4,AL1,PA,BM)
DO 72 M=1,4
DO 72 N=1,4
72 BM(M,N)=BM(M,N)*TAUD+AL1(M,N)
BM(4,1)=0.5*(U(I,J)*U(I,J)+V(I,J)*V(I,J))
BM(4,2)=-U(I,J)
BM(4,3)=-V(I,J)
BM(4,4)=1.
CALL SZERO(4,CM)
CALL MMM(4,AL1,PINV,AL2)
DO 73 M=1,4

```

```

      DM(M)=0.
      DO 73 K=1,4
73    DM(M)=DM(M)+AL2(M,K)*DQ(I,J,K)
      IF(PB.NE.O.DO)THEN
      DM(4)= (PB-P(IL,J))/GM1(IL,J)*Y(IL,J)/RJ(IL,J)
      ENDIF
      GO TO 95
75    CONTINUE
      CALL MMM(4,PINV,A,PA)
      CALL SMM(4,TAUD,PA,AM)
      CALL JACOB(1,A,I,J)
      CALL MMM(4,PINV,A,PA)
      CALL SMM(4,TAUD,PA,BM)
      DO 80 M=1,4
80    BM(M,M)=BM(M,M)+1.
      CALL SZERO(4,CM)
      DO 90 K=1,4
90    DM1(K)=DQ(I,J,K)
      CALL MMV(4,PINV,DM1,DM)
95    CONTINUE
      CALL EEL(I,4,IL,EE,EL,AM,BM,CM,DM,IN,AL,BE)

```

C\*

C\* SOLVE 4\*4 BLOCK TRIDIAGONAL SYSTEM

C\*

```

      CALL SOLU(W,IL,4,EE,EL)
      DO 100 I=1,IL
      DO 100 K=1,4
      DQ(I,J,K)=W(K,I)
100    CONTINUE
C* MULTIPLY DQ BY I-DT*D
C    I2=IL
C    IF(ISUP.EQ.0)I2=IL1
C    DO 200 I=2,I2
C    CALL SZERO(4,BM)
C    CALL DHDQ(D,I,J)
C    DO 120 M=1,4
C    BM(M,M)=BM(M,M)+1.0
C    DO 120 N=1,4
C    BM(M,N)=BM(M,N)-DELTAU(I,J)*D(M,N)
C 120 CONTINUE
C    DO 140 K=1,4
C    DM(K)=0.
C    DO 140 N=1,4
C    DM(K)=DM(K)+BM(K,N)*W(N,I)
C 140 CONTINUE
C    DO 160 K=1,4
C 160 DQ(I,J,K)=DM(K)
C 200 CONTINUE
      RETURN
      END

```

C-----

SUBROUTINE COEFY(I)

C\*

C\* SETTING COEFFICIENTS FOR LY-OPERATOR

C\*

C\*\*\*\*\*

```

      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
      >      P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
      >      ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
      >      ,ZMUT(IZ,JZ)
      >      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
      >      PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
      >      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))

```

C\*\*\*\*\*

```

      DIMENSION IN(4),EE(4,4,JZ),EL(4,JZ),W(4,JZ)
      DIMENSION AM(4,4),BM(4,4),CM(4,4),DM(4)
      DIMENSION AL(4,4),BE(4)
      DIMENSION B(4,4),BL1(4,4),D(4,4),A(4,4)

```

CHOI

```

      DIMENSION AMJL(4,4),BMJL(4,4),CMJL(4,4),DMJL(4)
      DIMENSION PINV(4,4),PPD(4,4),PRE(4,4),PINV1(4,4),PPDJL1(4,4)
      >      ,PID(4,4),PIA(4,4),PIB(4,4),DM1(4),DM2(4),DM10(4),DM20(4)

```

C\*\*\*\*\*

C\*

C\* ON THE CENTER LINE OF THE NOZZLE AT J=1

C\*

```

      J=1
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      DO 20 M=1,4
      DM(M)=0.
      BM(M,M)=BM(M,M)+1.0
20  CONTINUE
      CALL SZERO(4,CM)
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)

```

C\*

C\* INTERIOR NODS

C\*

```

      DO 80 J=2,JL1
      TAUD=0.5DO*DELTAU(I,J)*THETA/EYI
      TAUD2=2.*TAUD
      JM1=J-1
      JP1=J+1
      CALL JACOB(2,B,I,JM1)
      CALL PRECON(I,J,PRE)
      CALL DHDQ(D,I,J)
      DO 904 MM=1,4
      DO 904 NN=1,4
      PPD(MM,NN)=PRE(MM,NN)-TAUD2*D(MM,NN)
904  CONTINUE
      CALL INVER(4,PPD,PINV)
      CALL MMM(4,PINV,B,PIB)

```

```

      CALL SMM(4,TAUD,PIB,AM)
      CALL SZERO(4,BM)
      DO 60 M=1,4
60    BM(M,M)=BM(M,M)+1.
      CALL JACOB(2,B,I,JP1)
      CALL MMM(4,PINV,B,PIB)
      CALL SMM(4,-TAUD,PIB,CM)
C*
C*  INSERT VISCOUS JACOBIAN LHS HERE
C*
      IF(IVISC.EQ.1)THEN
        CALL VJACOB(A,B,D,I,J)
        CALL MMM(4,PINV,A,PIA)
        CALL MMM(4,PINV,B,PIB)
        CALL MMM(4,PINV,D,PID)
        DO 68 M=1,4
        DO 68 N=1,4
          AM(M,N)=AM(M,N)-DELTAU(I,J)*PIA(M,N)
          BM(M,N)=BM(M,N)+DELTAU(I,J)*PIB(M,N)
68      CM(M,N)=CM(M,N)-DELTAU(I,J)*PID(M,N)
      ELSE
      END IF
      DO 70 K=1,4
70    DM(K)=DQ(I,J,K)
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
80    CONTINUE
C*
C*  WALL BOUNDARY CONDITION
C*
CHOI      J=JL
CHOI      TAUD=THETA*DELTAU(I,J)/EYI
CHOI      IF(IVISC.EQ.1)GOTO 111
CHOI      CALL SZERO(4,AM)
CHOI      CALL JACOB(2,B,I,J-1)
CHOI      CALL EIGEN(2,BL1,I,J)
CHOI      DO 90 M=1,3
CHOI      DO 90 N=1,4
CHOI      DO 90 K=1,4
CHOI  90  AM(M,N)=AM(M,N)+TAUD*BL1(M,K)*B(K,N)
CHOI      CALL SZERO(4,BM)
CHOI      CALL JACOB(2,B,I,J)
CHOI      CALL DHDQ(D,I,J)
CHOI      DO 100 M=1,3
CHOI      DO 100 N=1,4
CHOI      BM(M,N)=BM(M,N)+BL1(M,N)
CHOI      DO 100 K=1,4
CHOI      BM(M,N)=BM(M,N)+TAUD*BL1(M,K)*(B(K,N)-D(K,N))
CHOI 100  CONTINUE
CHOI
CHOI
      J=JL
      TAUJL=DELTAU(I,JL)
      TAUJM=DELTAU(I,JL1)
      CALL PRECON(I,JL1,PRE)
      CALL DHDQ(D,I,JL1)

```

```

DO 905 MM=1,4
DO 905 NN=1,4
PPDJL1(MM,NN)=PRE(MM,NN)-TAUJM*D(MM,NN)
905 CONTINUE
CALL PRECON(I,JL,PRE)
CALL DHDQ(D,I,JL)
DO 906 MM=1,4
DO 906 NN=1,4
PPD(MM,NN)=PRE(MM,NN)-TAUJL*D(MM,NN)
906 CONTINUE
IF(:VISC.EQ.1) GOTO 111
CALL SZERO(4,AMJL)
CALL JACOB(2,B,I,J-1)
CALL EIGEN(2,BL1,I,J)
DO 1105 N=1,4
BL1(4,N)=0.DO
1105 CONTINUE
DO 1101 M=1,4
DO 1101 N=1,4
AMJL(M,N)=-TAUJL*(PPDJL1(M,N)-2.DO*TAUJM*B(M,N))
1101 CONTINUE
CALL MMM(4,BL1,AMJL,AM)
CALL SZERO(4,BMJL)
CALL JACOB(2,B,I,J)
DO 1201 M=1,4
DO 1201 N=1,4
BMJL(M,N)=TAUJM*(PPD(M,N)+2.DO*TAUJL*B(M,N))
1201 CONTINUE
CALL MMM(4,BL1,BMJL,BM)
CALL SZERO(4,CM)
DO 1501 MM=1,4
DM1(MM)=DQ(I,JL,MM)
1501 CONTINUE
DO 1502 MM=1,4
DM2(MM)=DQ(I,JL1,MM)
1502 CONTINUE
CALL MMV(4,PPD,DM1,DM10)
CALL MMV(4,PPDJL1,DM2,DM20)
DO 1300 M=1,4
DMJL(M)=TAUJM*DM10(M)+TAUJL*DM20(M)
1300 CONTINUE
CALL MMV(4,BL1,DMJL,DM)
CHOI
CHOI
BM(4,1)=-VN(I,J)
BM(4,2)=ETAX(I,J)
BM(4,3)=ETAY(I,J)
BM(4,4)=0.
CALL SZERO(4,CM)
CHOI DO 110 M=1,3
CHOI DM(M)=0.
CHOI DO 110 K=1,4
CHOI DM(M)=DM(M)+BL1(M,K)*DQ(I,J,K)
CHOI 110 CONTINUE
DM(4)=0.

```

```

      GOTO 119
111  CONTINUE
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      CALL SZERO(4,CM)
      DO 113 M=1,4
      DM(M)=0.
113  BM(M,M)=1.0
119  CONTINUE
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
C*
C* SOLVE 4*4 BLOCK TRIDIAGONAL MATRICES
C*
      CALL SOLU(W,JL,4,EE,EL)
      DO 120 J=1,JL
      DO 120 K=1,4
      DQ(I,J,K)=W(K,J)
120  CONTINUE
      RETURN
      END
C-----
      SUBROUTINE FLUXCL
C*
C* SUBROUTINE FOR FLUX VECTOR CALCULATION
C*
C*****
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=100)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
>      P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
>      ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
>      ,ZMUT(IZ,JZ)
>      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
>      PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND
      COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL
      DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHO(1,1)),
>      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
      ENTRY FLUX
C*
C* COMPUTE CONVECTIVE TERMS
C*
      DO 10 I=1,IL
      DO 10 J=1,JL
      F(I,J,1)=RHO(I,J)*UN(I,J)/RJ(I,J)*Y(I,J)
      F(I,J,2)=(RHOV(I,J)*UN(I,J)+SAIX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      F(I,J,3)=(RHOV(I,J)*UN(I,J)+SAIY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      F(I,J,4)=(E(I,J)+P(I,J))*UN(I,J)/RJ(I,J)*Y(I,J)
      G(I,J,1)=RHO(I,J)*VN(I,J)/RJ(I,J)*Y(I,J)
      G(I,J,2)=(RHOV(I,J)*VN(I,J)+ETAX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
      G(I,J,3)=(RHOV(I,J)*VN(I,J)+ETAY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)

```

```

      C(I,J,4)=(E(I,J)+P(I,J))*VN(I,J)/RJ(I,J)*Y(I,J)
10 CONTINUE
      RETURN
C* VISCOUS FLUX VECTOR
C*
      ENTRY VFLUX
      DO 30 I=2,IL
      DO 30 J=2,JL1
      JP1=J+1
      JM1=J-1
      ZMUP=0.5*(ZMU(I,J)+ZMU(I,JP1))
      ZMUM=0.5*(ZMU(I,J)+ZMU(I,JM1))
      IF(PRNT.EQ.0.DO) THEN
      GAMP=0.5*(GAMMA(I,J)+GAMMA(I,JP1))
      GAMM=0.5*(GAMMA(I,J)+GAMMA(I,JM1))
      GKCPP=ZMUP*GAMP/PRN
      GKCPM=ZMUM*GAMM/PRN
      ELSE
      ZMUTP = 0.5*(ZMUT(I,JP1)+ZMUT(I,J))
      ZMUTM = 0.5*(ZMUT(I,JM1)+ZMUT(I,J))
      ZMULP = ZMUP - ZMUTP
      ZMULM = ZMUM - ZMUTM
      CAMP=0.5*(GAMMA(I,J)+GAMMA(I,JP1))
      GAMM=0.5*(GAMMA(I,J)+GAMMA(I,JM1))
      GKCPP = GAMP*(ZMULP/PRN+ZMUTP/PRNT)
      GKCPM = GAMM*(ZMULM/PRN+ZMUTM/PRNT)
      ENDIF
      YYP=0.5*(Y(I,J)+Y(I,JP1))
      YYM=0.5*(Y(I,J)+Y(I,JM1))
      YZP=YYP*ZMUP
      YZM=YYM*ZMUM
      AAP1=A1(I,J)*YZP
      AAM1=A1(I,JM1)*YZM
      AAP2=A2(I,J)*YZP
      AAM2=A2(I,JM1)*YZM
      AAP3=A3(I,J)*YZP
      AAM3=A3(I,JM1)*YZM
      AAP4=A4(I,J)*YYP*GKCPP
      AAM4=A4(I,JM1)*YYM*GKCPM
      UP=U(I,JP1)-U(I,J)
      UM=-U(I,JM1)+U(I,J)
      VP=V(I,JP1)-V(I,J)
      VM=V(I,J)-V(I,JM1)
      ERP=E(I,JP1)/RHO(I,JP1)-E(I,J)/RHO(I,J)
      ERM=E(I,J)/RHO(I,J)-E(I,JM1)/RHO(I,JM1)
      U2P=U(I,JP1)**2-U(I,J)**2
      U2M=U(I,J)**2-U(I,JM1)**2
      V2P=V(I,JP1)**2-V(I,J)**2
      V2M=V(I,J)**2-V(I,JM1)**2
      UVP=U(I,JP1)*V(I,JP1)-U(I,J)*V(I,J)
      UVM=U(I,J)*V(I,J)-U(I,JM1)*V(I,JM1)
      G(I,J,1)=0.
      G(I,J,2)=(AAP1*UP-AAM1*UM)+(AAP2*VP-AAM2*VM)
      G(I,J,3)=(AAP2*UP-AAM2*UM)+(AAP3*VP-AAM3*VM)
      G(I,J,4)=(AAP4*ERP-AAM4*ERM)+0.5*((AAP1-AAP4)*U2P-

```

```

> (AAM1-AAM4)*U2M)+0.5*((AAP3-AAP4)*V2P-(AAM3-AAM4)*V2M)+
> (AAP2*UVP-AAM2*UVM)

```

C\*

C\* INSERT THE EXTRA FIRST ORDER TERMS IN CYLINDRICAL COORDINATE

C\* SYSTEMS

C\*

```

EYJ=ETAY(I,J)/RJ(I,J)
EXJ=ETAX(I,J)/RJ(I,J)
DMUV=0.5*(ZMU(I,JP1)*V(I,JP1)-ZMU(I,JM1)*V(I,JM1))
DDV =0.5*(V(I,JP1)-V(I,JM1))
DMUV2=0.5*(ZMU(I,JP1)*V(I,JP1)**2-ZMU(I,JM1)*V(I,JM1)**2)
DMUUV=0.5*(ZMU(I,JP1)*U(I,JP1)*V(I,JP1)-
*      ZMU(I,JM1)*U(I,JM1)*V(I,JM1))
DDU =0.5*(U(I,JP1)-U(I,JM1))
DDMU=0.5*(ZMU(I,JP1)-ZMU(I,JM1))
G(I,J,2)=G(I,J,2)-2./3.*EXJ*DMUV
G(I,J,3)=G(I,J,3)+2./3.*(ZMU(I,J)*EXJ*DDU-V(I,J)*EYJ*DDMU)
G(I,J,4)=G(I,J,4)-2./3.*(EYJ*DMUV2+EXJ*DMUUV)

```

30 CONTINUE

RETURN

END

C-----

C \*\* RIGHT HAND SIDE CALCULATION

C-----

SUBROUTINE RHSC

C \*\*\*\*\*

IMPLICIT REAL\*8(A-H,O-Z)

PARAMETER (IZ=150,JZ=100)

COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),

&gt; P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)

COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)

&gt; ,RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)

&gt; ,ZMUT(IZ,JZ)

&gt; ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)

COMMON/CONST/AIN,ATH,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,P0,TO,

&gt; PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF,COND

COMMON/CONST1/CP(IZ,JZ),CV(IZ,JZ),GAMMA(IZ,JZ),GM1(IZ,JZ),RGAS

COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,ISUP,IVISC,IWALL

DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)

EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),

&gt; (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))

C\*\*\*\*\*

ENTRY RHS

CALL FLUX

EXII=2.\*EXI

EYII=EYI\*2.

DO 10 I=1,IL

DO 10 J=1,JL

DO 10 K=1,4

10 DQ(I,J,K)=0.

I=1

DO 30 J=1,JL

DO 20 K=1,4

C 20 DQ(I,J,K)=DQ(I,J,K)+(-3.\*F(I,J,K)+4.\*F(I+1,J,K)-

C &gt; F(I+2,J,K))/EXII

```

20  DQ(I,J,K)=DQ(I,J,K)+(F(I+1,J,K)-F(I,J,K))/EXI
    IF(J.EQ.1.OR.J.EQ.JL) GO TO 30
    DO 25 K=1,4
25  DQ(I,J,K)=DQ(I,J,K)+(G(I,J+1,K)-G(I,J-1,K))/EYII
30  CONTINUE
    J=1
    DO 50 I=1,IL
    DO 40 K=1,4
C 40  DQ(I,J,K)=DQ(I,J,K)+(-3.*G(I,J,K)+4.*G(I,J+1,K)-
C      G(I,J+2,K))/EYII
    40  DQ(I,J,K)=DQ(I,J,K)+(G(I,J+1,K)-G(I,J,K))/EYI
    IF(I.EQ.1.OR.I.EQ.IL) GO TO 50
    DO 45 K=1,4
    45  DQ(I,J,K)=DQ(I,J,K)+(F(I+1,J,K)-F(I-1,J,K))/EXII
50  CONTINUE
    I=IL
    DO 70 J=1,JL
    DO 60 K=1,4
C 60  DQ(I,J,K)=DQ(I,J,K)+(F(I-2,J,K)-4.*F(I-1,J,K)+
C      3.*F(I,J,K))/EXII
    60  DQ(I,J,K)=DQ(I,J,K)+(F(I,J,K)-F(I-1,J,K))/EXI
    IF(J.EQ.1.OR.J.EQ.JL) GO TO 70
    DO 65 K=1,4
    65  DQ(I,J,K)=DQ(I,J,K)+(G(I,J+1,K)-G(I,J-1,K))/EYII
70  CONTINUE
    J=JL
    DO 90 I=1,IL
    DO 80 K=1,4
CHK1
    80  DQ(I,J,K)=DQ(I,J,K)+(G(I,J-2,K)-4.*G(I,J-1,K)+
        3.*G(I,J,K))/EYII
CHK1 80  DQ(I,J,K)=DQ(I,J,K)+(G(I,J,K)-G(I,J-1,K))/EYI
    IF(I.EQ.1.OR.I.EQ.IL) GO TO 90
    DO 85 K=1,4
    85  DQ(I,J,K)=DQ(I,J,K)+(F(I+1,J,K)-F(I-1,J,K))/EXII
90  CONTINUE
    DO 100 I=2,IL1
    DO 100 J=2,JL1
    IP1=I+1
    IM1=I-1
    JP1=J+1
    JM1=J-1
    DO 100 K=1,4
    DQ(I,J,K)=DQ(I,J,K)+(F(IP1,J,K)-F(IM1,J,K))/EXII+
        (G(I,JP1,K)-G(I,JM1,K))/EYII
100  CONTINUE
    DO 200 I=1,IL
    DO 200 J=2,JL
    DQ(I,J,3)=DQ(I,J,3)-P(I,J)/RJ(I,J)
200  CONTINUE
    RETURN
C* VISCOUS RIGHT HAND SIDE
C*
    ENTRY VRHS
    CALL VFLUX

```

```

      DO 300 I=2, IL
      DO 300 J=2, JL1
      DQ(I, J, 3)=DQ(I, J, 3)+4./3.*ZMU(I, J)*V(I, J)/(RJ(I, J)*Y(I, J))
      DO 300 K=2, 4
300   DQ(I, J, K)=DQ(I, J, K)-G(I, J, K)
      RETURN
      END
C *****
C   SERVICE SUBROUTINE
C *****
      SUBROUTINE SUPPLY
      IMPLICIT REAL*8(A-H, O-Z)
      PARAMETER (IZ=150, JZ=100)
      COMMON/VECTOR/DQ(IZ, JZ, 4), Q(IZ, JZ, 4), F(IZ, JZ, 4), G(IZ, JZ, 4),
>      P(IZ, JZ), U(IZ, JZ), V(IZ, JZ), UN(IZ, JZ), VN(IZ, JZ)
      COMMON/COORD/SAIX(IZ, JZ), SAIY(IZ, JZ), ETAX(IZ, JZ), ETAY(IZ, JZ)
>      RJ(IZ, JZ), X(IZ, JZ), Y(IZ, JZ), DELTAU(IZ, JZ)
>      ZMUT(IZ, JZ)
>      AREA(IZ), ZMU(IZ, JZ), A1(IZ, JZ), A2(IZ, JZ), A3(IZ, JZ), A4(IZ, JZ)
      COMMON/CONST/AIN, ATH, RL, EXI, EYI, OMEGAX, OMEGAY, CFL, THETA, PO, TO,
>      PRNT, PB, RM1, SUM(4), ZMUO, REN, PRN, TWALL, TREF, COND
      COMMON/CONST1/CP(IZ, JZ), CV(IZ, JZ), GAMMA(IZ, JZ), GM1(IZ, JZ), RGAS
      COMMON/INTEG/IL, JL, IL1, JL1, NEND, NBEG, NADV, ITIME, ISUP, IVISC, IWALL
      DIMENSION RHO(IZ, JZ), RHOU(IZ, JZ), RHOV(IZ, JZ), E(IZ, JZ)
      EQUIVALENCE(Q(1, 1, 1), RHO(1, 1)), (Q(1, 1, 2), RHOU(1, 1)),
>      (Q(1, 1, 3), RHOV(1, 1)), (Q(1, 1, 4), E(1, 1))
C *****
      DIMENSION SS(4), SS1(4), SS2(4)
      ENTRY CHECK
      DO 10 K=1, 4
      SS1(K)=0.DO
10    SS2(K)=0.DO
      IF(IVISC.EQ.1)THEN
      JEND=JL1
      ELSE
      JEND=JL
      ENDIF
      IF(ISUP.EQ.3)THEN
      IBEG=2
      ELSE
      IBEG=1
      ENDIF
      DO 20 I=IBEG, IL
      DO 20 J=2, JEND
      DO 20 K=1, 4
      QQ=Q(I, J, K)
C   IF(QQ.EQ.0.DO)GO TO 20
      SS1(K)=SS1(K)+(DQ(I, J, K)*RJ(I, J)/Y(I, J))**2
      SS2(K)=SS2(K)+QQ**2
20    CONTINUE
      DO 30 K=1, 4
30    SS(K)=DSQRT(SS1(K)/SS2(K))
      WRITE(19, 500)NADV, (SS(K), K=1, 4)
500   FORMAT(15, 3X, 4(1X, E14.7))
      RETURN

```

```

      E=PI*MASS
      E=1/ARCOS(-1.D0)
      DO 80 I=1,IL
      E=RT=0.
      DO 75 J=1,JL1
      DELR=DSQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
      CXCY=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CXCY1=DSQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
      FLRT=ELRT+0.5*PPI*(Y(I,J+1)+Y(I,J))*DELR
      *(RHO(I,J+1)*UN(I,J+1)/CXCY1+RHO(I,J)*UN(I,J)/CXCY)
75    CONTINUE
      WRITE(22,789)I,FLRT
80    CONTINUE
789  FORMAT(1X,I8,E14.7)
      RETURN
      ENTRY OUTPUT
      WRITE(22,550)NADV
550  FORMAT(//10(1H*)/ '      NADV=' ,I5//)
      DO 50 I=1,IL
      DO 50 J=1,JL
      ST=(E(I,J)/RHO(I,J)-GM1(I,J)*0.5/GAMMA(I,J)*(U(I,J)**2+
      *V(I,J)**2))/CV(I,J)
      VN=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
      P=DSQRT((U(I,J)*U(I,J)+V(I,J)*V(I,J))/GAMMA(I,J)
      *RHO(I,J)/P(I,J))
      SP=P(I,J)*(ST/TT)**(GAMMA(I,J)/GM1(I,J))
      WRITE(18,607)X(I,J),Y(I,J),P(I,J),RMA,TT,SP
      WRITE(66) (Q(I,J,K),K=1,4),DELTAU(I,J)
607  FORMAT(6(1X,E14.7))
C    WRITE(6,600)I,J,RHO(I,J),U(I,J),V(I,J),E(I,J),ST
C    WRITE(6,650)P(I,J),UN(I,J),VN(I,J),SP,TT
600  FORMAT(1X,'#',I2,',',I2,3X,5(1X,E10.3))
650  FORMAT(10X,5(1X,E10.3))
50    CONTINUE
C
C    WRITE THE LAST TWO LINES
C
      DO 55 I=116,117
      DO 55 J=1,JL
55    WRITE(68) (Q(I,J,K),K=1,4)
C
      RETURN
      END
C *****
C*
C*  LIBRARY SUBROUTINES
C*
      SUBROUTINE EEL(J,MM,JMAX,E,EL,AM,BM,CM,DM,IN,AL,BE)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION IN(MM),E(MM,MM,JMAX),EL(MM,JMAX)
      DIMENSION AM(MM,MM),BM(MM,MM),CM(MM,MM),DM(MM)
      DIMENSION AL(MM,MM),BE(MM)
      DO 30 M=1,MM
      TP=0.0D0
      DO 20 N=1,MM

```

```

T1=0.0D0
IF(J.EQ.1)GO TO 10
TP=TP+AM(M,N)*EL(N,J-1)
DO 5 K=1,MM
5 T1=T1+AM(M,K)*E(K,N,J-1)
10 CONTINUE
AL(M,N)=BM(M,N)-T1
20 CONTINUE
EL(M,J)=DM(M)+TP
30 CONTINUE
DO 50 M=1,MM
DO 40 N=1,MM
40 E(M,N,J)=CM(M,N)
50 CONTINUE
CALL AXB(MM,MM,AL,E(1,1,J),BE,0,IN)
CALL AXB(MM,1,AL,EL(1,J),BE,1,IN)
RETURN
END

```

```

C-----
SUBROUTINE SOLU(W,JMAX,MM,E,EL)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION W(MM,JMAX),E(MM,MM,JMAX),EL(MM,JMAX)
DO 40 M=1,MM
W(M,JMAX)=EL(M,JMAX)
40 CONTINUE
DO 50 J1=2,JMAX
J=JMAX+1-J1
DO 46 M=1,MM
SUM=0.0D0
DO 44 K=1,MM
SUM=SUM+E(M,K,J)*W(K,J+1)
44 CONTINUE
W(M,J)=SUM+EL(M,J)
46 CONTINUE
50 CONTINUE
RETURN
END

```

```

C-----
SUBROUTINE AXB(N,M,A,B,X,INIT,IPS)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION A(N,N),B(N,M),IPS(N),X(N)
IF(INIT.EQ.0)CALL DECOMP(N,A,IPS)
DO 10 I=1,M
CALL SOLV(N,A,B(1,I),X,IPS)
10 CONTINUE
RETURN
END

```

```

C-----
SUBROUTINE DECOMP(N,UL,IPS)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION UL(N,N),IPS(N)
DO 5 I=1,N
IPS(I)=I
5 CONTINUE
NM1=N-1

```

```

      DO 10 K=1,NM1
      IP=0.000
      DO 11 I=K,N
      IPS(I)
      DABS(UL(IP,K))
      P(SIZE-BIG)11,11,10
10  DO 12 G=SIZE
      KP1=I
11  CONTINUE
      IDXP1V=K)14,15,14
14  DO 13 I=K
      IPS(K)=IPS(IDXP1V)
      IPS(IDXP1V)=J
15  DO 16 I=K
      IPS(K)
      IDXP1V=UL(KP,K)
      KP1=I+1
      DO 16 I=KP1,N
      IPS(I)
      EM=UL(IP,K)/PIVOT
      UL(IP,K)=-EM
      DO 16 J=KP1,N
      UL(IP,J)=UL(IP,J)+EM*UL(KP,J)
16  CONTINUE
17  CONTINUE
      RETURN
      END

```

---

```

C-----
      SUBROUTINE SOLV(N,UL,B,X,IPS)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION UL(N,N),B(N),X(N),IPS(N)
      NP1=N+1
      IP=IPS(1)
      X(1)=B(IP)
      DO 2 I=2,N
      IP=IPS(I)
      IM1=I-1
      SUM=0.000
      DO 1 J=1,IM1
1  SUM=SUM+UL(IP,J)*X(J)
2  X(I)=B(IP)-SUM
      IP=IPS(N)
      B(I)=X(N)/UL(IP,N)
      DO 4 IBACK=2,N
      I=NP1-IBACK
      IP=IPS(I)
      IP1=I+1
      SUM=0.000
      DO 3 J=IP1,N
3  SUM=SUM+UL(IP,J)*B(J)
4  B(I)=(X(I)-SUM)/UL(IP,I)
      RETURN
      END

```

---

```

C-----
C      SET ZERO FOR MATRIC (M,M)
      SUBROUTINE SZERO(M,A)

```

```

      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      A(I,J)=0.0DO
10 CONTINUE
      RETURN
      END

```

```

C-----
C  SCALAR*METRIC (M,M)
      SUBROUTINE SMM(M,C,A,B)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      B(I,J)=C*A(I,J)
10 CONTINUE
      RETURN
      END

```

```

C-----
C  METRIX*METRIX (M*M)
      SUBROUTINE MMM(M,A,B,C)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M,M),C(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      C(I,J)=0.0DO
      DO 10 K=1,M
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
10 CONTINUE
      RETURN
      END

```

```

C*
      SUBROUTINE SYH(IL,IU,BB,DD,AA,CC)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION AA(1),BB(1),CC(1),DD(1)

```

```

C....
C....SUBROUTINE SYH SOLVES TRIDIAGONAL SYSTEM BY ELIMINATION
C....IL = SUBSCRIPT OF FIRST EQUATION
C....IU = SUBSCRIPT OF LAST EQUATION
C....BB = COEFFICIENT BEHIND DIAGONAL
C....DD = COEFFICIENT ON DIAGONAL
C....AA = COEFFICIENT AHEAD OF DIAGONAL
C....CC = ELEMENT OF CONSTANT VECTOR
C....
C....ESTABLISH UPPER TRIANGULAR MATRIX
C....

```

```

      LP = IL+1
      DO 10 I = LP,IU
      R = BB(I)/DD(I-1)
      DD(I) = DD(I)-R*AA(I-1)
10 CC(I) = CC(I)-R*CC(I-1)

```

```

C...
C... BACK SUBSTITUTION
C...

```

```

      CC(IU) = CC(IU)/DD(IU)
      DO 20 I =LP, IU
      J = IU-I+IL
20    CC(J) = (CC(J)-AA(J)*CC(J+1))/DD(J)
C...
C... SOLUTION STORED IN CC
C...
      RETURN
      END
C*****
      SUBROUTINE INVER(M,A,AINV)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(4,4),B(4,4),AINV(4,4),COF(4,4)
      A11=A(1,1)
      A12=A(1,2)
      A13=A(1,3)
      A14=A(1,4)
      A21=A(2,1)
      A22=A(2,2)
      A23=A(2,3)
      A24=A(2,4)
      A31=A(3,1)
      A32=A(3,2)
      A33=A(3,3)
      A34=A(3,4)
      A41=A(4,1)
      A42=A(4,2)
      A43=A(4,3)
      A44=A(4,4)
      DET=A11*(A22*A33*A44+A23*A34*A42+A24*A43*A32-A24*A33*A42
> -A23*A32*A44-A22*A43*A34)-
> A12*(A21*A33*A44+A23*A34*A41+A24*A43*A31-A24*A33*A41
> -A23*A31*A44-A21*A43*A34)+
> A13*(A21*A32*A44+A22*A34*A41+A24*A42*A31-A24*A32*A41
> -A22*A31*A44-A21*A42*A34)-
> A14*(A21*A32*A43+A22*A33*A41+A23*A42*A31-A23*A32*A41
> -A22*A31*A43-A21*A42*A33)
      COF(1,1)=A22*A33*A44+A23*A34*A42+A24*A43*A32-A24*A33*A42
> -A23*A32*A44-A22*A43*A34
      COF(1,2)=- (A21*A33*A44+A23*A34*A41+A24*A43*A31-A24*A33*A41
> -A23*A31*A44-A21*A43*A34)
      COF(1,3)=A21*A32*A44+A22*A34*A41+A24*A42*A31-A24*A32*A41
> -A22*A31*A44-A21*A42*A34
      COF(1,4)=- (A21*A32*A43+A22*A33*A41+A23*A42*A31-A23*A32*A41
> -A22*A31*A43-A21*A42*A33)
      COF(2,1)=- (A12*A33*A44+A13*A34*A42+A14*A32*A43-A14*A33*A42
> -A13*A32*A44-A12*A43*A34)
      COF(2,2)=A11*A33*A44+A13*A34*A41+A14*A31*A43-A14*A33*A41
> -A13*A31*A44-A11*A43*A34
      COF(2,3)=- (A11*A32*A44+A12*A34*A41+A14*A31*A42-A14*A32*A41
> -A12*A31*A44-A11*A42*A34)
      COF(2,4)=A11*A32*A43+A12*A33*A41+A13*A31*A42-A13*A32*A41
> -A12*A31*A43-A11*A42*A33
      COF(3,1)=A12*A23*A44+A13*A24*A42+A14*A22*A43-A14*A23*A42
> -A13*A22*A44-A12*A43*A24

```

```

COF(3,2)=- (A11*A23*A44+A13*A24*A41+A14*A21*A43-A14*A23*A41
> -A13*A21*A44-A11*A43*A24)
COF(3,3)=A11*A22*A44+A12*A24*A41+A14*A21*A42-A14*A22*A41
> -A12*A21*A44-A11*A42*A24
COF(3,4)=- (A11*A22*A43+A12*A23*A41+A13*A21*A42-A13*A22*A41
> -A12*A21*A43-A11*A42*A23)
COF(4,1)=- (A12*A23*A34+A13*A24*A32+A14*A22*A33-A14*A23*A32
> -A13*A22*A34-A12*A33*A24)
COF(4,2)=A11*A23*A34+A13*A24*A31+A14*A21*A33-A14*A23*A31
> -A13*A21*A34-A11*A33*A24
COF(4,3)=- (A11*A22*A34+A12*A24*A31+A14*A21*A32-A14*A22*A31
> -A12*A21*A34-A11*A32*A24)
COF(4,4)=A11*A22*A33+A12*A23*A31+A13*A21*A32-A13*A22*A31
> -A12*A21*A33-A11*A32*A23

```

```

AINV(1,1)=COF(1,1)/DET
AINV(1,2)=COF(2,1)/DET
AINV(1,3)=COF(3,1)/DET
AINV(1,4)=COF(4,1)/DET
AINV(2,1)=COF(1,2)/DET
AINV(2,2)=COF(2,2)/DET
AINV(2,3)=COF(3,2)/DET
AINV(2,4)=COF(4,2)/DET
AINV(3,1)=COF(1,3)/DET
AINV(3,2)=COF(2,3)/DET
AINV(3,3)=COF(3,3)/DET
AINV(3,4)=COF(4,3)/DET
AINV(4,1)=COF(1,4)/DET
AINV(4,2)=COF(2,4)/DET
AINV(4,3)=COF(3,4)/DET
AINV(4,4)=COF(4,4)/DET

```

```

C CALL MMM(4,A,AINV,B)
C DO 1 MM=1,4
C WRITE(5,10) (B(MM,NN),NN=1,4)
C 1 CONTINUE
10 FORMAT(4D16.7)
RETURN
END

```

C\*\*\*\*\*

```

SUBROUTINE MMV(M,A,B,C)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION A(M,M),B(M),C(M)
DO 10 I=1,M
C(I)=0.DO
DO 10 K=1,M
C(I)=C(I)+A(I,K)*B(K)
10 CONTINUE
RETURN
END

```

C\*\*\*\*\*

```

SUBROUTINE CPGAM(CP,CV,GAMMA,GM1,R,I,J,
> RHO,RHOU,RHOV,E,TCP)

```

C\*\*\*\*\*

```

PARAMETER(IZ=150,JZ=100)
IMPLICIT REAL*8 (A-H,O-Z)
COMMON/CPCOFF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7

```

```

> ,CPA8,CPA9,CPA10,ENE(101)
C=====
  IF(TCP.NE.0.0) GOTO 20
  UU=RHO/RHO
  VV=RHOV/RHO
  EE=E/RHO-0.5*(UU**2+VV**2)
  TT=300.0
  IF(EE.LE.ENE(1)) GO TO 20
  DO 10 MM=1,101
    EA= EE - ENE(MM)
    EB= EE - ENE(MM+1)
    ESIGN= EA*EB
    IF(ESIGN.LE.0.DO)THEN
      T1=300.0+27.611*DFLOAT(MM-1)
      T2=300.0+27.611*DFLOAT(MM)
      TT=(T2*EA-T1*EB)/(EA-EB)
      GO TO 20
    ELSE
      END IF
  10 CONTINUE
  TT=3061.1DO
  20 CONTINUE
  IF(TCP.NE.0.0) TT=TCP
C*
  IF(TT.LE.1000.0)THEN
    CP=(CPA6+CPA7*TT+CPA8*TT**2+CPA9*TT**3+CPA10*TT**4)
    CV=CP-R
  ELSE
    CP=(CPA1+CPA2*TT+CPA3*TT**2+CPA4*TT**3+CPA5*TT**4)
    CV=CP-R
  END IF
  GAMMA=CP/CV
  GM1=GAMMA-1.0
  RETURN
  END
C*****
  SUBROUTINE CPCOEF
C*****
  IMPLICIT REAL*8 (A-H,O-Z)
  COMMON/CPCOFF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
  > ,CPA8,CPA9,CPA10,ENE(101)
  DIMENSION Y(10),A1(10),A2(10),A3(10),A4(10),A5(10)
  > ,A6(10),A7(10),A8(10),A9(10),A10(10),WM(10)
  DATA RU,WMMIX/8314.3,20.405/
C=====
C CO
  WM(1)=28.010
  Y(1)= 0.13108
C CO2
  WM(2)=44.0
  Y(2)= 0.03636
C H
  WM(3)=1.0
  Y(3)= 0.02387
C H2

```

```

WM(4)=2.0
Y(4)= 0.15802
C H2O
WM(5)=18.0
Y(5)= 0.32366
C NO
WM(6)=30.0
Y(6)= 0.00260
C N2
WM(7)=28.0
Y(7)= 0.30407
C O
WM(8)=16.0
Y(8)= 0.00158
C OH
WM(9)=17.0
Y(9)= 0.01744
C O2
WM(10)=32.0
Y(10)= 0.00129
C-----CO
A1(1)= 0.29840696E+01
A2(1)= 0.14891390E-02
A3(1)=-0.57899684E-06
A4(1)= 0.10364577E-09
A5(1)=-0.69353550E-14
C
A6(1)= 0.37100928E+01
A7(1)=-0.16190964E-02
A8(1)= 0.36923594E-05
A9(1)=-0.20319674E-08
A10(1)= 0.23953344E-12
C-----CO2
A1(2)= 0.44608041E+01
A2(2)= 0.30981719E-02
A3(2)=-0.12392571E-05
A4(2)= 0.22741325E-09
A5(2)=-0.15525954E-13
C
A6(2)= 0.24007797E+01
A7(2)= 0.87350957E-02
A8(2)=-0.66070878E-05
A9(2)= 0.20021861E-08
A10(2)= 0.63274039E-15
C-----H
A1(3)= 0.25000000E+01
A2(3)= 0.00000000
A3(3)= 0.00000000
A4(3)= 0.00000000
A5(3)= 0.00000000
C
A6(3)= 0.25000000E+01
A7(3)= 0.00000000
A8(3)= 0.00000000
A9(3)= 0.00000000

```

A10(3)= 0.00000000

C-----H2

A1(4)= 0.30558123E+01  
A2(4)= 0.59740400E-03  
A3(4)=-0.16747471E-08  
A4(4)=-0.21247544E-10  
A5(4)= 0.25195487E-14

C

A6(4)= 0.29432327E+01  
A7(4)= 0.34815509E-02  
A8(4)=-0.77713819E-05  
A9(4)= 0.74997496E-08  
A10(4)=-0.25203379E-11

C-----H2O

A1(5)= 0.26340654E+01  
A2(5)= 0.31121899E-02  
A3(5)=-0.90278449E-06  
A4(5)= 0.12673054E-09  
A5(5)=-0.69164732E-14

C

A6(5)= 0.41675564E+01  
A7(5)=-0.18106868E-02  
A8(5)= 0.59450878E-05  
A9(5)=-0.48670871E-08  
A10(5)= 0.15284144E-11

C-----NO

A1(6)= 0.31486543E+01  
A2(6)= 0.14151823E-02  
A3(6)=-0.57574881E-06  
A4(6)= 0.10738529E-09  
A5(6)=-0.73900199E-14

C

A6(6)= 0.42484931E+01  
A7(6)=-0.48661106E-02  
A8(6)= 0.11634155E-04  
A9(6)=-0.99768494E-08  
A10(6)= 0.30483948E-11

C-----N2

A1(7)= 0.28536374E+01  
A2(7)= 0.16014368E-02  
A3(7)=-0.62888336E-06  
A4(7)= 0.11428932E-09  
A5(7)=-0.77953822E-14

C

A6(7)= 0.37034288E+01  
A7(7)=-0.14179405E-02  
A8(7)= 0.28625094E-05  
A9(7)=-0.12018374E-08  
A10(7)=-0.13475522E-13

C-----O

A1(8)= 0.25342961E+01  
A2(8)=-0.12478170E-04  
A3(8)=-0.12562724E-07  
A4(8)= 0.69029862E-11  
A5(8)=-0.63797095E-15

C

A6(8)= 0.30309401E+01  
 A7(8)=-0.22525853E-02  
 A8(8)= 0.39824540E-05  
 A9(8)=-0.32604921E-08  
 A10(8)= 0.10152035E-11

C-----OH

A1(9)= 0.28897814E+01  
 A2(9)= 0.10005879E-02  
 A3(9)=-0.22048807E-06  
 A4(9)= 0.20191288E-10  
 A5(9)=-0.39409831E-15

C

A6(9)= 0.38737300E+01  
 A7(9)=-0.13393772E-02  
 A8(9)= 0.16348351E-05  
 A9(9)=-0.52133639E-09  
 A10(9)= 0.41826974E-13

C-----O2

A1(10)= 0.36122139E+01  
 A2(10)= 0.74853166E-03  
 A3(10)=-0.19820647E-06  
 A4(10)= 0.33749008E-10  
 A5(10)=-0.23907374E-14

C

A6(10)= 0.37837135E+01  
 A7(10)=-0.30233634E-02  
 A8(10)= 0.99492751E-05  
 A9(10)=-0.98189101E-08  
 A10(10)= 0.33031825E-11

C=====

CPA1=0.DO

CPA2=0.DO

CPA3=0.DO

CPA4=0.DO

CPA5=0.DO

CPA6=0.DO

CPA7=0.DO

CPA8=0.DO

CPA9=0.DO

CPA10=0.DO

DO 10 J=1,10

CPA1=CPA1+Y(J)\*A1(J)\*RU/WMMIX

CPA2=CPA2+Y(J)\*A2(J)\*RU/WMMIX

CPA3=CPA3+Y(J)\*A3(J)\*RU/WMMIX

CPA4=CPA4+Y(J)\*A4(J)\*RU/WMMIX

CPA5=CPA5+Y(J)\*A5(J)\*RU/WMMIX

CPA6=CPA6+Y(J)\*A6(J)\*RU/WMMIX

CPA7=CPA7+Y(J)\*A7(J)\*RU/WMMIX

CPA8=CPA8+Y(J)\*A8(J)\*RU/WMMIX

CPA9=CPA9+Y(J)\*A9(J)\*RU/WMMIX

CPA10=CPA10+Y(J)\*A10(J)\*RU/WMMIX

10 CONTINUE

C...

R=RU/WMMIX

```

DO 20 MM=1,101
TT=300.0+27.611*DFLOAT(MM-1)
IF(TT.LE.1000.0)THEN
    CP=(CPA6+CPA7*TT+CPA8*TT**2+CPA9*TT**3+CPA10*TT**4)
    CV=CP-R
    ENE(MM)=CV*TT
ELSE
    CP=(CPA1+CPA2*TT+CPA3*TT**2+CPA4*TT**3+CPA5*TT**4)
    CV=CP-R
    ENE(MM)=CV*TT
END IF
20 CONTINUE
RETURN
END
//DATA.INPUT DD *
&INPUT IL=125,JL=80,NBEG=1,NEND=30,NITER=30,PO=1.D+06,TO=3061.1D0,
    CFL=5.0, OMEGAX=0.25,OMEGAY=0.25,RM1=0.04, RM2=1.2,ISUP=1,
    AIN=1.0, ATH=0.8, RL=1.3, THETA=1.0,CPO=7152.4853,GAMMA0=1.17,
    ITIME=1,IREAD=1,FST=0.00,TWALL=3512.07,FSTY=0.9,PB=0.,
    IIVISC=1,IWALL=0,PRN=0.7,REN=1.D5,TREF=3000.,ZMU0=0.D0,
    PRNT=0.7D0, COND=0.0,
&END
//DATA.FT38F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.H125M80.VIS,
// DISP=(OLD,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
// DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
// SPACE=(TRK,(9,5),RLSE)
//DATA.FT66F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.RERUN.VIS,
// DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
// DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
// SPACE=(TRK,(9,5),RLSE)
//DATA.FT19F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.DQ.VIS,
// DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120),
// SPACE=(TRK,(9,5),RLSE)
//DATA.FT18F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.SOLU.VIS,
// DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
// DCB=(RECFM=FB,LRECL=130,BLKSIZE=3120),
// SPACE=(TRK,(9,5),RLSE)
//DATA.FT22F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.MASS.VIS,
// DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
// DCB=(RECFM=FB,LRECL=130,BLKSIZE=3120),
// SPACE=(TRK,(9,5),RLSE)
//DATA.FT68F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.LINE.VIS,
// DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
// DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
// SPACE=(TRK,(9,5),RLSE)
// EXEC PROMPTME

```

X14140

USERID: V19 ORIGIN: PSUVM CREATED: 06/20/89 15:42:50  
FILENAME: PNSVIS FOR CLASS: A FORMAT: J  
SPOOLID: 2921 RECS: 3011 COPY: 1 DUPLICATE: 1

PRINTED AT: PSUVM ID: \$PPCBP01 AT: 06/20/89 15:42:54

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\* THIS FILE WAS SENT BY THE COMMAND:

\* PRT3812 PNSVIS FOR A1 ( PPCB1 COPIES 1 ORIENT N FONT 11

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```
//STIXXXX JOB
/*JP T=500, L=10000
// EXEC PGM=IEFBR14
//*
//D DD VOL=REF=STU.I19500.MYH100.LIB,DISP=(OLD,DELETE),
// DSN=STU.I19500.MYH100.HERMES2.DIF.SOLU.VIS
// EXEC FVCG,PARM.SOURCE='OPT(3)'
//* EXEC FWCG
//SYSIN DD *
C THIS VERSION USES TRUE JACOBIAN
C*****
C* PROGRAM NAME: NOZZLE *
C* AXISYMMETRIC SUPERSONIC NOZZLE FLOW *
C* IN GENERAL COORDINATE SYSTEM *
C* USING TIME ITERATIVE UW/CD DDADI METHOD *
C* WITH THIN-LAYER APPROXIMATED NAVIER-STOKE'S EQ. *
C*****
C*
C* MAIN PROGRAM
C*
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=80)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
> ,BIOT,TW1
COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
> ,IWBC,IFLOW
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
CALL INITIA
DO 10 NADV=NBEG,NEND
CALL SOLVE
CALL CHECK
10 CONTINUE
CALL MASS
CALL OUTPUT
STOP
END
C*
C* SET UP INITIAL CONDITION
C*
SUBROUTINE INITIA
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=80)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
```

```

>      P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
>      ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
>      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
>CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
>      ,BIOT,TW1
COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
>      ,IWBC,IFLOW
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
>      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
C*
C*      IF THE DIMENSION IN COMMON BLOCK MUST BE CHANGED
C*      PLEASE CHANGE THE PARAMETER STATEMENT
C*
      DIMENSION SS(3500,4)
      NAMELIST/INPUT/IL,JL,NEND,PO,TO,CFL,OMEGAX,OMEGAY,RM1,AIN,FST,
>      NITER,AEX,RL,THETA,CPO,GAMMAO,NBEG,ITIME,IVISC,NORD,IWALL,RM2
>      ,IREAD,PRN,REN,TREF,ZMUO,TWALL,FSTY,PB,PRNT,CFL1,IWBC,BIOT,TW1
>      ,IFLOW
      CALL ERRSET(208,256,-1,0,0,0)
C... IL=TOTAL GRID NUMBER IN XI DIRECTION
C... JL=TOTAL GRID NUMBER IN ETA DIRECTION
C... NBEG= COUNTING INDEX OF ITERATION STEP
C      =1 FOR THE FIRST RUN
C      =ANY NUMBER EXCEPT 1 FOR RERUN
C... NEND= NUMBER OF ITERATIONS FOR THE FIRST RUN ONLY
C... NITER=NUMBER IF ITERATIONS TO BE RUN WHEN RERUN(NBEG.NE.1)
C... PO = STAGNATION PRESSURE
C... PB=THE BACK PRESSURE AT THE EXIT OF NOZZLE
C      =0. (SUBSONIC FLOW EXTRAPOLATED FROM INTERIOR)
C      = THE SPECIFIED BACK PRESSURE (FIXED THE PRESSURE FOR
C          SUBSONIC PORTION AT EXIT)
C... TO = STAGNATION TEMPERATURE
C... CFL = CFL NUMBER
C... CFL1= CFL NUMBER FOR PNS MARCHING
C... OMEGAX=ARTIFICIAL DISSIPATION CONSTANT IN XI DIRECTION
C... OMEGAY=ARTIFICIAL DISSIPATION CONSTANT INETA DIRECTION
C... IREAD = 0 FOR DEFAULT CONICAL NOZZLE
C      1 READ GRID FROM DATA FILE
C... RM1 =THE INITIAL GUESS FOR INLET MACH NUMBER
C... RM2 =THE INITIAL GUESS FOR EXIT MACH NUMBER
C... AIN =THE INLET RADIUS FOR CONICAL NOZZLE (IGNORED IN IREAD=1)
C... AEX =THE EXIT RADIUS FOR CONICAL NOZZLE (IGNORED IF IREAD=1)
C... RL =TOTAL LENGTH OF CONICAL NOZZLE (IGNORED IF OREAD=1)
C... ITIME= 0 FOR CONSTANT DT 1 FOR CONSTANT CFL
C... IVISC= 0 INVISCID FLOW
C      1 VISCOUS FLOW
C... NORD = 0 FOR FIRST ORDER UPWIND IN XI
C      1 FOR SECOND ORDER UPWIND IN XI
C... FST = STRETCHING FACTOR IN XI DIRECTIO (0 FOR UNIFORM GRID)
C... FSTY= STRETCHING FACTOR IN ETA DIRECTION (0 FOR UNIFORM GRID)

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C... TWA = WALL TEMPERATURE (ONLY VALID FOR IFLOW=-1)
C... TREF = REFERENCE TEMPERATURE FOR VISCOSITY CALCULATION
C... ZMUC = THE VISCOSITY AT T=TREF
C... IWEL = 0 FOR EXPLICIT WALL B. C.
C...      1 FOR IMPLICIT WALL B. C.
C ** READ INLET DATA
    READ(5, INPUT)
    WRITE(13, INPUT)
C ** SET UP GEOMETRY
    IL1=IL-1
    JL1=JL-1
C
    CALL KROONE
C
    PLEDAIG S(-1.DO)
C TURN OF REVERSE COOLING FLOW
    IF(NBEG.EQ.1) IFLOW=1
C
    DO 10 I=1, IL
        AREA(I)=AIN+(AEX-AIN)*DFLOAT(I-1)/DFLOAT(IL1)
10    CONTINUE
    DO 20 I=1, IL
        DO 20 J=1, JL
            X(I,J)=DFLOAT(I-1)/DFLOAT(IL1)*RL
20    Y(I,J)=DFLOAT(J-1)/DFLOAT(JL1)*AREA(I)
        IF(FST.NE.0.DO) THEN
            DO=(FST-1.0)/(FST**IL1-1.)*RL
            DO 15 I=1, IL
                XL=DO*(FST**(I-1)-1.)/(FST-1.)
                AREA(I)=AIN+XL/RL*(AEX-AIN)
            DO 15 J=1, JL
                X(I,J)=XL
                Y(I,J)=DFLOAT(J-1)/DFLOAT(JL1)*AREA(I)
15    CONTINUE
        ELSE
            ENDIF
C* STRETCH THE GRID ALONG Y-DIRECECTION IN VISCOUS CASE
    IF(FSTY.NE.0.DO) THEN
        DO 17 I=1, IL

```

```

        Y(I,1)=0.
        DAO=(1.-FSTY)/(1.-FSTY**JL1)*AREA(I)
        DO 17 J=2,JL
            Y(I,J)=Y(I,J-1)+DAO*FSTY**(J-2)
17      CONTINUE
        ELSE
        ENDIF
C * READ GRID FROM DATA FILE
        IF(IREAD.EQ.1)THEN
            DO 25 I=1,IL
            DO 25 J=1,JL
                READ(38)III,JJJ,X(I,J),Y(I,J)
25      CONTINUE
        ELSE
        END IF
C ** COORDINATE TRANSFORMATION
        EXI=1.0
        EYI=1.0
        DO 30 I=1,IL
            IP1=I
            IM1=I-1
            IF(I.EQ.1)IM1=1
            IF(I.EQ.1)IP1=2
            DSAI=2.*EXI
            IF(I.EQ.1.OR.I.EQ.IL)DSAI=EXI
            DO 30 J=1,JL
                JP1=J+1
                JM1=J-1
                IF(J.EQ.1)JM1=1
                IF(J.EQ.JL)JP1=JL
                DETA=2.*EYI
                IF(J.EQ.1.OR.J.EQ.JL)DETA=EYI
                XSAI=(X(IP1,J)-X(IM1,J))
                YSAI=(Y(IP1,J)-Y(IM1,J))
                XETA=(X(I,JP1)-X(I,JM1))/DETA
                YETA=(Y(I,JP1)-Y(I,JM1))/DETA
                IF(I.GT.2.AND.I.LT.IL1)THEN
                    XSAI=XSAI+NORD*0.5*(X(I,J)-2.*X(I-1,J)+X(I-2,J))
                    YSAI=YS AI+NORD*0.5*(Y(I,J)-2.*Y(I-1,J)+Y(I-2,J))
                ENDIF
                IF(J.EQ.1)THEN
                    XETA=XETA-0.5*(X(I,J)-2.*X(I,J+1)+X(I,J+2))
                    YETA=YETA-0.5*(Y(I,J)-2.*Y(I,J+1)+Y(I,J+2))
                ELSE
                ENDIF
C
            IF(J.EQ.JL) THEN
                XETA=(3.DO*X(I,JL)-4.DO*X(I,JL-1)+X(I,JL-2))*0.5DO
                YETA=(3.DO*Y(I,JL)-4.DO*Y(I,JL-1)+Y(I,JL-2))*0.5DO
            ELSE
            ENDIF
C
        RJP=XSAI*YETA-XETA*YS AI
        RJ(I,J)=1./RJP
        SAIX(I,J)=YETA/RJP

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    SAIY(I,J)=-XETA/RJP
    ETAX(I,J)=-YSAI/RJP
30  ETAY(I,J)=XSAI/RJP
C ** INITIALIZATION
    RGAS=8314.3/20.405
    R=RGAS
    DO 991 I=1,IL
    DO 991 J=1,JL
    TTT=3061.1D0
    CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
> RHO(I,J),RHOI(I,J),RHOV(I,J),E(I,J),TTT)
991 CONTINUE
C    GM10=GAMMA0-1.
C    R=CP0*GM10/GAMMA0
C    CVO=CP0/GAMMA0
C
C*
C* GIVE THE INITIAL VALUE OF VISCOSTY
C* IF THE VISCOSITY AT T=TREF IS GIVEN FROM INPUT
C* THE CALCULATION FOR ZMUO MUST BE SWITCHED OFF
C*
C    TIN=TO/(1.+0.5*GM10*RM1**2)
C    UIN=RM1*DSQRT(GAMMA0*R*TIN)
C    PIN=PO*(TIN/TO)**(GAMMA0/GM10)
C    RIN=PIN/(R*TIN)
C    BIOT=BIOT*Y(1,JL)
C    ZMUO=(RIN*UIN*AREA(1)*2.)/REN
C* CALCULATE METRIC TERMS AT MID POINTS
C*
C    CALL MCONST
C ** SKIP TO RERUN THE CODE
C    IF(NBEG.NE.1)GOTO 300
C ** READ IN THE STARTING LINES
C    DO 60 I=1,2
C    DO 60 J=1,JL
C    READ(68) (Q(I,J,K),K=1,4)
C    TCP=0.D0
C    CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
> RHO(I,J),RHOI(I,J),RHOV(I,J),E(I,J),TCP)
50  CONTINUE
C    U(I,J)=RHOI(I,J)/RHO(I,J)
C    V(I,J)=RHOV(I,J)/RHO(I,J)
C    UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
C    VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
C    P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
60  CONTINUE
C    REWIND 68
C
C    RETURN
300 CONTINUE
310 READ(19,720,END=1000)NDUM,(SS(NDUM,K),K=1,4)
    GOTO 310
1000 CONTINUE
    REWIND 19
    NBEG=NDUM+1

```

```

      NEND=NBEG+NITER-1
      DO 320 N=1,NDUM
320   WRITE(19,720)N,(SS(N,K),K=1,4)
720   FORMAT(15,3X,4(1X,E14.7))
      DO 330 I=1,IL
      DO 330 J=1,JL
      READ(66) (Q(I,J,K),K=1,4),DELTAU(I,J)
      TCP=0.DO
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
> RHO(I,J),RHOI(I,J),RHOV(I,J),E(I,J),TCP)
      U(I,J)=RHOI(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
      CY=DSQRT(ETAX(I,J)**2+ETAY(I,J)**2)
      CX=(UN(I,J)+CX*CO)/EXI
      CY=(VN(I,J)+CY*CO)/EYI
      EIGNN=DABS(CX)
      IF(EIGNN.LE.DABS(CY))EIGNN=DABS(CY)
      DELTAU(I,J)=CFL/EIGNN
330   CONTINUE
      REWIND 66
      RETURN
      END

```

C-----  
 SUBROUTINE SOLVE

```

C*
C* SOLVE SUBROUTINE
C*
C*****
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
> ,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
> ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOI(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOI(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
C*
C* STRAT THE CODE BY PNS A PLUS MARCHING
C*
      IF(NADV.NE.1)GOTO 5
      CALL PNS

```

```

        RETURN
5      CONTINUE
C*
        CALL FLUX(1)
        CALL FLUX(2)
        IF(IVISC.EQ.1)THEN
            CALL MULAM(1)
            CALL MULAM(2)
        ENDIF
        DO 40 I=3,IL
C*
C*      THIS DO LOOP CONTROLS THE LOCAL ITERATION FOR
C*      EACH CONSTANT XI LINE
C*
        DO 35 LOCAL=1,1
        CALL RHS(I)
        IF(IVISC.EQ.1) THEN
            CALL MULAM(I)
            IF(PRNT.NE.0.DO) CALL MUTUR(I)
        ENDIF
        IF(IVISC.EQ.1)CALL VRHS(I)
C*      CALCULATE RESIDUAL
        DO 10 J=1,JL
        DO 10 K=1,4
10      DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
C*
C*      ADD ETA-DIRECTION 4TH ORDER ARITFICIAL VISCOSITY
C*
        IF(OMEGAY.NE.0.DO)CALL ADDY(I)
C*
C*      SOLVE L-ETA OPERATOR
C*
        CALL COEFY(I)
C*
C*      UPDATE VARIABLES AFTER X-SWEEP
C*
C      JEND=JL
C      IF(IVISC.EQ.1)JEND=JL1
        DO 20 J=2,JL
        RJJ=RJ(I,J)/Y(I,J)
        DO 15 K=1,4
15      Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
        TCP=0.DO
        CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
> RHO(I,J),RHOI(I,J),RHOV(I,J),E(I,J),TCP)
        U(I,J)=RHOI(I,J)/RHO(I,J)
        V(I,J)=RHOV(I,J)/RHO(I,J)
        UN(I,J)=SAIX(I,J)*U(I,J)+SAIY(I,J)*V(I,J)
        VN(I,J)=U(I,J)*ETAX(I,J)+ETAY(I,J)*V(I,J)
        P(I,J)=GM1(I,J)*(E(I,J)-0.5*RHO(I,J)*(U(I,J)**2+V(I,J)**2))
20      CONTINUE
        CALL CLBC(I)
        IF(IVISC.EQ.1.AND.IWBC.EQ.0)CALL WALLBC(I)
35      CONTINUE
40      CONTINUE

```

```

C*
C* BACKWARD SWEEP
C*
DO 90 IB=2, IL-2
I=IL-IB+1
DO 86 LOCAL=1,1
CALL RHS(I)
IF(IVISC.EQ.1) THEN
CALL MULAM(I)
IF(PRNT.NE.O.DO) CALL MUTUR(I)
ENDIF
IF(IVISC.EQ.1)CALL VRHS(I)
DO 50 J=1, JL
DO 50 K=1, 4
50 DQ(I, J, K)=-DELTAU(I, J)*DQ(I, J, K)
IF(OMEGAY.NE.O.DO)CALL ADDY(I)
CALL COEFY(I)

C*
C* UPDATING VARIABLES
C*
DO 70 J=2, JL
RJJ=RJ(I, J)/Y(I, J)
DO 60 K=1, 4
60 Q(I, J, K)=Q(I, J, K)+DQ(I, J, K)*RJJ
TCP=O.DO
CALL CPGAM(CP(I, J), CV(I, J), GAMMA(I, J), GM1(I, J), RGAS, I, J,
> RHO(I, J), RHOU(I, J), RHOV(I, J), E(I, J), TCP)
U(I, J)=RHOU(I, J)/RHO(I, J)
V(I, J)=RHOV(I, J)/RHO(I, J)
UN(I, J)=U(I, J)*SAIX(I, J)+V(I, J)*SAIY(I, J)
VN(I, J)=U(I, J)*ETAX(I, J)+V(I, J)*ETAY(I, J)
P(I, J)=GM1(I, J)*(E(I, J)-0.5*RHO(I, J)*(U(I, J)**2+V(I, J)**2))
CO=DSQRT(GAMMA(I, J)*P(I, J)/RHO(I, J))
CX=DSQRT(SAIX(I, J)**2+SAIY(I, J)**2)
CY=DSQRT(ETAX(I, J)**2+ETAY(I, J)**2)
CX=(UN(I, J)+CX*CO)
CY=(VN(I, J)+CY*CO)
EIGNN=DABS(CX)
IF(EIGNN.LE.DABS(CY))EIGNN=DABS(CY)
DELTAU(I, J)=ITIME*CFL/EIGNN+(1-ITIME)*DELTAU(I, J)
70 CONTINUE
C *
C * CENTERLINE BOUNDARY CONDITIONS
CALL CLBC(I)
IF(IVISC.EQ.1.AND.IWBC.EQ.O)CALL WALLBC(I)
86 CONTINUE
90 CONTINUE
RETURN
END

C*
C* THIS SUBROUTINE SOLVE THE FLOW FIELD BY
C* MARCHING IN XI DIRECTION
C*
SUBROUTINE PNS
C*****

```

```

      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
>      T(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
>      ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
>      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
>CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
>      ,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
>      ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
>      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
      DIMENSION SS(4)
      DATA INNER/200/
C ** FORWARD SWEEP
      WRITE(19,*) ' **** PNS MARCHING BEGINS **** '
      IF(IVISC.EQ.1) CALL MULAM(1)
      IF(IVISC.EQ.1) CALL MULAM(2)
      CALL FLUX(1)
      CALL FLUX(2)
      DO 999 I=3,IL
      WRITE(19,*) ' ### I=',I
C*
C* GIVE THE INITIAL GUESS FROM PREVIOUS LINE
C*
      DO 17 J=1,JL
C      DELTAU(I,J)=DELTAU(I-1,J)
      DO 16 K=1,4
16      Q(I,J,K)=Q(I-1,J,K)
      TCP=0.DO
      CALL CPGAM(CP(I,J),CV(I,J),GAMMA(I,J),GM1(I,J),RGAS,I,J,
>      RHO(I,J),RHOU(I,J),RHOV(I,J),E(I,J),TCP)
      RHO(I,J)=RHO(I-1,J)
      U(I,J)=U(I-1,J)
      V(I,J)=V(I-1,J)
      UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
      IF(J.EQ.JL) VN(I,J)=0.DO
      IF(J.EQ.JL) V(I,J)=-U(I,J)*ETAX(I,J)/ETAY(I,J)
      IF(J.EQ.JL) Q(I,J,2)=RHO(I,J)*U(I,J)
      IF(J.EQ.JL) Q(I,J,3)=RHO(I,J)*V(I,J)
      P(I,J)=P(I-1,J)
17      CONTINUE
C      IF(I.EQ.2) THEN
      DO 19 J=1,JL
      CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
      CY=VN(I,J)+DSQRT(ETAX(I,J)**2+ETAY(I,J)**2)*CO
      CX=UN(I,J)+DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)*CO
      DELTAU(I,J)=CFL1/DABS(CY)
C      DELTAU(I,J)=CFL1/DABS(CX)

```

```

19  CONTINUE
C   ENDIF
C*
      DO 998 ICOUNT=1, INNER
C*  RHS CALCULATION
      CALL RHS(I)
      IF(IVISC.EQ.1) CALL MULAM(I)
      IF(PRNT.NE.0.DO) CALL MUTUR(I)
      IF(IVISC.EQ.1) CALL VRHS(I)
      DO 40 J=1, JL
      DO 40 K=1, 4
40   DQ(I, J, K)=-DELTAU(I, J)*DQ(I, J, K)
C*
C*  ADD ETA-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
C*
      IF(OMEGAY.NE.0.ODO)CALL ADDY(I)
C*
C*  SOLVE LETA-OPERATOR
C*
      CALL COEFY(I)
C*
C*  UPDATING VARIABLES
C*
      DO 70 J=2, JL
      RJJ=RJ(I, J)/Y(I, J)
      DO 60 K=1, 4
60   Q(I, J, K)=Q(I, J, K)+DQ(I, J, K)*RJJ
      TCP=0.DO
      CALL CPGAM(CP(I, J), CV(I, J), GAMMA(I, J), GM1(I, J), RGAS, I, J,
>  RHO(I, J), RHOU(I, J), RHOV(I, J), E(I, J), TCP)
      U(I, J)=RHOU(I, J)/RHO(I, J)
      V(I, J)=RHOV(I, J)/RHO(I, J)
      UN(I, J)=U(I, J)*SAIX(I, J)+V(I, J)*SAIY(I, J)
      VN(I, J)=U(I, J)*ETAX(I, J)+V(I, J)*ETAY(I, J)
      P(I, J)=GM1(I, J)*(E(I, J)-0.5*RHO(I, J)*(U(I, J)**2+V(I, J)**2))
      CO=DSQRT(GAMMA(I, J)*P(I, J)/RHO(I, J))
      CX=DSQRT(SAIX(I, J)*SAIX(I, J)+SAIY(I, J)*SAIY(I, J))
      CY=DSQRT(ETAX(I, J)*ETAX(I, J)+ETAY(I, J)*ETAY(I, J))
      CX=(UN(I, J)+CX*CO)/EXI
      CY=(VN(I, J)+CY*CO)/EYI
      EIGNN=DABS(CY)
      DELTAU(I, J)=ITIME*CFL1/EIGNN+(1-ITIME)*DELTAU(I, J)
70  CONTINUE
C*
C*  EXTRAPOLATE FROM FIELD POINT TO CENTER LINE
C*
      CALL CLBC(I)
      IF(IVSC.EQ.1.AND.IWBC.EQ.0)CALL WALLBC(I)
C*
C*  CALCULATE THE ERROR
C*
      DO 110 K=1, 4
110  SS(K)=0.
      DO 120 J=1, JL
      DO 120 K=1, 4

```

```

      QQ=Q(I,J,K)
      IF(QQ.EQ.0.DO.OR.Y(I,J).EQ.0.DO)GO TO 120
      SS(K)=SS(K)+(DQ(I,J,K)/(QQ*Y(I,J)/RJ(I,J)))*2
120  CONTINUE
      QSUM=0.
      DO 130 K=1,4
      QSUM=QSUM+DSQRT(SS(K))
130  SS(K)=DSQRT(SS(K))/(IL*JL)
      QSUM=QSUM/4./(IL*JL)
      IF(QSUM.LE.1.D-13) GOTO 995
      WRITE(19,500)ICOUNT,(SS(K),K=1,4)
500  FORMAT(I5,3X,4(1X,E14.7))
998  CONTINUE
995  CONTINUE
      WRITE(19,510) (SS(K),K=1,4)
510  FORMAT('  &&& ',4(1X,E14.7))
999  CONTINUE
      WRITE(19,*) ' ****  PNS MARCHING ENDS  *****'
      CALL MASS
      RETURN
      END

```

C\*

C\* SUBROUTINE FOR CALCULATING METRIC TERMS

C\* AT THE MIDPOINT

SUBROUTINE MCONST

```

C*****
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
>      P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
>      ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
>      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
>CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
>      ,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
>      ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),
>      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
      DATA FD3,OD3/1.333333333333,0.333333333333/
      DO 20 I=2,IL
      DO 20 J=1,JL1
      IF(I.EQ.IL)THEN
      XSAI=0.5*(X(I,J)+X(I,J+1)-X(I-1,J)-X(I-1,J+1))
      YSAI=0.5*(Y(I,J)+Y(I,J+1)-Y(I-1,J)-Y(I-1,J+1))
      ELSE
      YSAI=0.25*(Y(I+1,J+1)+Y(I+1,J)-Y(I-1,J+1)-Y(I-1,J))
      XSAI=0.25*(X(I+1,J+1)+X(I+1,J)-X(I-1,J+1)-X(I-1,J))
      END IF
      YETA=Y(I,J+1)-Y(I,J)
      XETA=X(I,J+1)-X(I,J)

```

```

RJJ=1./(XSAI*YETA-XETA*YSAI)
A1(I,J)=RJJ*(FD3*YSAI**2+XSAI**2)
A2(I,J)=-RJJ*OD3*XSAI*YSAI
A3(I,J)=RJJ*(YSAI**2+FD3*XSAI**2)
A4(I,J)=RJJ*(XSAI**2+YSAI**2)

```

```

20 CONTINUE
RETURN
END

```

```

C-----
SUBROUTINE SMOOTH

```

```

C*
C* ADD ARTIFICIAL DISSIPATIONAL TERM FOR SAI,ETA-DIRECTION
C*
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=80)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
> ,BIOT,TW1
COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
> ,IWBC,IFLOW
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))

```

```

C*****

```

```

DIMENSION ADD(4)
C ** SAI-DIRECTION
ENTRY ADDX
COEF=0.125DO*OMEGAX
DO 70 J=1,JL
DO 70 I=1,IL
IF(I.EQ.1) GO TO 10
IF(I.EQ.2) GO TO 20
IF(I.EQ.IL1) GO TO 30
IF(I.EQ.IL) GO TO 40
DO 5 K=1,4
5 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
> +6.*Q(I,J,K)-4.*Q(I-1,J,K)
> +Q(I-2,J,K))
GO TO 50
10 DO 15 K=1,4
QM=2.*Q(1,J,K)-Q(2,J,K)
QMM=2.*QM-Q(1,J,K)
15 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
> +6.*Q(I,J,K)-4.*QM+QMM)
GO TO 50
20 DO 25 K=1,4
QMM=2.*Q(1,J,K)-Q(2,J,K)
25 ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)

```

```

>      +6.*Q(I,J,K)-4.*Q(I-1,J,K)
>      +QMM)
GO TO 50
30 DO 35 K=1,4
   QPP=2.*Q(I+1,J,K)-Q(I,J,K)
35 ADD(K)=COEF*(QPP-4.*Q(I+1,J,K)+6.*Q(I,J,K)
>      -4.*Q(I-1,J,K)+Q(I-2,J,K)
>      )
GO TO 50
40 DO 45 K=1,4
   QP=2.*Q(I,J,K)-Q(I-1,J,K)
   QPP=2.*QP-Q(I,J,K)
45 ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
>      Q(I-1,J,K)+Q(I-2,J,K))
50 CONTINUE
DO 60 K=1,4
60 DQ(I,J,K)=DQ(I,J,K)-ADD(K)/RJ(I,J)*Y(I,J)
70 CONTINUE
RETURN

C **
C ADD ETA-DIRECTON 4TH ORDER ARTLEFLCLAL VLSCOSLTY
C **
ENTRY ADDY(II)
I=II
COEF=0.125DO*OMEGAY
DO 170 J=1,JL
IF(J.EQ.1) GO TO 110
IF(J.EQ.2) GO TO 120
IF(J.EQ.JL1) GO TO 130
IF(J.EQ.JL) GO TO 140
DO 95 K=1,4
95 ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
>      +6.*Q(I,J,K)-4.*Q(I,J-1,K)
>      +Q(I,J-2,K))
GO TO 150
110 DO 115 K=1,4
   QM=2.*Q(I,1,K)-Q(I,2,K)
   QMM=2.*QM-Q(I,1,K)
115 ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
>      +6.*Q(I,J,K)-4.*QM+QMM)
GO TO 150
120 DO 125 K=1,4
   QMM=2.*Q(I,1,K)-Q(I,2,K)
125 ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
>      +6.*Q(I,J,K)-4.*Q(I,J-1,K)
>      +QMM)
GO TO 150
130 DO 135 K=1,4
   QPP=2.*Q(I,J+1,K)-Q(I,J,K)
135 ADD(K)=COEF*(QPP-4.*Q(I,J+1,K)+6.*Q(I,J,K)
>      -4.*Q(I,J-1,K)+Q(I,J-2,K)
>      )
GO TO 150
140 DO 145 K=1,4
   QP=2.*Q(I,J,K)-Q(I,J-1,K)

```

```

      QPP=2.*QP-Q(I,J,K)
145  ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
      > Q(I,J-1,K)+Q(I,J-2,K))
150  CONTINUE
      DO 160 K=1,4
160  DQ(I,J,K)=DQ(I,J,K)-ADD(K)/RJ(I,J)*Y(I,J)
170  CONTINUE
      RETURN
      END

```

```

C
C ** SUBROUTINE FOR CENTER LINE BOUNDARY CONDITIONS
      SUBROUTINE BC

```

```

C-----
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
      > P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
      > ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
      > ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
      > CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
      > ,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
      > ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
      > (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))

```

C\*\*\*\*\*

```

      DATA SCONST/196./
      ENTRY CLBC(II)
      I=II

```

```

C * THE QUANTITIES EXTRAPOLATED ARE U,P,T AND LET V=0
C

```

```

      SY=SAIY(I,1)
      EY=ETAY(I,1)
      DENOM=SY-1.5*EY
      IF(I.NE.2.AND.I.LT.IL1)DENOM=DENOM+0.5*NORD*SY
      IF(I.EQ.1)THEN
        UIM1=0.
        PIM1=0.
        RIM1=1.0
      ELSE
        UIM1=U(I-1,1)
        PIM1=P(I-1,1)
        RIM1=RHO(I-1,1)
      END IF
      V(I,1)=0.
      U(I,1)=(SY*UIM1-0.5*EY*(4.*U(I,2)-U(I,3)))/DENOM
      IF(I.NE.2.AND.I.LT.IL1) U(I,1)=U(I,1)+NORD*SY*(U(I-1,1)-
      * 0.5*U(I-2,1))/DENOM
      UN(I,1)=SAIX(I,1)*U(I,1)
      VN(I,1)=ETAX(I,1)*U(I,1)
      P(I,1)=(SY*PIM1-0.5*EY*(4.*P(I,2)-P(I,3)))/DENOM

```

```

IF(I.NE.2.AND.I.LT.IL1) P(I,1)=P(I,1)+NORD*SY*(P(I-1,1)-
* 0.5*P(I-2,1))/DENOM
RIV=1./RGAS
TIM1=PIM1/RIM1*RIV
T2=P(I,2)/RHO(I,2)*RIV
T3=P(I,3)/RHO(I,3)*RIV
T1=(SY*TIM1-0.5*EY*(4.*T2-T3))/DENOM
IF(I.NE.2.AND.I.LT.IL1)THEN
TIM2=P(I-2,1)/RHO(I-2,1)*RIV
T1=T1+NORD*SY*(TIM1-0.5*TIM2)/DENOM
ENDIF
CALL CPGAM(CP(I,1),CV(I,1),GAMMA(I,1),GM1(I,1),RGAS,I,1,
> RHO(I,1),RHOI(I,1),RHOV(I,1),E(I,1),T1)
RHO(I,1)=P(I,1)/T1*RIV
RHOI(I,1)=RHO(I,1)*U(I,1)
RHOV(I,1)=RHO(I,1)*V(I,1)
E(I,1)=P(I,1)/GM1(I,1)+0.5*RHO(I,1)*(U(I,1)**2+V(I,1)**2)
RETURN

```

C\*

```

ENTRY WALLBC(II)
I=II
J=JL
CC1=ETAX(I,J)*SAIX(I,J)+ETAY(I,J)*SAIY(I,J)
CC2=ETAX(I,J)**2+ETAY(I,J)**2
IF(I.NE.IL)THEN
AM=-0.5*CC1
BM=1.5*CC2
CM=0.5*CC1
DM=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
ELSE
AM=-CC1
BM=CC1+1.5*CC2
CM=0.
DM=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
END IF
IP1=I+1
IF(I.EQ.IL)IP1=IL
PSOL=(DM-AM*P(I-1,J)-CM*P(IP1,J))/BM
IF(I.EQ.IL.AND.PB.NE.O.DO)PSOL=PB
RIV=1./RGAS
IF(IWALL.EQ.O)THEN
T1=P(I,J-1)*RIV/RHO(I,J-1)
T2=P(I,J-2)*RIV/RHO(I,J-2)
DM=CC2*(2.*T1-0.5*T2)
TIM1=P(I-1,J)*RIV/RHO(I-1,J)
TIP1=P(IP1,J)*RIV/RHO(IP1,J)
TSOL=(DM-AM*TIM1-CM*TIP1)/BM
ELSE
ENDIF
IF(IWALL.EQ.O)THEN
TT=TSOL
ELSE
TT=TWALL
ENDIF
PP=PSOL

```

```

U(I,JL)=0.
V(I,JL)=0.
RHO(I,JL)=0.
RHOV(I,JL)=0.
RHO=PP*RIV/TT
RHO(I,JL)=RHO
CALL CPGAM(CP(I,JL),CV(I,JL),GAMMA(I,JL),GM1(I,JL),RGAS,I,JL,
> RHO(I,JL),RHO(I,JL),RHOV(I,JL),E(I,JL),TT)
E(I,JL)=PP/GM1(I,JL)
P(I,JL)=PP
UN(I,JL)=0.
VN(I,JL)=0.
RETURN

```

```

C*
C* LAMINAR VISCOSITY CALCULATION
C*

```

```

C ENTRY MULAM(II)
C I=II
C* USE SUTHERLAND LAW
C DO 60 J=1,JL
C TOS=TREF+SCONST
C TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
C TTS=TT+SCONST
C ZMU(I,J)=ZMUO*TOS/TTS*(TT/TREF)**1.5
C ZMU(I,J)=ZMUO
C ZMU(I,J)=ZMUO*(TT/TREF)**0.67
C 60 CONTINUE
C RETURN
C END

```

```

C*****
SUBROUTINE MULAM(NN)

```

```

C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=80)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,MEGAY,CFL,THETA,PO,TO,
> CFL1,FRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
> ,BIOT,TW1
COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
> ,IWBC,IFLOW
DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))

```

```

C*****
B1=4.3222557667160623D-06
B2=3.8885996244952953D-08
B3=-3.7263546610032919D-12
C DO 50 NN=1,IL
DO 50 MM=1,JL
TT=(E(NN,MM)/RHO(NN,MM)-0.5*(U(NN,MM)**2+V(NN,MM)**2))/CV(NN,MM)

```

```

      ZMU(NN,MM)=B1+B2*TT+B3*TT*TT
50    CONTINUE
      RETURN
      END

```

```

C
C    BOLDWIN & LOMAX TUPBULENCE MODEL
C

```

```

      SUBROUTINE MUTUR(II)
C*****
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
>      P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
>      ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
>      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
>CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
>      ,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
>      ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
>      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
      DIMENSION YVERT(JZ),ZMUI(JZ)
      DATA AP,CCP,CKLEB,CWK,VKCON,XK/26., 1.6, .3, .25, .4, .0168/
      DATA ZMUI/JZ*0.0/
      I=II
      FYMAX = 0.0
      YMAX = 0.0
      UDIF=0.
      YVERT(JL) = 0.0
      TAUW = ZMU(I,JL)*DABS(ETAY(I,JL)*(U(I,JL)-U(I,JL-1)))-
>      ETAX(I,JL)*(V(I,JL)-V(I,JL-1)))
      CYP = DSQRT(RHO(I,JL)*TAUW)/ZMU(I,JL)
C
      DO 10 KK = 2,JL1
      K = JL+1-KK
      YVER = YVERT(K+1) + 1.0/DSQRT(ETAX(I,K)**2 + ETAY(I,K)**2)
      OMG = DABS( ETAY(I,K)*(U(I,K+1)-U(I,K-1))*0.5
>      +SAIY(I,K)*(U(I,K) -U(I-1,K))
>      -ETAX(I,K)*(V(I,K+1)-V(I,K-1))*0.5
>      -SAIX(I,K)*(V(I,K) -V(I-1,K)) )
      YPLUS = CYP*YVER
      TURLN = VKCON*YVER*(1.0DO -DEXP(-YPLUS/AP))
      ZMUI(K) = RHO(I,K)*OMG*TURLN**2
      FY = TURLN/VKCON*OMG
      UTOTAL= DSQRT(U(I,K)**2+V(I,K)**2)
      IF(UTOTAL.GE.UDIF) UDIF=UTOTAL
      IF(FY.LT.FYMAX) GO TO 10
      FYMAX = FY
      YMAX = YVER
10    YVERT(K) = YVER

```

```

C
  VXDIF = UDIF
  FWAKE1=YMAX*FYMAX
  FWAKE2=CKW*YMAX*VXDIF**2/FYMAX
  FWAKE =DMIN1(FWAKE1,FWAKE2)
C
  DO 20 KK = 2, JL1
  K = JL+1-KK
  FKLEB = (CKLEB*YVERT(K)/YMAX)**6
  FKLEB = 1./(1.0 + 5.5*FKLEB)
  ZMUO = XK*CCP*RHO(I,K)*FWAKE*FKLEB
  IF(ZMUI(K).GT.ZMUO) THEN
    ZMUTUR = ZMUO
  ELSE
    ZMUTUR = ZMUI(K)
  END IF
  ZMUT(K)= ZMUTUR
  ZMU(I,K) = ZMU(I,K) + ZMUTUR
C
  WRITE(77,119)K,Y(I,K),YVERT(K),U(I,K),ZMUI(K),ZMUO,ZMU(I,K)
C119  FORMAT(2X,I3,6(2X,D13.6))
20  CONTINUE
C
  ZMUT(1)=0.
  ZMUT(JL)=0.
  RETURN
  END
C* SUORCE TERM JACOBIAN MATRIX
  SUBROUTINE DHDQ(D,I,J)
C-----
  IMPLICIT REAL*8(A-H,O-Z)
  PARAMETER (IZ=150,JZ=80)
  COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
  COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
  COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
> ,BIOT,TW1
  COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
  COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
> ,IWBC,IFLOW
  DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
  EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
  DIMENSION D(4,4)
  CALL SZERO(4,D)
  IF(IVISC.EQ.0)THEN
    R2MY=0.
  ELSE
    R2MY=4./3.*ZMU(I,J)/(Y(I,J)*Y(I,J)*RHO(I,J))
  END IF
  D(3,1)=.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/Y(I,J)+IVISC*V(I,J)*R2MY
  D(3,2)=-GM1(I,J)*U(I,J)/Y(I,J)

```

```

D(3,3)=-GM1(I,J)*V(I,J)/Y(I,J)-IVISC*R2MY
D(3,4)=GM1(I,J)/Y(I,J)
RETURN
END
SUBROUTINE JACCAL

```

```

C*
C* SUBROUTINE FOR JACOBIAN METRIX
C* IF IA=1, ACAP MATRIX
C* IF IA=2, BCAP MATRIX
C*
C*****
  IMPLICIT REAL*8(A-H,O-Z)
  PARAMETER (IZ=150,JZ=80)
  COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
>    P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
  COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
>    ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
>    ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
  COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
>CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
>    ,BIOT,TW1
  COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
  COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
>    ,IWBC,IFLOW
  DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
  EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
>    (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
  DIMENSION A(4,4),B(4,4),C(4,4),TEMP(4,4),BB(4,4),DIAG(4)
C*****
  ENTRY JACOB(IA,A,I,J)
  IF(IA.EQ.2)GO TO 10
  CX=SAIX(I,J)
  CY=SAIY(I,J)
  CONTRA=UN(I,J)
  GO TO 20
10 CX=ETAX(I,J)
  CY=ETAY(I,J)
  CONTRA=VN(I,J)
20 CONTINUE
  PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
  A(1,1)=0.0D0
  A(1,2)=CX
  A(1,3)=CY
  A(1,4)=0.0D0
  A(2,1)=CX*PHI2-U(I,J)*CONTRA
  A(2,2)=CONTRA-(GAMMA(I,J)-2.)*CX*U(I,J)
  A(2,3)=CY*U(I,J)-GM1(I,J)*CX*V(I,J)
  A(2,4)=GM1(I,J)*CX
  A(3,1)=CY*PHI2-V(I,J)*CONTRA
  A(3,2)=CX*V(I,J)-GM1(I,J)*CY*U(I,J)
  A(3,3)=CONTRA-CY*V(I,J)*(GAMMA(I,J)-2.)
  A(3,4)=GM1(I,J)*CY
  A(4,1)=CONTRA*(2.*PHI2-GAMMA(I,J)*E(I,J)/RHO(I,J))
  A(4,2)=CX*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA

```

```

> *U(I,J)
  A(4,3)=CY*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
> *V(I,J)
  A(4,4)=GAMMA(I,J)*CONTRA
  RETURN
C*
C* SPLITTED JACOBIAN MATRIX IN XI-DIRECTION
C*
  ENTRY AJACOB(IA,A,I,J)
C*
C* FOR THE FIRST ITERATION TURN OFF A MINUS
C*
  IF(NADV.EQ.1.AND.IA.EQ.2) THEN
    CALL SZERO(4,A)
    RETURN
  ENDIF
C  WRITE(6,*) I,J,RHO(I,J)
  CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
  CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
  CXCO=CX*CO
  EIG1=UN(I,J)
  EIG2=UN(I,J)
  EIG3=UN(I,J)+CXCO
  EIG4=UN(I,J)-CXCO
  IF(IA.EQ.1)THEN
    DIAG(1)=0.5*(EIG1+DABS(EIG1))
    DIAG(2)=DIAG(1)
    DIAG(3)=0.5*(EIG3+DABS(EIG3))
    DIAG(4)=0.5*(EIG4+DABS(EIG4))
  ELSE
    DIAG(1)=0.5*(EIG1-DABS(EIG1))
    DIAG(2)=DIAG(1)
    DIAG(3)=0.5*(EIG3-DABS(EIG3))
    DIAG(4)=0.5*(EIG4-DABS(EIG4))
  ENDIF
  CALL EIGEN(1,BB,I,J)
  DO 40 II=1,4
  DO 40 JJ=1,4
    TEMP(II,JJ)=DIAG(II)*BB(II,JJ)
40  CONTINUE
  CALL EIGAR(BB,I,J)
  CALL MMM(4,BB,TEMP,A)
  RETURN
C*
C* TRUE JACOBIAN FOR DE+/-/DQ
C*
  ENTRY TRUEJ(IA,A,I,J)
C  CHECK THE FOURTH EIGEN VALUE
  CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
  CX=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
  CXCO=CX*CO
  EIG4=UN(I,J)-CXCO
  IF(UN(I,J).LT.0.DO)GOTO 60
  IF(EIG4.LT.0.DO)GOTO 50
C

```

```

IF(IA.EQ.1)THEN
CX=SAIX(I,J)
CY=SAIY(I,J)
CONTRA=UN(I,J)
PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
A(1,1)=0.0DO
A(1,2)=CX
A(1,3)=CY
A(1,4)=0.DO
A(2,1)=CX*PHI2-U(I,J)*CONTRA
A(2,2)=CONTRA-(GAMMA(I,J)-2.)*CX*U(I,J)
A(2,3)=CY*U(I,J)-GM1(I,J)*CX*V(I,J)
A(2,4)=GM1(I,J)*CX
A(3,1)=CY*PHI2-V(I,J)*CONTRA
A(3,2)=CX*V(I,J)-GM1(I,J)*CY*U(I,J)
A(3,3)=CONTRA-CY*V(I,J)*(GAMMA(I,J)-2.)
A(3,4)=GM1(I,J)*CY
A(4,1)=CONTRA*(2.*PHI2-GAMMA(I,J)*E(I,J)/RHO(I,J))
A(4,2)=CX*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
> *U(I,J)
A(4,3)=CY*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
> *V(I,J)
A(4,4)=GAMMA(I,J)*CONTRA
ELSE
CALL SZERO(4,A)
ENDIF
RETURN

```

C

```

50 CONTINUE
IF(NADV.EQ.1.AND. IA.EQ.2)THEN
CALL SZERO(4,A)
RETURN
ELSE
PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
ERC=E(I,J)/RHO(I,J)/CO
ECR=E(I,J)*CO/RHO(I,J)
R1=SAIX(I,J)
R2=SAIY(I,J)
R1T=R1/CX
R2T=R2/CX
G2M2=(2.*GAMMA(I,J)-1.)*.5/GAMMA(I,J)
G23G=(-GAMMA(I,J)**2+3.*GAMMA(I,J)-1.)*.5/GAMMA(I,J)
G34G=(3.*GAMMA(I,J)-2.)*.25/GAMMA(I,J)
GM12=GM1(I,J)**2*.5/GAMMA(I,J)
CGEC=CO*.5/GAMMA(I,J)-0.25*GM1(I,J)*ERC
RKUU=CX*U(I,J)+R1T*UN(I,J)
RKVV=CX*V(I,J)+R2T*UN(I,J)
U2V2=PHI2/GM1(I,J)*2.
RKU2=.25*GM1(I,J)*(CX*.5*U2V2+UN(I,J)**2/CX)

```

C

```

IF(IA.EQ.1)THEN
A(1,1)=.25*GM1(I,J)*CX*ERC
A(1,2)=G2M2*R1-.25*GM1(I,J)*CX*U(I,J)/CO
A(1,3)=G2M2*R2-.25*GM1(I,J)*CX*V(I,J)/CO
A(1,4)=.25*GM1(I,J)*CX/CO

```

```

A(2,1)=-G2M2*U(I,J)*UN(I,J)+.5*R1*PHI2-CGEC*RKUU
A(2,2)=G23G*R1*U(I,J)+G2M2*UN(I,J)+.5*(CX+R1*R1T)/GAMMA(I,J)*CO-
> 0.25*GM1(I,J)*U(I,J)/CO*RKUU
A(2,3)=G2M2*R2*U(I,J)-.5*GM1(I,J)*R1*V(I,J)+.5*R1T*R2
> /GAMMA(I,J)*CO-0.25*GM1(I,J)*V(I,J)/CO*RKUU
A(2,4)=.5*GM1(I,J)*R1+.25*GM1(I,J)*RKUU/CO
A(3,1)=-G2M2*V(I,J)*UN(I,J)+0.5*R2*PHI2-CGEC*RKVU
A(3,2)=G2M2*R1*V(I,J)-.5*GM1(I,J)*R2*U(I,J)+0.5*R1*R2T
> /GAMMA(I,J)*CO-0.25*GM1(I,J)*U(I,J)/CO*RKVU
A(3,3)=G2M2*UN(I,J)+G23G*R2*V(I,J)+(CX+R2T*R2)*.5/GAMMA(I,J)*CO-
> 0.25*GM1(I,J)*V(I,J)/CO*RKVU
A(3,4)=.5*GM1(I,J)*R2+.25*GM1(I,J)*RKVU/CO
A(4,1)=GM12*UN(I,J)*U2V2-.5*GAMMA(I,J)*UN(I,J)*E(I,J)
> /RHO(I,J)+CX/GAMMA(I,J)*PHI2*CO-UN(I,J)**2*CO/GAMMA(I,J)/CX
> -.25*CX*ECR+RKU2*ERC
A(4,2)=-GM12*U(I,J)*UN(I,J)+.5*R1*GAMMA(I,J)*E(I,J)/RHO(I,J)
> -GM1(I,J)*.5/GAMMA(I,J)*R1*PHI2-G34G*CX*U(I,J)*CO+R1T
> /GAMMA(I,J)*UN(I,J)*CO-RKU2*U(I,J)/CO
A(4,3)=-GM12*V(I,J)*UN(I,J)+.5*R2*GAMMA(I,J)*E(I,J)/RHO(I,J)
> -GM1(I,J)*.5/GAMMA(I,J)*R2*PHI2-G34G*CX*V(I,J)*CO+R2T
> /GAMMA(I,J)*UN(I,J)*CO-RKU2*V(I,J)/CO
A(4,4)=.5*GAMMA(I,J)*UN(I,J)+.75*CX*CO+RKU2/CO
ELSE
G11G=(1.+GAMMA(I,J)-GAMMA(I,J)**2)*.5/GAMMA(I,J)
G22M=(GAMMA(I,J)**2-1.)*.5/GAMMA(I,J)
A(1,1)=-.25*GM1(I,J)*CX*ERC
A(1,2)=.5/GAMMA(I,J)*R1+.25*GM1(I,J)*CX*U(I,J)/CO
A(1,3)=.5/GAMMA(I,J)*R2+.25*GM1(I,J)*CX*V(I,J)/CO
A(1,4)=-.25*GM1(I,J)*CX/CO
A(2,1)=-.5/GAMMA(I,J)*U(I,J)*UN(I,J)+.5*R1*PHI2+CGEC*RKUU
A(2,2)=G11G*R1*U(I,J)+.5/GAMMA(I,J)*UN(I,J)-.5*(CX+R1*R1T)
> /GAMMA(I,J)*CO+0.25*GM1(I,J)*U(I,J)/CO*RKUU
A(2,3)=.5/GAMMA(I,J)*R2*U(I,J)-.5*GM1(I,J)*R1*V(I,J)-.5*R1T*R2
> /GAMMA(I,J)*CO+0.25*GM1(I,J)*V(I,J)/CO*RKUU
A(2,4)=.5*GM1(I,J)*R1-.25*GM1(I,J)*RKUU/CO
A(3,1)=-.5/GAMMA(I,J)*V(I,J)*UN(I,J)+0.5*R2*PHI2+CGEC*RKVU
A(3,2)=.5/GAMMA(I,J)*R1*V(I,J)-.5*GM1(I,J)*R2*U(I,J)-0.5*R1*R2T
> /GAMMA(I,J)*CO+0.25*GM1(I,J)*U(I,J)/CO*RKVU
A(3,3)=.5/GAMMA(I,J)*UN(I,J)+G11G*R2*V(I,J)-(CX+R2T*R2)*.5
> /GAMMA(I,J)*CO+0.25*GM1(I,J)*V(I,J)/CO*RKVU
A(3,4)=.5*GM1(I,J)*R2-.25*GM1(I,J)*RKVU/CO
A(4,1)=G22M*UN(I,J)*U2V2-.5*GAMMA(I,J)*UN(I,J)*E(I,J)/RHO(I,J)-
> CX/GAMMA(I,J)*PHI2*CO+UN(I,J)**2*CO/GAMMA(I,J)/CX
> +.25*CX*ECR-RKU2*ERC
A(4,2)=-G22M*U(I,J)*UN(I,J)+.5*R1*GAMMA(I,J)*E(I,J)/RHO(I,J)
> -(GAMMA(I,J)+1.)*.5/GAMMA(I,J)*R1*PHI2+G34G*CX*U(I,J)
> *CO-R1T/GAMMA(I,J)*UN(I,J)*CO+RKU2*U(I,J)/CO
A(4,3)=-G22M*V(I,J)*UN(I,J)+.5*R2*GAMMA(I,J)*E(I,J)/RHO(I,J)
> -(GAMMA(I,J)+1.)*.5/GAMMA(I,J)*R2*PHI2+G34G*CX*V(I,J)
> *CO-R2T/GAMMA(I,J)*UN(I,J)*CO+RKU2*V(I,J)/CO
A(4,4)=.5*GAMMA(I,J)*UN(I,J)-.75*CX*CO-RKU2/CO
ENDIF
ENDIF
RETURN

```

60 CONTINUE

C\*

C\* REVERSE FLOW REGION

C\*

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      IF(NADV.EQ.1) THEN
        WRITE(6,1010)
1010  FORMAT(' *** REVERSE FLOW FOR PNS MARCHING ***')
        RETURN
      ENDIF
      EIG3=UN(I,J)+CXCO
      IF(EIG3.LT.0.DO) THEN
        IF(IA.EQ.1) THEN
          CALL SZERO(4,A)
          RETURN
        ELSE
          CX=SAIX(I,J)
          CY=SAIY(I,J)
          CONTRA=UN(I,J)
          PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
          A(1,1)=0.0DO
          A(1,2)=CX
          A(1,3)=CY
          A(1,4)=0.DO
          A(2,1)=CX*PHI2-U(I,J)*CONTRA
          A(2,2)=CONTRA-(GAMMA(I,J)-2.)*CX*U(I,J)
          A(2,3)=CY*U(I,J)-GM1(I,J)*CX*V(I,J)
          A(2,4)=GM1(I,J)*CX
          A(3,1)=CY*PHI2-V(I,J)*CONTRA
          A(3,2)=CX*V(I,J)-GM1(I,J)*CY*U(I,J)
          A(3,3)=CONTRA-CY*V(I,J)*(GAMMA(I,J)-2.)
          A(3,4)=GM1(I,J)*CY
          A(4,1)=CONTRA*(2.*PHI2-GAMMA(I,J)*E(I,J)/RHO(I,J))
          A(4,2)=CX*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
> *U(I,J)
          A(4,3)=CY*(GAMMA(I,J)*E(I,J)/RHO(I,J)-PHI2)-GM1(I,J)*CONTRA
> *V(I,J)
          A(4,4)=GAMMA(I,J)*CONTRA
          RETURN
        ENDIF
      ENDIF

```

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      PHI2=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)
      ERC=E(I,J)/RHO(I,J)/CO
      ECR=E(I,J)*CO/RHO(I,J)
      R1=SAIX(I,J)
      R2=SAIY(I,J)
      R1T=R1/CX
      R2T=R2/CX
      G2M2=(2.*GAMMA(I,J)-1.)*.5/GAMMA(I,J)
      G23G=(-GAMMA(I,J)**2+3.*GAMMA(I,J)-1.)*.5/GAMMA(I,J)
      G34G=(3.*GAMMA(I,J)-2.)*.25/GAMMA(I,J)
      GM12=GM1(I,J)**2*.5/GAMMA(I,J)
      CGEC=CO*.5/GAMMA(I,J)-0.25*GM1(I,J)*ERC
      RKUU=CX*U(I,J)+R1T*UN(I,J)
      RUVU=CX*V(I,J)+R2T*UN(I,J)
      U2V2=PHI2/GM1(I,J)*2.

```

```

RKU2=.25*GM1(I,J)*(CX*.5*U2V2+UN(I,J)**2/CX)
G11G=(1.+GAMMA(I,J)-GAMMA(I,J)**2)*.5/GAMMA(I,J)
G22M=(GAMMA(I,J)**2-1.)*.5/GAMMA(I,J)

```

C

```

IF(IA.EQ.1)THEN
  A(1,1)=.25*GM1(I,J)*CX*ERC
  A(1,2)=0.5/GAMMA(I,J)*R1-.25*GM1(I,J)*CX*U(I,J)/CO
  A(1,3)=0.5/GAMMA(I,J)*R2-.25*GM1(I,J)*CX*V(I,J)/CO
  A(1,4)=.25*GM1(I,J)*CX/CO
  A(2,1)=-0.5/GAMMA(I,J)*U(I,J)*UN(I,J)+.5*R1*PHI2-CGEC*RKUU
  A(2,2)=G11G*R1*U(I,J)+0.5/GAMMA(I,J)*UN(I,J)+.5*(CX+R1*R1T)
  > /GAMMA(I,J)*CO-0.25*GM1(I,J)*U(I,J)/CO*RKUU
  A(2,3)=0.5/GAMMA(I,J)*R2*U(I,J)-.5*GM1(I,J)*R1*V(I,J)+.5*R1T*R2
  > /GAMMA(I,J)*CO-0.25*GM1(I,J)*V(I,J)/CO*RKUU
  A(2,4)=.5*GM1(I,J)*R1+.25*GM1(I,J)*RKUU/CO
  A(3,1)=-0.5/GAMMA(I,J)*V(I,J)*UN(I,J)+0.5*R2*PHI2-CGEC*RKVV
  A(3,2)=0.5/GAMMA(I,J)*R1*V(I,J)-.5*GM1(I,J)*R2*U(I,J)+0.5*R1
  > *R2T/GAMMA(I,J)*CO-0.25*GM1(I,J)*U(I,J)/CO*RKVV
  A(3,3)=0.5/GAMMA(I,J)*UN(I,J)+G11G*R2*V(I,J)+(CX+R2T*R2)*.5
  > /GAMMA(I,J)*CO-0.25*GM1(I,J)*V(I,J)/CO*RKVV
  A(3,4)=.5*GM1(I,J)*R2+.25*GM1(I,J)*RKVV/CO
  A(4,1)=G22M*UN(I,J)*U2V2-.5*GAMMA(I,J)*UN(I,J)*E(I,J)/RHO(I,J)+
  > CX/GAMMA(I,J)*PHI2*CO-UN(I,J)**2*CO/GAMMA(I,J)/CX-.25
  > *CX*ECR+RKU2*ERC
  A(4,2)=-G22M*U(I,J)*UN(I,J)+.5*R1*GAMMA(I,J)*E(I,J)/RHO(I,J)
  > -(GAMMA(I,J)+1.)*.5/GAMMA(I,J)*R1*PHI2-G34G*CX*U(I,J)
  > *CO+R1T/GAMMA(I,J)*UN(I,J)*CO-RKU2*U(I,J)/CO
  A(4,3)=-G22M*V(I,J)*UN(I,J)+.5*R2*GAMMA(I,J)*E(I,J)/RHO(I,J)
  > -(GAMMA(I,J)+1.)*.5/GAMMA(I,J)*R2*PHI2-G34G*CX*V(I,J)
  > *CO+R2T/GAMMA(I,J)*UN(I,J)*CO-RKU2*V(I,J)/CO
  A(4,4)=.5*GAMMA(I,J)*UN(I,J)+.75*CX*CO+RKU2/CO
ELSE
  A(1,1)=-.25*GM1(I,J)*CX*ERC
  A(1,2)=G2M2*R1+.25*GM1(I,J)*CX*U(I,J)/CO
  A(1,3)=G2M2*R2+.25*GM1(I,J)*CX*V(I,J)/CO
  A(1,4)=-.25*GM1(I,J)*CX/CO
  A(2,1)=-G2M2*U(I,J)*UN(I,J)+.5*R1*PHI2+CGEC*RKUU
  A(2,2)=G23G*R1*U(I,J)+G2M2*UN(I,J)-.5*(CX+R1*R1T)/GAMMA(I,J)
  > *CO+0.25*GM1(I,J)*U(I,J)/CO*RKUU
  A(2,3)=G2M2*R2*U(I,J)-.5*GM1(I,J)*R1*V(I,J)-.5*R1T*R2
  > /GAMMA(I,J)*CO+0.25*GM1(I,J)*V(I,J)/CO*RKUU
  A(2,4)=.5*GM1(I,J)*R1-.25*GM1(I,J)*RKUU/CO
  A(3,1)=-G2M2*V(I,J)*UN(I,J)+0.5*R2*PHI2+CGEC*RKVV
  A(3,2)=G2M2*R1*V(I,J)-.5*GM1(I,J)*R2*U(I,J)-0.5*R1*R2T
  > /GAMMA(I,J)*CO+0.25*GM1(I,J)*U(I,J)/CO*RKVV
  A(3,3)=G2M2*UN(I,J)+G23G*R2*V(I,J)-(CX+R2T*R2)*.5/GAMMA(I,J)*CO+
  > 0.25*GM1(I,J)*V(I,J)/CO*RKVV
  A(3,4)=.5*GM1(I,J)*R2-.25*GM1(I,J)*RKVV/CO
  A(4,1)=GM12*UN(I,J)*U2V2-.5*GAMMA(I,J)*UN(I,J)*E(I,J)
  > /RHO(I,J)-CX/GAMMA(I,J)*PHI2*CO+UN(I,J)**2*CO/GAMMA(I,J)/CX+.25
  > *CX*ECR-RKU2*ERC
  A(4,2)=-GM12*U(I,J)*UN(I,J)+.5*R1*GAMMA(I,J)*E(I,J)/RHO(I,J)
  > -GM1(I,J)*.5/GAMMA(I,J)*R1*PHI2+G34G*CX*U(I,J)*CO-R1T
  > /GAMMA(I,J)*UN(I,J)*CO+RKU2*U(I,J)/CO
  A(4,3)=-GM12*V(I,J)*UN(I,J)+.5*R2*GAMMA(I,J)*E(I,J)/RHO(I,J)

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```
> -GM1(I,J)*.5/GAMMA(I,J)*R2*PHI2+G34G*CX*V(I,J)*CO-R2T
> /GAMMA(I,J)*UN(I,J)*CO+RKU2*V(I,J)/CO
A(4,4)=.5*GAMMA(I,J)*UN(I,J)-.75*CX*CO-RKU2/CO
ENDIF
RETURN
```

C\*

C\* VISCOUS TERM JACOBIAN MATRIX

C\*

```
ENTRY VJACOB(A,B,C,I,J)
JP1=J+1
JM1=J-1
ZMUP=0.5*(ZMU(I,J)+ZMU(I,JP1))
ZMUM=0.5*(ZMU(I,J)+ZMU(I,JM1))
YYP =0.5*(Y(I,J)+Y(I,JP1))
YYM =0.5*(Y(I,J)+Y(I,JM1))
YJP =RJ(I,JP1)/Y(I,JP1)
IF(JM1.EQ.1)THEN
YJM=0.
ELSE
YJM =RJ(I,JM1)/Y(I,JM1)
ENDIF
IF(PRNT.EQ.0.DO)THEN
GAMP=0.5*(GAMMA(I,JP1)+GAMMA(I,J))
GAMM=0.5*(GAMMA(I,JM1)+GAMMA(I,J))
GKCPP=ZMUP*GAMP/PRN
GKCPM=ZMUM*GAMM/PRN
ELSE
ZMUTP = 0.5*(ZMUT(JP1)+ZMUT(J))
ZMUTM = 0.5*(ZMUT(JM1)+ZMUT(J))
ZMULP = ZMUP - ZMUTP
ZMULM = ZMUM - ZMUTM
GAMP=0.5*(GAMMA(I,JP1)+GAMMA(I,J))
GAMM=0.5*(GAMMA(I,JM1)+GAMMA(I,J))
GKCPP = GAMP*(ZMULP/PRN+ZMUTP/PRNT)
GKCPM = GAMM*(ZMULM/PRN+ZMUTM/PRNT)
ENDIF
EXJ=ETAX(I,J)/RJ(I,J)
EYJ=ETAY(I,J)/RJ(I,J)
ZMUU=ZMU(I,J)
OR=1./RHO(I,J)
ORP=1./RHO(I,JP1)
ORM=1./RHO(I,JM1)
ZMURP=ZMU(I,JP1)*ORP
ZMURM=ZMU(I,JM1)*ORM
UR =U(I,J)*OR
URP=U(I,JP1)*ORP
URM=U(I,JM1)*ORM
VR =V(I,J)*OR
VRM=V(I,JM1)*ORM
VRP=V(I,JP1)*ORP
UMRP=URP*ZMU(I,JP1)
UMRM=URM*ZMU(I,JM1)
VMRP=VRP*ZMU(I,JP1)
VMRM=VRM*ZMU(I,JM1)
U2R =UR*U(I,J)
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```

U2RP=URP*U(I,JP1)
U2RM=URM*U(I,JM1)
V2R =VR*V(I,J)
V2RP=VRP*V(I,JP1)
V2RM=VRM*V(I,JM1)
UVR =UR*V(I,J)
UVRP=URP*V(I,JP1)
UVRM=URM*V(I,JM1)
ER2 =E(I,J)*OR**2
ER2P=E(I,JP1)*ORP**2
ER2M=E(I,JM1)*ORM**2
ZRYJP=ZMURP*YJP
ZRYJM=ZMURM*YJM
ORYJP=ORP*YJP
ORYJM=ORM*YJM
VMRP=-ZMURP*V(I,JP1)*YJP
VMRM=-ZMURM*V(I,JM1)*YJM
URYJP=-URP*YJP
URYJM=-URM*YJM
VYJP=2.*ZMU(I,JP1)*VRP*YJP
VYJM=2.*ZMU(I,JM1)*VRM*YJM
V2YJP=-V2RP*2.*ZMU(I,JP1)*YJP
V2YJM=-V2RM*2.*ZMU(I,JM1)*YJM
UVYJP=-2.*ZMU(I,JP1)*UVRP*YJP
UVYJM=-2.*ZMU(I,JM1)*UVRM*YJM
VYJP2=VYJP*0.5
VYJM2=0.5*VYJM
UYJP=ZMU(I,JP1)*URP*YJP
UYJM=ZMU(I,JM1)*URM*YJM
AAP1= ZMUP*A1(I,J)*YYP
AAP2= ZMUP*A2(I,J)*YYP
AAP3= ZMUP*A3(I,J)*YYP
AAF4= GKCPP*A4(I,J)*YYP
AAM1= ZMUM*A1(I,JM1)*YYM
AAM2= ZMUM*A2(I,JM1)*YYM
AAM3 =ZMUM*A3(I,JM1)*YYM
AAM4 =GKCPM*A4(I,JM1)*YYM
IF(JM1.EQ.1)THEN
CALL SZERO(4,A)
ELSE
A(1,1) =0.
A(1,2) =0.
A(1,3) =0.
A(1,4) =0.
A21=(AAM1*URM+AAM2*VRM)*RJ(I,JM1)/Y(I,JM1)
A(2,1) =A21-1./3.*EXJ*VMRM
A(2,2) =-AAM1*ORM*RJ(I,JM1)/Y(I,JM1)
A(2,3) =-AAM2*ORM*RJ(I,JM1)/Y(I,JM1)-1./3.*EXJ*ZRYJM
A(2,4) =0.
A31=(AAM2*URM+AAM3*VRM)*RJ(I,JM1)/Y(I,JM1)
A(3,1) =A31+1./3.*ZMU(I,J)
* EXJ*URYJM
A(3,2) =-AAM2*ORM*RJ(I,JM1)/Y(I,JM1)+1./3.*ZMU(I,J)*EXJ*ORYJM
A(3,3) =-AAM3*ORM*RJ(I,JM1)/Y(I,JM1)
A(3,4) =0.

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A(4,1) =(-AAM4*(-ER2M+U2RM+V2RM)+AAM1*U2RM+AAM3*V2RM+
+      2.*AAM2*UVRM)*RJ(I,JM1)/Y(I,JM1)-
+      1./3.*EYJ*V2YJM-1./3.*EXJ*UVYJM
A(4,2) =AAM4*URM*RJ(I,JM1)/Y(I,JM1)-A21-1./3.*EXJ*VYJM2
A(4,3) =AAM4*VRM*RJ(I,JM1)/Y(I,JM1)-A31-1./3.*EYJ*VYJM-
*      1./3.*EXJ*UYJM
A(4,4) =-AAM4*ORM*RJ(I,JM1)/Y(I,JM1)
ENDIF
C(1,1) =0.
C(1,2) =0.
C(1,3) =0.
C(1,4) =0.
C21=(AAP1*URP+AAP2*VRP)*RJ(I,JP1)/Y(I,JP1)
C(2,1) =C21+1./3.*EXJ*VMRP
C(2,2) =-AAP1*ORP*RJ(I,JP1)/Y(I,JP1)
C(2,3) =-AAP2*ORP*RJ(I,JP1)/Y(I,JP1)+1./3.*EXJ*ZRYJP
C(2,4) =0.
C31=(AAP2*URP+AAP3*VRP)*RJ(I,JP1)/Y(I,JP1)
C(3,1) =C31-1./3.*ZMU(I,J)
*      *EXJ*URYJP
C(3,2) =-AAP2*ORP*RJ(I,JP1)/Y(I,JP1)-1./3.*ZMU(I,J)*EXJ*ORYJP
C(3,3) =-AAP3*ORP*RJ(I,JP1)/Y(I,JP1)
C(3,4) =0.
C(4,1) =(-AAP4*(-ER2P+U2RP+V2RP)+AAP1*U2RP+AAP3*V2RP+
+      2.*AAP2*UVRP)*RJ(I,JP1)/Y(I,JP1)+
+      1./3.*EYJ*V2YJP+1./3.*EXJ*UVYJP
C(4,2) =AAP4*URP*RJ(I,JP1)/Y(I,JP1)-C21+1./3.*EXJ*VYJP2
C(4,3) =AAP4*VRP*RJ(I,JP1)/Y(I,JP1)-C31+1./3.*EYJ*VYJP+
+      1./3.*EXJ*UYJP
C(4,4) =-AAP4*ORP*RJ(I,JP1)/Y(I,JP1)
AA1 =AAP1+AAM1
AA2 =AAP2+AAM2
AA3 =AAP3+AAM3
AA4 =AAP4+AAM4
B(1,1) =0.
B(1,2) =0.
B(1,3) =0.
B(1,4) =0.
B(2,1) =(-AA1*UR-AA2*VR)*RJ(I,J)/Y(I,J)
B(2,2) =AA1*OR*RJ(I,J)/Y(I,J)
B(2,3) =AA2*OR*RJ(I,J)/Y(I,J)
B(2,4) =0.
B(3,1) =(-AA2*UR-AA3*VR)*RJ(I,J)/Y(I,J)
B(3,2) =AA2*OR*RJ(I,J)/Y(I,J)
B(3,3) =AA3*OR*RJ(I,J)/Y(I,J)
B(3,4) =0.
B(4,1) =(AA4*(-ER2+U2R+V2R)-AA1*U2R-AA3*V2R-
*      2.*AA2*UVR)*RJ(I,J)/Y(I,J)
B(4,2) =-AA4*UR*RJ(I,J)/Y(I,J)-B(2,1)
B(4,3) =-AA4*VR*RJ(I,J)/Y(I,J)-B(3,1)
B(4,4) =AA4*OR*RJ(I,J)/Y(I,J)
RETURN
END

```

C-----  
SUBROUTINE EIGMTX

```

C*
C* SUBROUTINE FOR EIGENVECTOR MATRIX CALCULATION
C* IF IA=1 L FOR ACAP
C* IF IA=2 L FOR BCAP
C*
C*****
  IMPLICIT REAL*8(A-H,O-Z)
  PARAMETER (IZ=150,JZ=80)
  COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
  COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
  COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
> ,BIOT,TW1
  COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
  COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
> ,IWBC,IFLOW
  DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
  EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
  DIMENSION A(4,4)
C*****
  ENTRY EIGEN(IA,A,I,J)
  IF(IA.EQ.2)GO TO 10
  CX=SAIX(I,J)
  CY=SAIY(I,J)
  GO TO 20
10 CX=ETAX(I,J)
  CY=ETAY(I,J)
20 CONTINUE
  SQ2=DSQRT(2.D0)
  C=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
  C1=CX/DSQRT(CX**2+CY**2)
  C2=CY/DSQRT(CX**2+CY**2)
  A(1,1)=1.-0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/C**2
  A(1,2)=GM1(I,J)*U(I,J)/C**2
  A(1,3)=GM1(I,J)*V(I,J)/C**2
  A(1,4)=-GM1(I,J)/C**2
  A(2,1)=(-C2*U(I,J)+C1*V(I,J))/RHO(I,J)
  A(2,2)=C2/RHO(I,J)
  A(2,3)=-C1/RHO(I,J)
  A(2,4)=0.
  A(3,1)=- (C1*U(I,J)+C2*V(I,J))/SQ2/RHO(I,J)+
> 0.5/SQ2*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/RHO(I,J)/C
  A(3,2)=C1/SQ2/RHO(I,J)-GM1(I,J)/SQ2*U(I,J)/RHO(I,J)/C
  A(3,3)=C2/SQ2/RHO(I,J)-GM1(I,J)/SQ2*V(I,J)/RHO(I,J)/C
  A(3,4)=GM1(I,J)/SQ2/RHO(I,J)/C
  A(4,1)=(C1*U(I,J)+C2*V(I,J))/SQ2/RHO(I,J)+0.5/SQ2*GM1(I,J)*
> (U(I,J)**2+V(I,J)**2)/RHO(I,J)/C
  A(4,2)=-C1/SQ2/RHO(I,J)-GM1(I,J)/SQ2*U(I,J)/RHO(I,J)/C
  A(4,3)=-C2/SQ2/RHO(I,J)-GM1(I,J)/SQ2*V(I,J)/RHO(I,J)/C
  A(4,4)=GM1(I,J)/SQ2/RHO(I,J)/C

```

RETURN

C\*

C\* LEFT & RIGHT EIGENMATRIX FOR XI DIRECTION

C\*

```

ENTRY EIGAR(A,I,J)
CX=SAIX(I,J)
CY=SAIY(I,J)
SQ2=1./DSQRT(2.DO)
C=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
CXCX=1./DSQRT(CX**2+CY**2)
C1=CX*CXCX
C2=CY*CXCX
A(1,1)=1.
A(1,2)=0.
A(1,3)=RHO(I,J)*SQ2/C
A(1,4)=A(1,3)
A(2,1)=U(I,J)
A(2,2)=RHO(I,J)*C2
A(2,3)=SQ2*RHO(I,J)*(U(I,J)/C+C1)
A(2,4)=SQ2*RHO(I,J)*(U(I,J)/C-C1)
A(3,1)=V(I,J)
A(3,2)=-RHO(I,J)*C1
A(3,3)=SQ2*RHO(I,J)*(V(I,J)/C+C2)
A(3,4)=SQ2*RHO(I,J)*(V(I,J)/C-C2)
A(4,1)=0.5*(U(I,J)**2+V(I,J)**2)
A(4,2)=RHO(I,J)*(U(I,J)*C2-V(I,J)*C1)
TEMP=0.5*SQ2*RHO(I,J)*(U(I,J)**2+V(I,J)**2)/C
+RHO(I,J)*SQ2*C/GM1(I,J)
RUC=SQ2*RHO(I,J)*(U(I,J)*C1+V(I,J)*C2)
A(4,3)=TEMP+RUC
A(4,4)=TEMP-RUC
RETURN
END

```

C-----  
C-----

SUBROUTINE COEFY(I)

C\*

C\* SETTING COEFFICIENTS FOR LY-OPERATOR

C\*

C\*\*\*\*\*

```

IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=80)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
>P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
>ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
>AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
>CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
>,BIOT,TW1
COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
>,IWBC,IFLOW
DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),

```

```

> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
  DIMENSION AM(4,4,JZ),BM(4,4,JZ),CM(4,4,JZ),DM(4,JZ)
  DIMENSION DTEMP(4),ISUB(JZ)
  DIMENSION B(4,4),BL1(4,4),D(4,4),A(4,4),AJM(4,4)
CHOIBEGIN
  DIMENSION AMIL1(4,4),BMIL1(4,4),CMIL1(4,4),DMIL1(4)
  DIMENSION BJ2(4,4),BJ1(4,4),DD(4,4)
  DIMENSION AMIL(4,4),BMIL(4,4),CMIL(4,4),DMIL(4)
  DIMENSION AMINV(4,4)
  DIMENSION AB1(4,4),AB2(4,4),AB3(4,4),AB4(4,4)
  DIMENSION D1(4),D2(4),D3(4),D4(4)
CHOIEND
  DATA ISUB/JZ*0/
C*****
C* CHECK THE SONIC POINT AT DOWNSTREAM END
  IF(IVISC.NE.1)GOTO 15
  IF(I.NE.1L)GOTO 15
  DO 5 J=1,JL
  CO=DSQRT(GAMMA(I,J)*P(I,J)/RHO(I,J))
  CONTRA=UN(I,J)-DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)*CO
  IF(CONTRA.LT.0.DO)THEN
    ISUB(J)=1
  ELSE
    ISUB(J)=0
  ENDIF
  IF(UN(I,J).LT.0.DO)ISUB(J)=2
  IF(PB.EQ.0.DO)ISUB(J)=0
  IF(NADV.EQ.1)ISUB(J)=0
  5 CONTINUE
  15 CONTINUE
C*
C* ON THE CENTER LINE OF THE NOZZLE AT J=1
C*
  J=1
  CALL SZERO(4,AM(1,1,J))
  CALL SZERO(4,BM(1,1,J))
  DO 20 M=1,4
  DM(M,J)=0.
  BM(M,M,J)=BM(M,M,J)+1.0
  20 CONTINUE
  CALL SZERO(4,CM(1,1,J))
C*
C* INTERIOR NODS
C*
  DO 80 J=2,JL1
  TAUD=0.5DO*DELTAU(I,J)*THETA/EYI
  TAUD2=2.*TAUD
  JM1=J-1
  JP1=J+1
  CALL JACOB(2,B,I,JM1)
  CALL SMM(4,-TAUD,B,AM(1,1,J))
  CALL SZERO(4,BM(1,1,J))
  DO 60 M=1,4
  60 BM(M,M,J)=BM(M,M,J)+1.

```

```

IF(I.EQ.IL.AND.ISUB(J).NE.O)THEN
  CALL AJACOB(1,A,I,J)
  CALL SZERO(4,AJM)
ELSE
  CALL TRUEJ(1,A,I,J)
  CALL TRUEJ(2,AJM,I,J)
ENDIF
CALL DHDQ(D,I,J)
DO 65 M=1,4
DO 65 N=1,4
BM(M,N,J)=BM(M,N,J)-TAUD2*(D(M,N)-A(M,N)+AJM(M,N))
IF(I.NE.2.AND.I.LT.IL1)BM(M,N,J)=BM(M,N,J)+NORD*TAUD*
* (A(M,N)-AJM(M,N))
65 CONTINUE
CALL JACOB(2,B,I,JP1)
CALL SMM(4,TAUD,B,CM(1,1,J))
C*
C* INSERT VISCOUS JACOBIAN LHS HERE
C*
IF(IVISC.EQ.1)THEN
  CALL VJACOB(A,B,D,I,J)
  DO 68 M=1,4
  DO 68 N=1,4
    AM(M,N,J)=AM(M,N,J)+DELTAU(I,J)*A(M,N)
    BM(M,N,J)=BM(M,N,J)+DELTAU(I,J)*B(M,N)
68    CM(M,N,J)=CM(M,N,J)+DELTAU(I,J)*D(M,N)
  ELSE
  END IF
  DO 70 K=1,4
70  DM(K,J)=DQ(I,J,K)
C
C SUBSONIC REGION KEEP BACK PRESSURE
C
IF(IVISC.EQ.1.AND.(I.EQ.IL.AND.ISUB(J).EQ.1))THEN
  CALL EIGEN(1,BL1,I,J)
  DO 72 K=1,4
72  BL1(4,K)=0.
  CALL MMM(4,BL1,AM(1,1,J),A)
  CALL MMM(4,BL1,BM(1,1,J),B)
  CALL MMM(4,BL1,CM(1,1,J),D)
  DO 74 M=1,4
  DO 74 N=1,4
    AM(M,N,J)=A(M,N)
    BM(M,N,J)=B(M,N)
74  CM(M,N,J)=D(M,N)
  DO 76 M=1,4
  DTEMP(M)=0.
  DO 76 K=1,4
  DTEMP(M)=DTEMP(M)+BL1(M,K)*DM(K,J)
76 CONTINUE
  DO 78 M=1,4
78  DM(M,J)=DTEMP(M)
  BM(4,1,J)=0.5*GM1(I,J)*(U(I,J)**2+V(I,J)**2)/Y(1,J)
  BM(4,2,J)=-GM1(I,J)*U(I,J)/Y(I,J)
  BM(4,3,J)=-GM1(I,J)*V(I,J)/Y(I,J)

```

```

BM(4,4,J)=GM1(I,J)/Y(I,J)
IF(PB.NE.O.DO)THEN
DM(4,J)=(PB-P(I,J))/RJ(I,J)
ELSE
DM(4,J)=0.
ENDIF
ELSE
END IF

```

```

C
C REVERSE FLOW REGION
C

```

```

IF(IVISC.EQ.1.AND.(I.EQ.IL.AND.ISUB(J).EQ.2))THEN
CALL EIGEN(1,BL1,I,J)
DO 73 K=1,4
BL1(1,K)=0.
BL1(2,K)=0.
73 BL1(4,K)=0.
CALL MMM(4,BL1,AM(1,1,J),A)
CALL MMM(4,BL1,BM(1,1,J),B)
CALL MMM(4,BL1,CM(1,1,J),D)
DO 75 M=1,4
DO 75 N=1,4
AM(M,N,J)=A(M,N)
BM(M,N,J)=B(M,N)
75 CM(M,N,J)=D(M,N)
DO 77 M=1,4
DTEMP(M)=0.
DO 77 K=1,4
DTEMP(M)=DTEMP(M)+BL1(M,K)*DM(K,J)
77 CONTINUE
DO 79 M=1,4
79 DM(M,J)=DTEMP(M)
RJYY=RJ(I,J)/Y(I,J)
RCV=RHO(I,J)*CV(I,J)
RJRCV=RJYY/RCV
BM(1,1,J)=(-E(I,J)/RHO(I,J)+GM1(I,J)/GAMMA(I,J)*(U(I,J)**2
> +V(I,J)**2))*RJRCV
BM(1,2,J)=-GM1(I,J)/GAMMA(I,J)*U(I,J)*RJRCV
BM(1,3,J)=-GM1(I,J)/GAMMA(I,J)*V(I,J)*RJRCV
BM(1,4,J)=RJRCV
C1=(RHO(I,J)*E(I,J)-0.5*RHO(I,J)**2*(U(I,J)**2+V(I,J)**2))
C2=(RHO(I,J)*E(I,J)-0.5*GM1(I,J)/GAMMA(I,J)*RHO(I,J)**2*(U(I,J)**2
> +V(I,J)**2))
C3=(C2/C1)**(GAMMA(I,J)/GM1(I,J))
C4=GAMMA(I,J)/GM1(I,J)/C1*(C2/C1)**(1.DO/GM1(I,J))
BM(2,1,J)=(0.5*(U(I,J)**2+V(I,J)**2)*C3+C4*E(I,J)*(C1-C2)/RHO(I,J)
> )*GM1(I,J)*RJYY
BM(2,2,J)=(-U(I,J)*C3+C4*U(I,J)*(C2-GM1(I,J)/GAMMA(I,J)*C1))
> *GM1(I,J)*RJYY
BM(2,3,J)=(-V(I,J)*C3+C4*V(I,J)*(C2-GM1(I,J)/GAMMA(I,J)*C1))
> *GM1(I,J)*RJYY
BM(2,4,J)=(C3+C4*(C1-C2))*GM1(I,J)*RJYY
BM(4,1,J)=-VN(I,J)*RJYY/RHO(I,J)
BM(4,2,J)=ETAX(I,J)*RJYY/RHO(I,J)
BM(4,3,J)=ETAY(I,J)*RJYY/RHO(I,J)

```

```

BM(4,4,J)=0.
TON=(E(I,J)/RHO(I,J)-0.5*GM1(I,J)/GAMMA(I,J)*(U(I,J)**2
> +V(I,J)**2))/CV(I,J)
TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
PON=P(I,J)*(TON/TT)**(GAMMA(I,J)/GM1(I,J))
DM(1,J)=(TWALL-TON)
DM(2,J)=(PB-PON)
DM(4,J)=-VN(I,J)
END IF

```

```

C
CHOI
CHOI

```

```

IF(IVISC.EQ.0.AND.J.EQ.JL1) GOTO 8001

```

```

GO TO 80

```

```

8001 DO 8002 M=1,4
DO 8002 N=1,4
AMIL1(M,N)=AM(M,N,JL1)

```

```

8002 CONTINUE
DO 8003 M=1,4
DO 8003 N=1,4
BMIL1(M,N)=BM(M,N,JL1)

```

```

8003 CONTINUE
DO 8004 M=1,4
DO 8004 N=1,4
CMIL1(M,N)=CM(M,N,JL1)

```

```

8004 CONTINUE
DO 8005 M=1,4
DMIL1(M)=DM(M,JL1)

```

```

8005 CONTINUE

```

```

CHOI

```

```

CHOI

```

```

80 CONTINUE

```

```

C*

```

```

C* WALL BOUNDARY CONDITION

```

```

C*

```

```

CHOI J=JL

```

```

CHOI TAUD=THETA*DELTAU(I,J)/EYI

```

```

CHOI IF(IVISC.EQ.1)GOTO 111

```

```

CHOI CALL SZERO(4,AM(1,1,J))

```

```

CHOI CALL JACOB(2,B,I,J-1)

```

```

CHOI CALL AJACOB(1,A,I,J)

```

```

CHOI CALL AJACOB(2,AJM,I,J)

```

```

CHOI CALL EIGEN(2,BL1,I,J)

```

```

CHOI DO 90 M=1,3

```

```

CHOI DO 90 N=1,4

```

```

CHOI DO 90 K=1,4

```

```

CHOI 90 AM(M,N,J)=AM(M,N,J)-TAUD*BL1(M,K)*B(K,N)

```

```

CHOI CALL SZERO(4,BM(1,1,J))

```

```

CHOI CALL JACOB(2,B,I,J)

```

```

CHOI CALL DHDQ(D,I,J)

```

```

CHOI DO 100 M=1,3

```

```

CHOI DO 100 N=1,4

```

```

CHOI BM(M,N,J)=BM(M,N,J)+BL1(M,N)

```

```

CHOI DO 100 K=1,4

```

```

CHOI BM(M,N,J)=BM(M,N,J)+TAUD*BL1(M,K)*(B(K,N)+A(K,N)-D(K,N)-AJM(K,N))

```

```

CHOI      IF(I.NE.2.AND.I.LT.IL1) BM(M,N,J)=BM(M,N,J)+NORD*0.5*TAUD*
CHOI      *      BL1(M,K)*(A(K,N)-AJM(K,N))
CHOI 100  CONTINUE
CHOI
CHOIBEG
      J=JL
      TAUD=THETA*DELTAU(I,J)/EYI
      IF(IVISC.EQ.1) GOTO 111
      CALL JACOB(2,BJ2,I,J-2)
      CALL JACOB(2,BJ1,I,J-1)
      CALL JACOB(2,B,I,J)
      CALL AJACOB(1,A,I,J)
      CALL AJACOB(2,AJM,I,J)
      CALL EIGEN(2,BL1,I,J)
      DO 899 N=1,4
899  BL1(4,N)=0.DO
      CALL HJAC(DD,J)
      DO 90 M=1,4
      DO 90 N=1,4
      AMIL(M,N)=0.5DO*BJ2(M,N)*TAUD
90  CONTINUE
      DO 91 M=1,4
      DO 91 N=1,4
      BMIL(M,N)=-2.DO*BJ1(M,N)*TAUD
91  CONTINUE
      CALL JACOB(2,B,I,J)
      CALL DHDQ(D,I,J)
      DO 100 M=1,4
      DO 100 N=1,4
      CMIL(M,N)=DD(M,N)+TAUD*(1.5DO*B(M,N)+A(M,N)-D(M,N)-AJM(M,N))
      IF(I.NE.2.AND.I.LT.IL1) CMIL(M,N)=CMIL(M,N)+NORD*0.5DO*TAUD*
      > (A(M,N)-AJM(M,N))
100 CONTINUE
      DO 1001 M=1,4
1001 DMIL(M)=DQ(I,JL,M)
C      DO 2001 M=1,4
CC      WRITE(6,2002) I,(AMIL1(M,N),N=1,4)
C2001 CONTINUE
C2002 FORMAT(2X,I5,2X,4D14.5)
      CALL INVER(4,AMIL1,AMINV)
      CALL MMM(4,AMINV,BMIL1,AB1)
      CALL MMM(4,AMIL,AB1,AB2)
      DO 101 M=1,4
      DO 101 N=1,4
101  AB3(M,N)=AB2(M,N)-BMIL(M,N)
      CALL MMM(4,BL1,AB3,AB4)
      DO 102 M=1,4
      DO 102 N=1,4
102  AM(M,N,J)=AB4(M,N)
      CALL MMM(4,AMINV,CMIL1,AB1)
      CALL MMM(4,AMIL,AB1,AB2)
      DO 103 M=1,4
      DO 103 N=1,4
103  AB3(M,N)=AB2(M,N)-CMIL(M,N)
      CALL MMM(4,BL1,AB3,AB4)

```

```

DO 104 M=1,4
DO 104 N=1,4
104 BM(M,N,J)=AB4(M,N)
CALL MMV(4,AMINV,DMIL1,D1)
CALL MMV(4,AMIL,D1,D2)
DO 105 M=1,4
105 D3(M)=D2(M)-DMIL(M)
CALL MMV(4,BL1,D3,D4)
DO 106 M=1,4
106 DM(M,J)=D4(M)
CHOI
CHOIEND
    BM(4,1,J)=-VN(I,J)
    BM(4,2,J)=ETAX(I,J)
    BM(4,3,J)=ETAY(I,J)
    BM(4,4,J)=0.
    CALL SZERO(4,CM(1,1,J))
CHOI    DO 110 M=1,3
CHOI    DM(M,J)=0.
CHOI    DO 110 K=1,4
CHOI    DM(M,J)=DM(M,J)+BL1(M,K)*DQ(I,J,K)
CHOI 110 CONTINUE
C    WRITE(6,*) I,J,BM(4,1,J)
    DM(4,J)=0.
    GOTO 119
111 CONTINUE
    CALL SZERO(4,AM(1,1,J))
    CALL SZERO(4,CM(1,1,J))
    CALL SZERO(4,BM(1,1,J))
    DO 112 M=1,4
    DM(M,J)=0.
112 BM(M,M,J)=1.0
    IF(IWBC.EQ.1)THEN
        OR=1./RHO(I,J)
        ORCV=OR/CV(I,J)
        U2V2=U(I,J)**2+V(I,J)**2
        U2V21=U(I,JL1)**2+V(I,JL1)**2
        YJJL=RJ(I,JL)/Y(I,JL)
        YJJL1=RJ(I,JL1)/Y(I,JL1)
        BM(1,1,J)=(-E(I,J)*OR+U2V2)*YJJL*ORCV
        BM(1,2,J)=-U(I,J)*YJJL*ORCV
        BM(1,3,J)=-V(I,J)*YJJL*ORCV
        BM(1,4,J)=YJJL*ORCV
        BM(2,1,J)=0.
        BM(2,2,J)=YJJL
        BM(2,3,J)=0.
        BM(2,4,J)=0.
        BM(3,1,J)=0.
        BM(3,3,J)=YJJL
        BM(3,4,J)=0.
        C1=SAIX(I,J)*ETAX(I,J)+SAIY(I,J)*ETAY(I,J)
        C2=ETAX(I,J)**2+ETAY(I,J)**2
        CB=C1+C2
        IF(I.GT.2) CB=CB+0.5*FLOAT(NORD)*C1
        CD=C1*P(I-1,J)

```

```

IF(I.GT.2) CD=CD+NORD*C1*(P(I-1,J)-0.5*P(I-2,J))
BM(4,1,J)=0.5*U2V2*YJL*GM1(I,J)*CB
BM(4,2,J)=-U(I,J)*YJL*GM1(I,J)*CB
BM(4,3,J)=-V(I,J)*YJL*GM1(I,J)*CB
BM(4,4,J)=YJL*GM1(I,J)*CB
AM(4,1,J)=-0.5*U2V21*YJL1*GM1(I,J)*C2
AM(4,2,J)=U(I,J-1)*YJL1*GM1(I,J)*C2
AM(4,3,J)=V(I,J-1)*YJL1*GM1(I,J)*C2
AM(4,4,J)=-YJL1*GM1(I,J)*C2
DO 113 M=1,3
113 DM(M,J)=0.
TJJ=P(I,J)/RHO(I,J)/RGAS
DM(1,J)=TWALL-TJJ
DM(4,J)=CD+C2*P(I,JL1)-CB*P(I,JL)

```

C  
C ADIABATIC WALL  
C

```

IF(IWALL.EQ.0)THEN
ORCV=1./RHO(I,J)/CV(I,J)
ORCV1=1./RHO(I,J-1)/CV(I,J-1)
RUU=RGAS
TIM1=P(I-1,J)/RHO(I-1,J)/RUU
CD=C1*TIM1
IF(I.GT.2) THEN
TIM2=P(I-2,J)/RHO(I-2,J)/RUU
CD=CD+NORD*C1*(TIM1-0.5*TIM2)
ENDIF
BM(1,1,J)=(-E(I,J)*OR+U2V2)*YJL*ORCV*CB
BM(1,2,J)=-U(I,J)*YJL*ORCV*CB
BM(1,3,J)=-V(I,J)*YJL*ORCV*CB
BM(1,4,J)=YJL*ORCV*CB
AM(1,1,J)=-(-E(I,J-1)*OR+U2V21)*YJL1*ORCV1*C2
AM(1,2,J)=U(I,J-1)*YJL1*ORCV1*C2
AM(1,3,J)=V(I,J-1)*YJL1*ORCV1*C2
AM(1,4,J)=-YJL1*ORCV1*C2
TJM1=P(I,J-1)/RHO(I,J-1)/RUU
TJJ=P(I,J)/RHO(I,J)/RUU
DM(1,J)=CD+C2*TJM1-CB*TJJ
ENDIF

```

C  
C WALL COOLING (FROM UPSTREAM TO DOWNSTREAM)  
C

```

IF(IWALL.EQ.2.AND.IFLOW.EQ.1)THEN
C1=C1/RJ(I,J)
C2=C2/RJ(I,J)
C3=BIOT/Y(I,J)
CB=C1+C2+C3
IF(I.GT.2) CB=CB+0.5*FLOAT(NORD)*(C1+C3)
ORCV=1./RHO(I,J)/CV(I,J)
ORCV1=1./RHO(I,J-1)/CV(I,J-1)
RUU=RGAS
TIM1=P(I-1,J)/RHO(I-1,J)/RUU
CD=(C1+C3)*TIM1
IF(I.GT.2) THEN
TIM2=P(I-2,J)/RHO(I-2,J)/RUU

```

```

      CD=CD+NORD*(C1+C3)*(TIM1-0.5*TIM2)
    ENDIF
    BM(1,1,J)=(-E(I,J)*OR+U2V2)*YJJL*ORCV*CB
    BM(1,2,J)=-U(I,J)*YJJL*ORCV*CB
    BM(1,3,J)=-V(I,J)*YJJL*ORCV*CB
    BM(1,4,J)=YJJL*ORCV*CB
    AM(1,1,J)=-(-E(I,J-1)*OR+U2V21)*YJJL1*ORCV1*C2
    AM(1,2,J)=U(I,J-1)*YJJL1*ORCV1*C2
    AM(1,3,J)=V(I,J-1)*YJJL1*ORCV1*C2
    AM(1,4,J)=-YJJL1*ORCV1*C2
    TJM1=P(I,J-1)/RHO(I,J-1)/RUU
    TJJ=P(I,J)/RHO(I,J)/RUU
    DM(1,J)=CD+C2*TJM1-CB*TJJ
  ENDIF

```

C  
C  
C

INVERSE COOLING FLOW

```

    IF(IWALL.EQ.2.AND.IFLOW.EQ.-1)THEN
      IF(I.EQ.IL)THEN
        DM(1,J)=TW1-TJJ
        GOTO 119
      ENDIF
      C1=C1/RJ(I,J)
      C2=C2/RJ(I,J)
      C3=-BIOT/Y(I,J)
      CB=C2-(C1+C3)
      IF(I.LT.IL1) CB=CB-0.5*FLOAT(NORD)*(C1+C3)
      ORCV=1./RHO(I,J)/CV(I,J)
      ORCV1=1./RHO(I,J-1)/CV(I,J-1)
      RUU=RGAS
      TIM1=P(I+1,J)/RHO(I+1,J)/RUU
      CD=-(C1+C3)*TIM1
      IF(I.LT.IL1) THEN
        TIM2=P(I+2,J)/RHO(I+2,J)/RUU
        CD=CD+NORD*(C1+C3)*(-TIM1+0.5*TIM2)
      ENDIF
      BM(1,1,J)=(-E(I,J)*OR+U2V2)*YJJL*ORCV*CB
      BM(1,2,J)=-U(I,J)*YJJL*ORCV*CB
      BM(1,3,J)=-V(I,J)*YJJL*ORCV*CB
      BM(1,4,J)=YJJL*ORCV*CB
      AM(1,1,J)=-(-E(I,J-1)*OR+U2V21)*YJJL1*ORCV1*C2
      AM(1,2,J)=U(I,J-1)*YJJL1*ORCV1*C2
      AM(1,3,J)=V(I,J-1)*YJJL1*ORCV1*C2
      AM(1,4,J)=-YJJL1*ORCV1*C2
      TJM1=P(I,J-1)/RHO(I,J-1)/RUU
      TJJ=P(I,J)/RHO(I,J)/RUU
      DM(1,J)=CD+C2*TJM1-CB*TJJ
    ENDIF

```

C

ENDIF

119 CONTINUE

C\*

C\* SOLVE 4\*4 BLOCK TRIDIAGONAL MATRICES

C\*

CALL NBTRIP(AM,BM,CM,DM,1,JL,4)

```

DO 120 J=1,JL
DO 120 K=1,4
DQ(I,J,K)=DM(K,J)
120 CONTINUE
RETURN
END

```

```

C-----
SUBROUTINE FLUXCL
C*
C* SUBROUTINE FOR FLUX VECTOR CALCULATION
C*
C*****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=80)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
> P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
> ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
> ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
> CEL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
> ,BIOT,TW1
COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
> ,IWBC,IFLOW
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
DIMENSION A(4,4)
ENTRY FLUX(II)
I=II
C*
C* COMPUTE CONVECTIVE TERMS
C*
DO 10 J=1,JL
C F(I,J,1)=RHO(I,J)*UN(I,J)/RJ(I,J)*Y(I,J)
C F(I,J,2)=(RHOU(I,J)*UN(I,J)+SAIX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
C F(I,J,3)=(RHOV(I,J)*UN(I,J)+SAIY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
C F(I,J,4)=(E(I,J)+P(I,J))*UN(I,J)/RJ(I,J)*Y(I,J)
CALL AJACOB(1,A,I,J)
DO 3 K=1,4
F(I,J,K)=0.
DO 3 JJ=1,4
3 F(I,J,K)=F(I,J,K)+A(K,JJ)*Q(I,J,JJ)*Y(I,J)/RJ(I,J)
G(I,J,1)=RHO(I,J)*VN(I,J)/RJ(I,J)*Y(I,J)
G(I,J,2)=(RHOU(I,J)*VN(I,J)+ETAX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
G(I,J,3)=(RHOV(I,J)*VN(I,J)+ETAY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
G(I,J,4)=(E(I,J)+P(I,J))*VN(I,J)/RJ(I,J)*Y(I,J)
10 CONTINUE
RETURN
C*
C* E MINUS FLUX VECTOR
C*
ENTRY FLUXM(II)

```

```

I=II
DO 20 J=1,JL
CALL AJACOB(2,A,I,J)
DO 17 K=1,4
G(I,J,K)=0.
DO 17 JJ=1,4
17 G(I,J,K)=G(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
20 CONTINUE
RETURN

```

C\*

C\* VISCOUS FLUX VECTOR

C\*

```

ENTRY VFLUX(II)
I=II
DO 30 J=2,JL1
JP1=J+1
JM1=J-1
ZMUP=0.5*(ZMU(I,J)+ZMU(I,JP1))
ZMUM=0.5*(ZMU(I,J)+ZMU(I,JM1))
IF(PRNT.EQ.0.DO)THEN
GAMP=0.5*(GAMMA(I,JP1)+GAMMA(I,J))
GAMM=0.5*(GAMMA(I,JM1)+GAMMA(I,J))
GKCPP=ZMUP*GAMP/PRN
GKCPM=ZMUM*GAMM/PRN
ELSE
ZMUTP = 0.5*(ZMUT(JP1)+ZMUT(J))
ZMUTM = 0.5*(ZMUT(JM1)+ZMUT(J))
ZMULP = ZMUP - ZMUTP
ZMULM = ZMUM - ZMUTM
GAMP=0.5*(GAMMA(I,JP1)+GAMMA(I,J))
GAMM=0.5*(GAMMA(I,JM1)+GAMMA(I,J))
GKCPP = GAMP*(ZMULP/PRN+ZMUTP/PRNT)
GKCPM = GAMM*(ZMULM/PRN+ZMUTM/PRNT)
ENDIF
YYP=0.5*(Y(I,J)+Y(I,JP1))
YYM=0.5*(Y(I,J)+Y(I,JM1))
YZP=YYP*ZMUP
YZM=YYM*ZMUM
AAP1=A1(I,J)*YZP
AAM1=A1(I,JM1)*YZM
AAP2=A2(I,J)*YZP
AAM2=A2(I,JM1)*YZM
AAP3=A3(I,J)*YZP
AAM3=A3(I,JM1)*YZM
AAP4=A4(I,J)*YYP*GKCPP
AAM4=A4(I,JM1)*YYM*GKCPM
UP=U(I,JP1)-U(I,J)
UM=-U(I,JM1)+U(I,J)
VP=V(I,JP1)-V(I,J)
VM=V(I,J)-V(I,JM1)
ERP=E(I,JP1)/RHO(I,JP1)-E(I,J)/RHO(I,J)
ERM=E(I,J)/RHO(I,J)-E(I,JM1)/RHO(I,JM1)
U2P=U(I,JP1)**2-U(I,J)**2
U2M=U(I,J)**2-U(I,JM1)**2
V2P=V(I,JP1)**2-V(I,J)**2

```

```

V2M=V(I,J)**2-V(I,JM1)**2
UVP=U(I,JP1)*V(I,JP1)-U(I,J)*V(I,J)
UVM=U(I,J)*V(I,J)-U(I,JM1)*V(I,JM1)
G(I,J,1)=0.
G(I,J,2)=(AAP1*UP-AAM1*UM)+(AAP2*VF-AAM2*VM)
G(I,J,3)=(AAP2*UP-AAM2*UM)+(AAP3*VP-AAM3*VM)
G(I,J,4)=(AAP4*ERP-AAM4*ERM)+0.5*((AAP1-AAP4)*U2P-
  (AAM1-AAM4)*U2M)+0.5*((AAP3-AAP4)*V2P-(AAM3-AAM4)*V2M)+
  (AAP2*UVP-AAM2*UVM)

```

```

C*
C* INSERT THE EXTRA FIRST ORDER TERMS IN CYLINDRICAL COORDINATE
C* SYSTEMS
C*

```

```

EYJ=ETAY(I,J)/RJ(I,J)
EXJ=ETAX(I,J)/RJ(I,J)
DMUV=0.5*(ZMU(I,JP1)*V(I,JP1)-ZMU(I,JM1)*V(I,JM1))
DDV=0.5*(V(I,JP1)-V(I,JM1))
DMUV2=0.5*(ZMU(I,JP1)*V(I,JP1)**2-ZMU(I,JM1)*V(I,JM1)**2)
DMUUV=0.5*(ZMU(I,JP1)*U(I,JP1)*V(I,JP1)-
  * ZMU(I,JM1)*U(I,JM1)*V(I,JM1))
DDU=0.5*(U(I,JP1)-U(I,JM1))
DDMU=0.5*(ZMU(I,JP1)-ZMU(I,JM1))
G(I,J,2)=G(I,J,2)-2./3.*EXJ*DMUV
G(I,J,3)=G(I,J,3)+2./3.*(ZMU(I,J)*EXJ*DDU-V(I,J)*EYJ*DDMU)
G(I,J,4)=G(I,J,4)-2./3.*(EYJ*DMUV2+EXJ*DMUUV)

```

```

30 CONTINUE
RETURN
END

```

```

C-----
C ** RIGHT HAND SIDE CALCULATION
C-----

```

## SUBROUTINE RHSCAL

```

C *****
IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (IZ=150,JZ=80)
COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
  * P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
  * ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
  * ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
  * CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
  * ,BIOT,TW1
COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
  * ,IWBC,IFLOW
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
  * (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C *****
ENTRY RHS(II)
I=II
CALL FLUX(I-1)
C IF((I.NE.2.AND.I.NE.IL1).AND.NORD.EQ.1)CALL FLUX(I-2)
CALL FLUX(I)

```

```

      EXII=2.*EXI
      EYII=EYI*2.
      DO 10 J=1,JL
      DO 10 K=1,4
10    DQ(I,J,K)=0.
      J=JL
      JM1=J-1
      IM1=I-1
      DO 20 K=1,4
      DQ(I,J,K)=DQ(I,J,K)+F(I,J,K)-F(I-1,J,K)+
CHOI *      G(I,J,K)-G(I,JM1,K)
CHOI
      > (3.DO*G(I,J,K)-4.DO*G(I,J-1,K)+G(I,J-2,K))*0.5DO
CHOI
20    CONTINUE
      DO 100 J=2,JL1
      JP1=J+1
      JM1=J-1
      DO 100 K=1,4
      IF(I.NE.1)THEN
      DQ(I,J,K)=DQ(I,J,K)+F(I,J,K)-F(I-1,J,K)+
      >      (G(I,JP1,K)-G(I,JM1,K))*0.5
      ELSE
      DQ(I,J,K)=DQ(I,J,K)+0.5*(G(I,JP1,K)-G(I,JM1,K))
      ENDIF
100   CONTINUE
      IF(I.EQ.IL) GOTO 120
      IF(I.NE.2.AND.I.NE.IL1)THEN
      DO 110 J=1,JL
      DO 110 K=1,4
      DQ(I,J,K)=DQ(I,J,K)+NORD*0.5*(F(I,J,K)-2.*F(I-1,J,K)+
      *      F(I-2,J,K))
110   CONTINUE
      ENDIF
120   CONTINUE
      IF(I.EQ.IL)GOTO 180
      IP1=I+1
      CALL FLUXM(IP1)
      CALL FLUXM(I)
      IF((I.NE.IL1.AND.I.NE.2).AND.NORD.EQ.1)CALL FLUXM(I+2)
      DO 170 J=2,JL
      DO 170 K=1,4
      DQ(I,J,K)=DQ(I,J,K)+G(IP1,J,K)-G(I,J,K)
      IF(I.NE.IL1.AND.I.NE.2)DQ(I,J,K)=DQ(I,J,K)-NORD*0.5*
      *      (G(I+2,J,K)-2.*G(I+1,J,K)+G(I,J,K))
170   CONTINUE
180   CONTINUE
      DO 200 J=2,JL
      DQ(I,J,3)=DQ(I,J,3)-P(I,J)/RJ(I,J)
200   CONTINUE
      RETURN
C*
C* VISCOUS RIGHT HAND SIDE
C*
      ENTRY VRHS(II)

```

```

      I=II
      CALL VFLUX(I)
      DO 300 J=2,JL1
      DO 300 K=2,4
300    DQ(I,J,K)=DQ(I,J,K)-G(I,J,K)
      DO 400 J=2,JL
      DQ(I,J,3)=DQ(I,J,3)+4./3.*ZMU(I,J)*V(I,J)/(RJ(I,J)*Y(I,J))
400    CONTINUE
      RETURN
      END
C *****
C SERVICE SUBROUTINE
C *****
      SUBROUTINE SUPPLY
      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (IZ=150,JZ=80)
      COMMON/VECTOR/DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),G(IZ,JZ,4),
>      P(IZ,JZ),U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ)
      COMMON/COORD/SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),ETAY(IZ,JZ)
>      ,ZMUT(JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),DELTAU(IZ,JZ)
>      ,AREA(IZ),ZMU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),A4(IZ,JZ)
      COMMON/CONST/AIN,AEX,RL,EXI,EYI,OMEGAX,OMEGAY,CFL,THETA,PO,TO,
>      CFL1,PRNT,PB,RM1,SUM(4),ZMUO,REN,PRN,TWALL,TREF
>      ,BIOT,TW1
      COMMON/CONST1/GAMMA(IZ,JZ),GM1(IZ,JZ),CP(IZ,JZ),CV(IZ,JZ),RGAS
      COMMON/INTEG/IL,JL,IL1,JL1,NEND,NBEG,NADV,ITIME,IVISC,NORD,IWALL
>      ,IWBC,IFLOW
      DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),E(IZ,JZ)
      EQUIVALENCE(Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
>      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),E(1,1))
C*****
      DIMENSION SS(4)
      DATA GO,PATM/9.8067,101325./
      ENTRY CHECK
      DO 10 K=1,4
10    SS(K)=0.
      DO 20 I=2,IL
      DO 20 J=2,JL
      DO 20 K=1,4
      QQ=Q(I,J,K)
      IF(QQ.EQ.0.DO)GO TO 20
      SS(K)=SS(K)+(DQ(I,J,K)*RJ(I,J)/Y(I,J)/QQ)**2
20    CONTINUE
      DO 30 K=1,4
30    SS(K)=DSQRT(SS(K))/(IL*JL)
      WRITE(19,500)NADV,(SS(K),K=1,4)
500  FORMAT(15,3X,4(1X,E14.7))
      RETURN
      ENTRY MASS
C
C MASS FLOW RATE
C
      PPI=DARCOS(-1.DO)
      DO 80 I=1,IL
      FLRT=0.

```

```

DO 75 J=1,JL1
DELR=DSQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
CXCXY=DSQRT(SAIX(I,J)**2+SAIY(I,J)**2)
CXCXY1=DSQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
FLRT=FLRT+0.5*PPI*(Y(I,J+1)+Y(I,J))*DELR
+      *(RHO(I,J+1)*UN(I,J+1),CXCXY1+RHO(I,J)*UN(I,J)/CXCXY)
75  CONTINUE
    WRITE(18,789)I,FLRT
80  CONTINUE
789  FORMAT(1X,18,E14.7)
C
C THRUST AND ISP CALCULATIONS
C
    I=IL
    THRUST=0.
    DO 85 J=1,JL1
    DELR=DSQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
    THRUST=THRUST+0.5*PPI*(Y(I,J+1)+Y(I,J))*DELR*
    >      (RHO(I,J+1)*U(I,J+1)**2+P(I,J+1)-PATM+
    >      RHO(I,J)*U(I,J)**2+P(I,J)-PATM)
85  CONTINUE
    CCC=THRUST/FLRT
    SPI=CCC/GO
    WRITE(18,788) THRUST,SPI
788  FORMAT(//,'*** THRUST=',E14.7,/,',',E14.7,/,',',E14.7)
C
    RETURN
    ENTRY OUTPUT
    WRITE(18,550)NADV
550  FORMAT(//10(1H*),/,' NADV=',I5//)
    DO 50 I=1,IL
    DO 50 J=1,JL
    ST=(E(I,J)/RHO(I,J)-GM1(I,J)*0.5/GAMMA(I,J)*(U(I,J)**2+
    >      V(I,J)**2))/CV(I,J)
    TT=(E(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2))/CV(I,J)
    RMA=DSQRT((U(I,J)*U(I,J)+V(I,J)*V(I,J))/GAMMA(I,J)
    >      *RHO(I,J)/P(I,J))
    SP=P(I,J)*(ST/TT)**(GAMMA(I,J)/GM1(I,J))
    WRITE(18,607)X(I,J),Y(I,J),P(I,J),RMA,TT,V(I,J)
    WRITE(66) (Q(I,J,K),K=1,4),DELTAU(I,J)
607  FORMAT(6(1X,E14.7))
C    WRITE(6,600)I,J,RHO(I,J),U(I,J),V(I,J),E(I,J),ST
C    WRITE(6,650)P(I,J),UN(I,J),VN(I,J),SP,TT
600  FORMAT(1X,'#',I2,',',I2,3X,5(1X,E10.3))
650  FORMAT(10X,5(1X,E10.3))
50  CONTINUE
C
C WRITE THE LAST TWO LINES
C
C    DO 70 I=IL1,IL
C    DO 70 J=1,JL
C70  WRITE(63) (Q(I,J,K),K=1,4)
C
    RETURN
    END

```

C \*\*\*\*\*

C\*

C\* LIBRARY SUBROUTINES

C\*

```

SUBROUTINE NBTRIP(A,B,C,D,ILO,IU,ORDER)
  IMPLICIT REAL*8(A-H,O-Z)
  DIMENSION A(1),B(1),C(1),D(1),IPS(5),X(5)
  INTEGER ORDER,ORDSQ
  ORDSQ=ORDER**2
  I=ILO
  IOMAT=1+(I-1)*ORDSQ
  IOVEC=1+(I-1)*ORDER
  CALL LUDPVT(B(IOMAT),ORDER,IPS)
  CALL LUSPVT(B(IOMAT),D(IOVEC),D(IOVEC),X,ORDER,IPS)
  DO 100 J=1,ORDER
    IOMATJ=IOMAT+(J-1)*ORDER
    CALL LUSPVT(B(IOMAT),C(IOMATJ),C(IOMATJ),X,ORDER,IPS)
100  CONTINUE
200  CONTINUE
    I=I+1
    IOMAT=1+(I-1)*ORDSQ
    IOVEC=1+(I-1)*ORDER
    I1MAT=IOMAT-ORDSQ
    I1VEC=IOVEC-ORDER
    CALL MULPUT(A(IOMAT),D(I1VEC),D(IOVEC),ORDER)
    DO 300 J=1,ORDER
      IOMATJ=IOMAT+(J-1)*ORDER
      I1MATJ=I1MAT+(J-1)*ORDER
      CALL MULPUT(A(IOMAT),C(I1MATJ),B(IOMATJ),ORDER)
300  CONTINUE
      IF(I.EQ.IU) GO TO 500
      CALL LUDECO(B(IOMAT),ORDER)
      CALL LUSOLV(B(IOMAT),D(IOVEC),D(IOVEC),ORDER)
      DO 400 J=1,ORDER
        IOMATJ=IOMAT+(J-1)*ORDER
        CALL LUSOLV(B(IOMAT),C(IOMATJ),C(IOMATJ),ORDER)
400  CONTINUE
        GO TO 200
500  CONTINUE
      CALL LUDPVT(B(IOMAT),ORDER,IPS)
      CALL LUSPVT(B(IOMAT),D(IOVEC),D(IOVEC),X,ORDER,IPS)
600  CONTINUE
      I=I-1
      IOMAT=1+(I-1)*ORDSQ
      IOVEC=1+(I-1)*ORDER
      I1VEC=IOVEC+ORDER
      CALL MULPUT(C(IOMAT),D(I1VEC),D(IOVEC),ORDER)
      IF(I.GT.ILO) GO TO 600
      RETURN
    END

```

C-----

```

SUBROUTINE LUDPVT(A,ORDER,IPS)
  IMPLICIT REAL*8 (A-H,O-Z)
  INTEGER ORDER
  DIMENSION A(ORDER,1),IPS(ORDER)

```

```

DO 5 I=1,ORDER
  IPS(I)=I
5 CONTINUE
  NM1=ORDER-1
  DO 17 K=1,NM1
    BIG=0.0DO
    DO 11 I=K,ORDER
      IP=IPS(I)
      SIZE=DABS(A(IP,K))
      IF(SIZE-BIG)11,11,10
10 BIG=SIZE
      IDXPIV=I
11 CONTINUE
      IF(IDXPIV-K)14,15,14
14 J=IPS(K)
      IPS(K)=IPS(IDXPIV)
      IPS(IDXPIV)=J
15 KP=IPS(K)
      PIVOT=A(KP,K)
      KP1=K+1
      DO 16 I=KP1,ORDER
        IP=IPS(I)
        EM=-A(IP,K)/PIVOT
        A(IP,K)=-EM
      DO 16 J=KP1,ORDER
        A(IP,J)=A(IP,J)+EM*A(KP,J)
16 CONTINUE
17 CONTINUE
      RETURN
      END

```

C-----

```

SUBROUTINE MULPUT(A,B,C,ORDER)
  IMPLICIT REAL*8(A-H,O-Z)
  INTEGER ORDER
  DIMENSION A(1),B(1),C(1)
  DO 200 JR=1,ORDER
    SUM=0.0
    DO 100 JC=1,ORDER
      IA=JR+(JC-1)*ORDER
100 SUM=SUM+A(IA)*B(JC)
200 C(JR)=C(JR)-SUM
      RETURN
      END

```

C-----

```

SUBROUTINE LUSPVT(A,B,C,X,ORDER,IPS)
  IMPLICIT REAL*8(A-H,O-Z)
  INTEGER ORDER
  DIMENSION A(ORDER,1),B(1),C(1),X(1),IPS(1)
  NP1=ORDER+1
  IP=IPS(1)
  X(1)=B(IP)
  DO 2 I=2,ORDER
    IP=IPS(I)
    IM1=I-1
    SUM=0.0DO

```

```

DO 1 J=1,IM1
1 SUM=SUM+A(IP,J)*X(J)
2 X(I)=B(IP)-SUM
  IP=IPS(ORDER)
  C(ORDER)=X(ORDER)/A(IP,ORDER)
DO 4 IBACK=2,ORDER
  I=NP1-IBACK
  IP=IPS(I)
  IP1=I+1
  SUM=0.0DO
DO 3 J=IP1,ORDER
3 SUM=SUM+A(IP,J)*C(J)
4 C(I)=(X(I)-SUM)/A(IP,I)
RETURN
END

```

```

C-----
SUBROUTINE LUDECO(A,ORDER)
IMPLICIT REAL*8(A-H,O-Z)
INTEGER ORDER
DIMENSION A(ORDER,1)
DO 8 JC=2,ORDER
8 A(1,JC)=A(1,JC)/A(1,1)
  JRJC=1
10 CONTINUE
  JRJC=JRJC+1
  JRJCM1=JRJC-1
  JRJCP1=JRJC+1
DO 14 JR=JRJC,ORDER
  SUM=A(JR,JRJC)
DO 12 JM=1,JRJCM1
12 SUM=SUM-A(JR,JM)*A(JM,JRJC)
14 A(JR,JRJC)=SUM
  IF(JRJC.EQ.ORDER) RETURN
DO 18 JC=JRJCP1,ORDER
  SUM=A(JRJC,JC)
DO 16 JM=1,JRJCM1
16 SUM=SUM-A(JRJC,JM)*A(JM,JC)
18 A(JRJC,JC)=SUM/A(JRJC,JRJC)
GO TO 10
END

```

```

C-----
SUBROUTINE LUSOLV(A,B,C,ORDER)
IMPLICIT REAL*8(A-H,O-Z)
INTEGER ORDER
DIMENSION A(ORDER,1),B(1),C(1)
C(1)=C(1)/A(1,1)
DO 14 JR=2,ORDER
  JRM1=JP-1
  SUM=B(JR)
DO 12 JM=1,JRM1
12 SUM=SUM-A(JR,JM)*C(JM)
14 C(JR)=SUM/A(JR,JR)
DO 18 JRJR=2,ORDER
  JR=ORDER-JRJR+1
  JRP1=JR+1

```

```

      SUM=C(JR)
      DO 16 JMJM=JRP1,ORDER
      JM=ORDER-JMJM+JRP1
16     SUM=SUM-A(JR,JM)*C(JM)
18     C(JR)=SUM
      RETURN
      END

```

```

C-----
C     SET ZERO FOR MATRIC (M,M)
      SUBROUTINE SZERO(M,A)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      A(I,J)=0.0DO
10     CONTINUE
      RETURN
      END

```

```

C-----
C     SCALAR*METRIC (M,M)
      SUBROUTINE SMM(M,C,A,B)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      B(I,J)=C*A(I,J)
10     CONTINUE
      RETURN
      END

```

```

C-----
C     METRIX*METRIX (M*M)
      SUBROUTINE MMM(M,A,B,C)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(M,M),B(M,M),C(M,M)
      DO 10 I=1,M
      DO 10 J=1,M
      C(I,J)=0.0DO
      DO 10 K=1,M
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
10     CONTINUE
      RETURN
      END

```

```

C*****
      SUBROUTINE HJAC(A,J)
C*****
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(4,4)
      CALL SZERO(4,A)
      A(1,1)=1.DO
      A(2,2)=1.DO
      A(3,3)=1.DO
      A(4,4)=1.DO
      RETURN
      END
C*****

```

```

SUBROUTINE MMV(M,A,B,C)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION A(M,M),B(M),C(M)
DO 10 I=1,M
C(I)=0.DO
DO 10 K=1,M
C(I)=C(I)+A(I,K)*B(K)
10 CONTINUE
RETURN
END

```

C\*\*\*\*\*

```

SUBROUTINE INVER(M,A,AINV)
IMPLICIT REAL*8(A-H,O-Z)
DIMENSION A(4,4),B(4,4),AINV(4,4),COF(4,4)
A11=A(1,1)
A12=A(1,2)
A13=A(1,3)
A14=A(1,4)
A21=A(2,1)
A22=A(2,2)
A23=A(2,3)
A24=A(2,4)
A31=A(3,1)
A32=A(3,2)
A33=A(3,3)
A34=A(3,4)
A41=A(4,1)
A42=A(4,2)
A43=A(4,3)
A44=A(4,4)
DET=A11*(A22*A33*A44+A23*A34*A42+A24*A43*A32-A24*A33*A42
> -A23*A32*A44-A22*A43*A34)-
> A12*(A21*A33*A44+A23*A34*A41+A24*A43*A31-A24*A33*A41
> -A23*A31*A44-A21*A43*A34)+
> A13*(A21*A32*A44+A22*A34*A41+A24*A42*A31-A24*A32*A41
> -A22*A31*A44-A21*A42*A34)-
> A14*(A21*A32*A43+A22*A33*A41+A23*A42*A31-A23*A32*A41
> -A22*A31*A43-A21*A42*A33)
COF(1,1)=A22*A33*A44+A23*A34*A42+A24*A43*A32-A24*A33*A42
> -A23*A32*A44-A22*A43*A34
COF(1,2)=- (A21*A33*A44+A23*A34*A41+A24*A43*A31-A24*A33*A41
> -A23*A31*A44-A21*A43*A34)
COF(1,3)=A21*A32*A44+A22*A34*A41+A24*A42*A31-A24*A32*A41
> -A22*A31*A44-A21*A42*A34
COF(1,4)=- (A21*A32*A43+A22*A33*A41+A23*A42*A31-A23*A32*A41
> -A22*A31*A43-A21*A42*A33)
COF(2,1)=- (A12*A33*A44+A13*A34*A42+A14*A32*A43-A14*A33*A42
> -A13*A32*A44-A12*A43*A34)
COF(2,2)=A11*A33*A44+A13*A34*A41+A14*A31*A43-A14*A33*A41
> -A13*A31*A44-A11*A43*A34
COF(2,3)=- (A11*A32*A44+A12*A34*A41+A14*A31*A42-A14*A32*A41
> -A12*A31*A44-A11*A42*A34)
COF(2,4)=A11*A32*A43+A12*A33*A41+A13*A31*A42-A13*A32*A41
> -A12*A31*A43-A11*A42*A33
COF(3,1)=A12*A23*A44+A13*A24*A42+A14*A22*A43-A14*A23*A42

```

```

> -A13*A22*A44-A12*A43*A24
COF(3,2)=- (A11*A23*A44+A13*A24*A41+A14*A21*A43-A14*A23*A41
> -A13*A21*A44-A11*A43*A24)
COF(3,3)=A11*A22*A44+A12*A24*A41+A14*A21*A42-A14*A22*A41
> -A12*A21*A44-A11*A42*A24
COF(3,4)=- (A11*A22*A43+A12*A23*A41+A13*A21*A42-A13*A22*A41
> -A12*A21*A43-A11*A42*A23)
COF(4,1)=- (A12*A23*A34+A13*A24*A32+A14*A22*A33-A14*A23*A32
> -A13*A22*A34-A12*A33*A24)
COF(4,2)=A11*A23*A34+A13*A24*A31+A14*A21*A33-A14*A23*A31
> -A13*A21*A34-A11*A33*A24
COF(4,3)=- (A11*A22*A34+A12*A24*A31+A14*A21*A32-A14*A22*A31
> -A12*A21*A34-A11*A32*A24)
COF(4,4)=A11*A22*A33+A12*A23*A31+A13*A21*A32-A13*A22*A31
> -A12*A21*A33-A11*A32*A23
AINV(1,1)=COF(1,1)/DET
AINV(1,2)=COF(2,1)/DET
AINV(1,3)=COF(3,1)/DET
AINV(1,4)=COF(4,1)/DET
AINV(2,1)=COF(1,2)/DET
AINV(2,2)=COF(2,2)/DET
AINV(2,3)=COF(3,2)/DET
AINV(2,4)=COF(4,2)/DET
AINV(3,1)=COF(1,3)/DET
AINV(3,2)=COF(2,3)/DET
AINV(3,3)=COF(3,3)/DET
AINV(3,4)=COF(4,3)/DET
AINV(4,1)=COF(1,4)/DET
AINV(4,2)=COF(2,4)/DET
AINV(4,3)=COF(3,4)/DET
AINV(4,4)=COF(4,4)/DET
C CALL MMM(4,A,AINV,B)
C DO 1 MM=1,4
C WRITE(6,10) (B(MM,NN),NN=1,4)
C 1 CONTINUE
10 FORMAT(4D16.7)
RETURN
END
C*****
SUBROUTINE CPGAM(CP,CV,GAMMA,GM1,R,I,J,
> RHO,RHOU,RHOV,E,TCP)
C*****
PARAMETER(IZ=150,JZ=100)
IMPLICIT REAL*8 (A-H,O-Z)
COMMON/CPCOFF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
> ,CPA8,CPA9,CPA10,ENE(101)
C=====
IF(TCP.NE.0.0) GOTO 20
UU=RHOU/RHO
VV=RHOV/RHO
EE=E/RHO-0.5*(UU**2+VV**2)
TT=300.0
IF(EE.LE.ENE(1)) GO TO 20
DO 10 MM=1,101
EA= EE - ENE(MM)

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```

      EB= EE - ENE(MM+1)
      ESIGN= EA*EB
      IF(ESIGN.LE.0.DO)THEN
        T1=300.0+27.611*DFLOAT(MM-1)
        T2=300.0+27.611*DFLOAT(MM)
        TT=(T2*EA-T1*EB)/(EA-EB)
        GO TO 20
      ELSE
        END IF
10    CONTINUE
      TT=3061.1DO
20    CONTINUE
      IF(TCP.NE.0.0) TT=TCP
C*
      IF(TT.LE.1000.0)THEN
        CP=(CPA6+CPA7*TT+CPA8*TT**2+CPA9*TT**3+CPA10*TT**4)
        CV=CP-R
      ELSE
        CP=(CPA1+CPA2*TT+CPA3*TT**2+CPA4*TT**3+CPA5*TT**4)
        CV=CP-R
      END IF
      GAMMA=CP/CV
      GM1=GAMMA-1.0
      RETURN
      END
C*****
      SUBROUTINE CPCOEF
C*****
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/CPCOEF/ CPA1,CPA2,CPA3,CPA4,CPA5,CPA6,CPA7
      > ,CPA8,CPA9,CPA10,ENE(101)
      DIMENSION Y(10),A1(10),A2(10),A3(10),A4(10),A5(10)
      > ,A6(10),A7(10),A8(10),A9(10),A10(10),WM(10)
      DATA RU,WMMIX/8314.3,20.405/
C=====
C CO
      WM(1)=28.010
      Y(1)= 0.13108
C CO2
      WM(2)=44.0
      Y(2)= 0.03636
C H
      WM(3)=1.0
      Y(3)= 0.02387
C H2
      WM(4)=2.0
      Y(4)= 0.15802
C H2O
      WM(5)=18.0
      Y(5)= 0.32366
C NO
      WM(6)=30.0
      Y(6)= 0.00260
C N2
      WM(7)=28.0

```

```

      Y(7)= 0.30407
C O
      WM(8)=16.0
      Y(8)= 0.00158
C OH
      WM(9)=17.0
      Y(9)= 0.01744
C O2
      WM(10)=32.0
      Y(10)= 0.00129
C-----CO
      A1(1)= 0.29840696E+01
      A2(1)= 0.14891390E-02
      A3(1)=-0.57899684E-06
      A4(1)= 0.10364577E-09
      A5(1)=-0.69353550E-14
C
      A6(1)= 0.37100928E+01
      A7(1)=-0.16190964E-02
      A8(1)= 0.36923594E-05
      A9(1)=-0.20319674E-08
      A10(1)= 0.23953344E-12
C-----CO2
      A1(2)= 0.44608041E+01
      A2(2)= 0.30981719E-02
      A3(2)=-0.12392571E-05
      A4(2)= 0.22741325E-09
      A5(2)=-0.15525954E-13
C
      A6(2)= 0.24007797E+01
      A7(2)= 0.87350957E-02
      A8(2)=-0.66070878E-05
      A9(2)= 0.20021861E-08
      A10(2)= 0.63274039E-15
C-----H
      A1(3)= 0.25000000E+01
      A2(3)= 0.00000000
      A3(3)= 0.00000000
      A4(3)= 0.00000000
      A5(3)= 0.00000000
C
      A6(3)= 0.25000000E+01
      A7(3)= 0.00000000
      A8(3)= 0.00000000
      A9(3)= 0.00000000
      A10(3)= 0.00000000
C-----H2
      A1(4)= 0.30558123E+01
      A2(4)= 0.59740400E-03
      A3(4)=-0.16747471E-08
      A4(4)=-0.21247544E-10
      A5(4)= 0.25195487E-14
C
      A6(4)= 0.29432327E+01
      A7(4)= 0.34815509E-02

```

A8(4)=-0.77713819E-05  
 A9(4)= 0.74997496E-08  
 A10(4)=-0.25203379E-11

C-----H2O

A1(5)= 0.26340654E+01  
 A2(5)= 0.31121899E-02  
 A3(5)=-0.90278449E-06  
 A4(5)= 0.12673054E-09  
 A5(5)=-0.69164732E-14

C

A6(5)= 0.41675564E+01  
 A7(5)=-0.18106868E-02  
 A8(5)= 0.59450878E-05  
 A9(5)=-0.48670871E-08  
 A10(5)= 0.15284144E-11

C-----NO

A1(6)= 0.31486543E+01  
 A2(6)= 0.14151823E-02  
 A3(6)=-0.57574881E-06  
 A4(6)= 0.10738529E-09  
 A5(6)=-0.73900199E-14

C

A6(6)= 0.42484931E+01  
 A7(6)=-0.48661106E-02  
 A8(6)= 0.11634155E-04  
 A9(6)=-0.99768494E-08  
 A10(6)= 0.30483948E-11

C-----N2

A1(7)= 0.28536374E+01  
 A2(7)= 0.16014368E-02  
 A3(7)=-0.62888336E-06  
 A4(7)= 0.11428932E-09  
 A5(7)=-0.77953822E-14

C

A6(7)= 0.37034288E+01  
 A7(7)=-0.14179405E-02  
 A8(7)= 0.28625094E-05  
 A9(7)=-0.12018374E-08  
 A10(7)=-0.13475522E-13

C-----O

A1(8)= 0.25342961E+01  
 A2(8)=-0.12478170E-04  
 A3(8)=-0.12562724E-07  
 A4(8)= 0.69029862E-11  
 A5(8)=-0.63797095E-15

C

A6(8)= 0.30309401E+01  
 A7(8)=-0.22525853E-02  
 A8(8)= 0.39824540E-05  
 A9(8)=-0.32604921E-08  
 A10(8)= 0.10152035E-11

C-----OH

A1(9)= 0.28897814E+01  
 A2(9)= 0.10005879E-02  
 A3(9)=-0.22048807E-06

A4(9)= 0.20191288E-10  
A5(9)=-0.39409831E-15

C

A6(9)= 0.38737300E+01  
A7(9)=-0.13393772E-02  
A8(9)= 0.16348351E-05  
A9(9)=-0.52133639E-09  
A10(9)= 0.41826974E-13

C-----02

A1(10)= 0.36122139E+01  
A2(10)= 0.74853166E-03  
A3(10)=-0.19820647E-06  
A4(10)= 0.33749008E-10  
A5(10)=-0.23907374E-14

C

A6(10)= 0.37837135E+01  
A7(10)=-0.30233634E-02  
A8(10)= 0.99492751E-05  
A9(10)=-0.98189101E-08  
A10(10)= 0.33031825E-11

C=====

CPA1=0.D0  
CPA2=0.D0  
CPA3=0.D0  
CPA4=0.D0  
CPA5=0.D0  
CPA6=0.D0  
CPA7=0.D0  
CPA8=0.D0  
CPA9=0.D0  
CPA10=0.D0  
DO 10 J=1,10  
CPA1=CPA1+Y(J)\*A1(J)\*RU/WMMIX  
CPA2=CPA2+Y(J)\*A2(J)\*RU/WMMIX  
CPA3=CPA3+Y(J)\*A3(J)\*RU/WMMIX  
CPA4=CPA4+Y(J)\*A4(J)\*RU/WMMIX  
CPA5=CPA5+Y(J)\*A5(J)\*RU/WMMIX  
CPA6=CPA6+Y(J)\*A6(J)\*RU/WMMIX  
CPA7=CPA7+Y(J)\*A7(J)\*RU/WMMIX  
CPA8=CPA8+Y(J)\*A8(J)\*RU/WMMIX  
CPA9=CPA9+Y(J)\*A9(J)\*RU/WMMIX  
CPA10=CPA10+Y(J)\*A10(J)\*RU/WMMIX

10 CONTINUE

C...

R=RU/WMMIX  
DO 20 MM=1,101  
TT=300.0+27.611\*DFLOAT(MM-1)  
IF(TT LE.1000.0)THEN  
CP=(CPA6+CPA7\*TT+CPA8\*TT\*\*2+CPA9\*TT\*\*3+CPA10\*TT\*\*4)  
CV=CP-R  
ENE(MM)=CV\*TT  
ELSE  
CP=(CPA1+CPA2\*TT+CPA3\*TT\*\*2+CPA4\*TT\*\*3+CPA5\*TT\*\*4)  
CV=CP-R  
ENE(MM)=CV\*TT

```

      END IF
20    CONTINUE
      RETURN
    END

```

```

DATA INPUT DD *
&INPUT IL=135, JL=80, NBEG=1, NEND=1, NITER=1, PO=1 D+06, TO=3061.1D0,
  CFL1=0.5D+04, CFL=100., OMEGAX=0., OMEGAY=0.5, RM1=1.2, RM2=4.0, NORD=1,
  AIN=0.05, AEX=.236, RL=.695, THETA=1.0, CPO=7152.4853, GAMMA0=1.17,
  ITIME=1, IREAD=1, FST=0.00, TWALL=3000., FSTY=0.9, PB=0., PRNT=0.7,
  IVISC=1, IWALL=0, PRN=0.7, REN=1.D5, TREF=3000., ZMUO=8.5D-03,
  IWBC=1 BIOT=15., TW1=500., IFLOW=1
&END

DATA FT38F001 DD DSN=STU.I19500.MYH100.HERMES.DIF.H135M80.VIS,
  DISP=(OLD,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
  DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
  SPACE=(TRK,(9,5),RLSE)
DATA FT66F001 DD DSN=STU.I19500.MYH100.HERMES2.DIF.RERUN.VIS,
  DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
  DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
  SPACE=(TRK,(9,5),RLSE)
DATA FT19F001 DD DSN=STU.I19500.MYH100.HERMES2.DIF.DQ.VIS,
  DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
  DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120),
  SPACE=(TRK,(9,5),RLSE)
DATA FT18F001 DD DSN=STU.I19500.MYH100.HERMES2.DIF.SOLU.VIS,
  DISP=(NEW,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
  DCB=(RECFM=FB,LRECL=130,BLKSIZE=3120),
  SPACE=(TRK,(9,5),RLSE)
DATA FT68F001 DD DSN=STU.I19500.MYH100.HERMES.CONV.LINE.VIS,
  DISP=(OLD,KEEP),VOL=REF=STU.I19500.MYH100.LIB,
  DCB=(RECFM=VBS,LRECL=80,BLKSIZE=3120),
  SPACE=(TRK,(9,5),RLSE)
EXEC PROMPTME

```

X14140

USERID: V19                      ORIGIN: PSUVM                      CREATED: 06/20/89                      15:48:19  
FILENAME: NPROG11                      FOR                      CLASS: A                      FORMAT: J  
SPOOLID: 2822                      RECS: 3707                      COPY: 1                      DUPLICATE: 1

PRINTED AT: PSUVM                      ID: \$PPCBP01                      AT: 06/20/89                      15:48:27

\*\*\*\*\*  
\*  
\* THIS FILE WAS SENT BY THE COMMAND:  
\* PRT3812 NPROG11 FOR A1 ( PPCB1 COPIES 1 ORIENT N FONT 11  
\*  
\*\*\*\*\*

```

PROGRAM NOZZLE(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
> TAPE1,TAPE2,TAPE3,TAPE4,TAPE7,TAPE8,TAPE9,TAPE10,
> TAPE11,TAPE12)
*****
* PROGRAM NAME: NOZZLE *
* AXISYMMETRIC SUPERSONIC NOZZLE FLOW *
* IN GENERAL COORDINATE SYSTEM *
* USING TIME ITERATIVE UW/CD DDADI METHOD *
* WITH THIN-LAYER APPROXIMATED NAVIER-STOKES' EQS. *
*****
*
* MAIN PROGRAM
*
*****
* TAPE1 - READ NAMELIST /INPUT/
* TAPE2 - WRITE NAMELIST /INPUT/
* TAPE3 - READ X(I,J), Y(I,J)
* TAPE4 - WRITE FLRT
* TAPE5 - READ INPUT DATA
* TAPE6 - WRITE OUTPUT DATA
* TAPE7 - READ DELTAU(I,J), Q(I,J,K)
* TAPE8 - WRITE DELTAU(I,J), Q(I,J,K)
* TAPE9 - READ NEND, SS(K) (=DQ/Q)
* TAPE10 - WRITE NEND, SS(K) (=DQ/Q)
* TAPE11 - READ NAMELIST /DINPL/
* TAPE12 - WRITE NAMELIST /DINPL/
PARAMETER (IZ=60,JZ=40)
COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
> G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
> U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
> ZMU(JZ),ZMUT(JZ),ZK(JZ)
COMMON /COORD/ SAIY(IZ,JZ),SAIX(IZ,JZ),ETAX(IZ,JZ),
> ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
> DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
> A4(IZ,JZ)
COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
> RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
> PO,TO,TWALL,PB,SUM(4)
COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
> IVISC,IWALL,IWRT
COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
> X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
> X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
> X7(9),Y7(9),F7(9,9)
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
*****
CALL INITIA
WRITE (6,500)
500 FORMAT(1H1//)
DO 10 NADV=NBEG,NEND
CALL SOLVE
CALL CHECK

```

```

10 CONTINUE
  WRITE (6,500)
  CALL MASS
  WRITE (6,500)
  CALL OUTPUT
  STOP
  END
  SUBROUTINE INITIA

```

```

*****

```

```

*
*   SET UP INITIAL CONDITIONS
*

```

```

*****

```

```

  PARAMETER (IZ=60,JZ=40)
  COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
>    G(IZ,JZ,4),P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
>    U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
>    ZMU(JZ),ZMUT(JZ),ZK(JZ)
  COMMON /COORD/ SAIY(IZ,JZ),SAIX(IZ,JZ),ETAX(IZ,JZ),
>    ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
>    DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
>    A4(IZ,JZ)
  COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
>    RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
>    PC,TO,TWALL,PB,SUM(4)
  COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
>    IVISC,IWALL,IWRT
  COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
>    X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
>    X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
>    X7(9),Y7(9),F7(9,9)
  DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
  EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
>    (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
  DIMENSION SS(4)
  NAMELIST /INPUT/ IL,JL,NBEG,NEND,NITER,THETA,NORD,CFL,CFL1,
>    ITIME,OMEGAX,OMEGAY,AIN,AEX,RL,FST,FSTY,RM1,RM2,
>    IVISC,IWALL,RG,AMWO,GAMMAO,CP,REN,PRN,PRNT,TREF,
>    ZMUO,OMEGA,PO,TO,TWALL,PB,IREAD,IWRT,IRUN
  NAMELIST /DINPL/ X1,Y1,F1,X2,Y2,F2,X3,Y3,F3,
>    X4,Y4,F4,X5,Y5,F5,X6,Y6,F6,
>    X7,Y7,F7

```

```

*****

```

```

*
*   IF THE DIMENSION IN COMMON BLOCK MUST BE CHANGED
*   PLEASE CHANGE THE PARAMETER STATEMENT
*

```

```

... IL=TOTAL GRID NUMBER IN XI DIRECTION
... JL=TOTAL GRID NUMBER IN ETA DIRECTION
... NBEG=COUNTING INDEX OF ITERATION STEP
    =1 FOR THE FIRST RUN
    =ANY NUMBER EXCEPT 1 FOR RERUN
... NEND=NUMBER OF ITERATIONS FOR THE FIRST RUN ONLY
... NITER=NUMBER IF ITERATIONS TO BE RUN WHEN RERUN (NBEG.NE.1)
... THETA=ALWAYS EQUALS 1

```

```

... NORD=IN USE IN PNS, NOT IN USE IN TLNS
... CFL=CFL NUMBER
... CFL1=CFL NUMBER FOR PNS MARCHING
... ITIME=0 FOR CONSTANT DT
      =1 FOR CONSTANT CFL
... OMEGAX=ARTIFICIAL DISSIPATION CONSTANT IN XI DIRECTION
... OMEGAY=ARTIFICIAL DISSIPATION CONSTANT IN ETA DIRECTION
... AIN=THE INLET RADIUS FOR CONICAL NOZZLE (IGNORED IN IREAD=1)
... AEX=THE EXIT RADIUS FOR CONICAL NOZZLE (IGNORED IF IREAD=1)
... RL=TOTAL LENGTH OF CONICAL NOZZLE (IGNORED IF IREAD=1)
... FST=STRETCHING FACTOR IN XI DIRECTIO (0 FOR UNIFORM GRID)
      (IGNORED IN IREAD=1) (NOT IN USE IN TLNS)
... FSTY=STRETCHING FACTOR IN ETA DIRECTION (0 FOR UNIFORM GRID)
      (IGNORED IN IREAD=1) (NOT IN USE IN TLNS)
... RM1=THE INITIAL GUESS FOR INLET MACH NUMBER
      (IGNORED IN IREAD=1)
... RM2=THE INITIAL GUESS FOR EXIT MACH NUMBER
      (IGNORED IN IREAD=1)
... IVISC=0 INVISCID FLOW
      =1 VISCOUS FLOW
... IWALL=0 FOR ADIABATIC WALL
      =1 FOR CONSTANT WALL TEMPERATURE
... RG=UNIVERSAL GAS CONSTANT (NOT IN USE IN PNS SOLUTION)
... AMWO=MOLECULAR WEIGHT IN STAGNATION CHAMBER
      (NOT IN USE IN PNS)
... GAMMA0=SPECIFIC HEAT RATIO (STAGNATION CHAMBER VALUE WHEN
      USED FOR REAL CASES IN TLNS)
... CP=CONSTANT PRESSURE SPECIFIC HEAT (NOT IN USE IN TLNS)
... REN=REYNOLDS NUMBER
      (CAN BE SWITCH ON OR OFF IN THIS SUBROUTINE)
... PRN=PRANDTL NUMBER
... PRNT=TURBULENT PRANDTL NUMBER
      =0. FOR LAMINAR FLOW
      =0.9 FOR TURBULENT FLOW
... TREF=THE REFERENCE TEMPERATURE FOR VISCOSITY CALCULATION
... ZMUO=THE VISCOSITY AT T=TREF
... OMEGA=EXPONENTIAL VISCOSITY LAW
... PO=STAGNATION PRESSURE
... TO=STAGNATION TEMPERATURE
... TWALL=GIVEN WALL TEMPERATURE FOR IWALL=1
... PB=THE BACK PRESSURE AT THE EXIT OF NOZZLE
      =0. (SUBSONIC FLOW EXTRAPOLATED FROM INTERIOR)
      =THE SPECIFIED BACK PRESSURE (FIXED THE PRESSURE FOR
      SUBSONIC PORTION AT EXIT)
... IREAD=0 FOR DEFAULT CONICAL NOZZLE
      =1 READ GRID FROM DATA FILE
... IWRT=1 PRINTING OF FLOWFIELD RESULTS
      =0 NO PRINTING OF FLOWFIELD RESULTS
... IRUN=0 FOR 1ST RUN
*
* READ INPUT DATA
*
READ (1,INPUT)
READ (11,DINPL)
IRUN=IRUN+1

```



```

CALL MCONST
*
*   INITIALIZATION - COMPUTE Q(I,J,K)
*
*
*   GIVE THE INITIAL VALUE OF VISCOSTY
*   IF THE VISCOSITY AT T=TREF IS GIVEN FROM INPUT
*   THE CALCULATION FOR ZMUO MUST BE SWITCHED OFF
*
GM1=GAMMAO-1.
R=RG/AMWO
CV=CP/GAMMAO
TIN=TO/(1.+0.5*GM1*RM1**2)
UIN=RM1*SQRT(GAMMAO*R*TIN)
PIN=PO*(TIN/TO)**(GAMMAO/GM1)
RIN=PIN/(R*TIN)
ZMUO=(RIN*UIN*Y(1)*2.)/REN
*
*   SKIP TO RERUN THE CODE
*
IF(IRUN.NE.1) GO TO 100
DO 40 I=1,IL
IF(I.EQ.1) THEN
    AMWS=AMWO
    GAMMA=GAMMAO
    GM1=GAMMA-1.
    RO=PO/(RG/AMWS)/TO
END IF
42 RM=RM1+FLOAT(I-1)/FLOAT(IL1)*(RM2-RM1)
GMM=1.+0.5*GM1*RM**2
TS=TO/GMM
PS=PO/GMM**(GAMMA/GM1)
RS=PS/(RG/AMWS)/TS
IF(I.EQ.1) THEN
    WRITE (6,504) TS,PS,RS,AMWS,GAMMA
504   FORMAT(/,1X,' TS=',E11.5,' PS=',E11.5,' RS=',E11.5,
>         16X,' AMW=',E11.5,' GAMMA=',E11.5)
41   TS1=TS
    PS1=PS
    RS1=RS
    ES=FE(RS,TS)
    AMWS=FAMW(RS,TS)
    GAMMA=1.+(RG/AMWS)/(ES/TS)
    GM1=GAMMA-1
    GMM=1.+0.5*GM1*RM**2
    TS=TO/GMM
    PS=PO/GMM**(GAMMA/GM1)
    RS=PS/(RG/AMWS)/TS
    WRITE (6,503) TS,PS,RS,ES,AMWS,GAMMA
503   FORMAT(1X,' TS=',E11.5,' PS=',E11.5,' RS=',E11.5,
>         ' ES=',E11.5,' AMW=',E11.5,' GAMMA=',E11.5)
    IF(ABS(TS-TS1).GT.1.E-5.OR.ABS(PS-PS1).GT.1.E-5.OR.
>     ABS(RS-RS1).GT.1.E-5) GO TO 41
END IF
ES=FE(RS,TS)

```

```

CO=SQRT(FCO2(PS,RS,TS,ES,AMWS))
UU=RM*CO
DO 40 J=1,JL
IF(I.EQ.1.OR.I.EQ.IL) THEN
  IF(I.EQ.1) SLOPE=(Y(I+1,J)-Y(I,J))/(X(I+1,J)-X(I,J))
  IF(I.EQ.IL) SLOPE=(Y(I,J)-Y(I-1,J))/(X(I,J)-X(I-1,J))
ELSE
  SLOPE=(Y(I+1,J)-Y(I-1,J))/(X(I+1,J)-X(I-1,J))
END IF
DENOM=SQRT(1.+SLOPE*SLOPE)
U(I,J)=UU/DENOM
V(I,J)=UU*SLOPE/DENOM
UN(I,J)=SAIX(I,J)*U(I,J)+SAIY(I,J)*V(I,J)
VN(I,J)=ETAX(I,J)*U(I,J)+ETAY(I,J)*V(I,J)

```

```

*
* SLIP INITIAL CONDITION, IVISC=0
*

```

```

IF(J.EQ.JL.AND.IVISC.EQ.0) THEN
  U(I,J)=UU/DENOM
  V(I,J)=-ETAX(I,J)/ETAY(I,J)*U(I,J)
  UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
  VN(I,J)=0.
END IF

```

```

*
* NO-SLIP INITIAL CONDITION, IVISC=1
*

```

```

IF(J.EQ.JL.AND.IVISC.EQ.1) THEN
  U(I,J)=0.
  V(I,J)=0.
  UN(I,J)=0.
  VN(I,J)=0.
END IF
AMW(I,J)=AMWS
E(I,J)=ES
T(I,J)=TS
P(I,J)=PO/(TO/T(I,J))*(GAMMA/GM1)
IF(J.EQ.JL.AND.IVISC.EQ.1) THEN
  IF(IWALL.EQ.1) T(I,J)=TWALL
  P(I,J)=P(I,J-1)
  IF(I.EQ.IL.AND.PB.NE.0.0) P(I,J)=PB
ELSE
END IF

```

```

RHO(I,J)=P(I,J)/(RG/AMW(I,J))/T(I,J)
RHOU(I,J)=RHO(I,J)*U(I,J)
RHOV(I,J)=RHO(I,J)*V(I,J)
EO(I,J)=RHO(I,J)*(E(I,J)+0.5*(U(I,J)**2+V(I,J)**2))

```

```

40 CONTINUE

```

```

*
* INITIALIZATION - COMPUTE DELTAU(I,J)
*

```

```

EIGMAX=0.
DO 50 I=1,IL
DO 50 J=1,JL
CO=SQRT(FCO2(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J)))
CX=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)

```

```

CY=SQRT(ETAX(I,J)**2+ETAY(I,J)**2)
CX=(UN(I,J)+CX*CO)/EXI
CY=(VN(I,J)+CY*CO)/EYI
EIGNN=ABS(CX)
IF(EIGNN.LE.ABS(CY)) EIGNN=ABS(CY)
IF(ETIME.EQ.1) GO TO 55
IF(CX.GE.EIGMAX) EIGMAX=CX
IF(CY.GT.EIGMAX) EIGMAX=CY
55 DELTAU(I,J)=CFL/EIGNN
50 CONTINUE
WRITE (6,INPUT)
WRITE (2,INPUT)
WRITE (6,DINPL)
IF(ETIME.EQ.1) RETURN
DO 60 I=1,IL
DO 60 J=1,JL
DELTAU(I,J)=CFL/EIGMAX
60 CONTINUE
RETURN
100 CONTINUE
*
* READ FLOWFIELD DATA, (NBEG, NEND ARE DETERMIND BY NDUM)
*
70 READ (9,502,END=65) NDUM,(SS(K),K=1,4)
502 FORMAT(15,3X,4(1X,E14.7))
WRITE (10,502) NDUM,(SS(K),K=1,4)
GO TO 70
65 CONTINUE
NBEG=NDUM+1
NEND=NBEG+NITER-1
READ (7) ((DELTAU(I,J),I=1,IL),J=1,JL)
READ (7) ((RHO(I,J),RHOV(I,J),RHOV(I,J),EO(I,J),
> I=1,IL),J=1,JL)
DO 80 I=1,IL
DO 80 J=1,JL
U(I,J)=RHOV(I,J)/RHO(I,J)
V(I,J)=RHOV(I,J)/RHO(I,J)
UN(I,J)=U(I,J)*SAIX(I,J)+V(I,J)*SAIY(I,J)
VN(I,J)=U(I,J)*ETAX(I,J)+V(I,J)*ETAY(I,J)
E(I,J)=EO(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2)
T(I,J)=FT(RHO(I,J),E(I,J))
AMW(I,J)=FAMW(RHO(I,J),T(I,J))
P(I,J)=RHO(I,J)*(RG/AMW(I,J))*T(I,J)
80 CONTINUE
*
* CHANGES IN /INPUT/ PUT HERE AND ADD - WRITE (2,INPUT)
*
WRITE (6,INPUT)
WRITE (6,DINPL)
RETURN
END
SUBROUTINE SOLVE
*****
*
* SOLVE SUBROUTINE

```

```

*
*****
PARAMETER (IZ=60,JZ=40)
COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
> G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
> U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
> ZMU(JZ),ZMUT(JZ),ZK(JZ)
COMMON /COORD/ SAIY(IZ,JZ),SAIX(IZ,JZ),ETAX(IZ,JZ),
> ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
> DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
> A4(IZ,JZ)
COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
> RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
> PO,TO,TWALL,PB,SUM(4)
COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
> IVISC,IWALL,IWRT
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
*****
JEND=JL
IF(IVISC.EQ.1) JEND=JL1

*
* FORWARD SWEEP
*
*
* RHS CALCULATIONS
*
DO 20 I=2,IL
CALL RHSEF(I)
IF(IVISC.EQ.1) THEN
CALL MULAM(I)
IF(PRNT.NE.0.0) CALL MUTUR(I)
CALL KLAM(I)
IF(PRNT.NE.0.0) CALL KTUR(I)
CALL RHSVS(I)
END IF
CALL RHSH(I)

*
* CALCULATE RESIDUAL
*
DO 20 J=1,JL
DO 20 K=1,4
DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
20 CONTINUE

*
* ADD SAI DIRECTION 4TH ORDER ARITFICIAL VISCOSITY
*
IF(OMEGAX.NE.0.0) CALL ADDX

*
* ADD ETA DIRECTION 4TH ORDER ARITFICIAL VISCOSITY
*
IF(OMEGAY.NE.0.0) CALL ADDY
DO 30 I=2,IL

```

```

*      SOLVE L-ETA OPERATOR
*
      CALL COEFY(I)
*
*      UPDATE VARIABLES FORWARD SWEEP
*
      DO 40 J=2,JEND
      RJJ=RJ(I,J)/Y(I,J)
      DO 45 K=1,4
      Q(I,J,K)=Q(I,J,K)+DQ(I,J,K)*RJJ
45  CONTINUE
      U(I,J)=RHOU(I,J)/RHO(I,J)
      V(I,J)=RHOV(I,J)/RHO(I,J)
      UN(I,J)=SAIX(I,J)*U(I,J)+SAIY(I,J)*V(I,J)
      VN(I,J)=U(I,J)*ETAX(I,J)+ETAY(I,J)*V(I,J)
      E(I,J)=EO(I,J)/RHO(I,J)-0.5*(U(I,J)**2+V(I,J)**2)
      T(I,J)=FT(RHO(I,J),E(I,J))
      AMW(I,J)=FAMW(RHO(I,J),T(I,J))
      P(I,J)=RHO(I,J)*(RG/AMW(I,J))*T(I,J)
40  CONTINUE
      CALL MULAM(I)
*      CENTERLINE BOUNDARY CONDITIONS
*
      CALL CLBC(I)
*
*      WALL BOUNDARY CONDITIONS
*
      IF(IVISC.EQ.1) CALL WALLBC(I)
30  CONTINUE
*
*      BACKWARD SWEEP
*
*
*      RHS CALCULATIONS
*
      DO 70 IB=2,IL1
      I=IL1-IB+2
      CALL RHSEF(I)
      IF(IVISC.EQ.1) THEN
        CALL MULAM(I)
        IF(PRNT.NE.O.O) CALL MUTUR(I)
        CALL KLAM(I)
        IF(PRNT.NE.O.O) CALL KTUR(I)
        CALL RHSVS(I)
      END IF
      CALL RHSH(I)
*
*      CALCULATE RESIDUAL
*
      DO 70 J=1,JL
      DO 70 K=1,4
      DQ(I,J,K)=-DELTAU(I,J)*DQ(I,J,K)
70  CONTINUE
*
*      ADD SAI DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY

```

```

*
  IF(OMEGAX.NE.0.0) CALL ADDX
*
*  ADD ETA DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
*
  IF(OMEGAY.NE.0.0) CALL ADDY
  DO 80 IB=2, IL1
    I=IL1-IB+2
*
*  SOLVE L-ETA OPERATOR
*
  CALL COEFY(I)
*
*  UPDATING VARIABLES BACKWARD SWEEP
*
  DO 90 J=2, JEND
    RJJ=RJ(I, J)/Y(I, J)
    DO 95 K=1, 4
      Q(I, J, K)=Q(I, J, K)+DQ(I, J, K)*RJJ
95  CONTINUE
    U(I, J)=RHOU(I, J)/RHO(I, J)
    V(I, J)=RHOV(I, J)/RHO(I, J)
    UN(I, J)=U(I, J)*SAIX(I, J)+V(I, J)*SAIY(I, J)
    VN(I, J)=U(I, J)*ETAX(I, J)+V(I, J)*ETAY(I, J)
    E(I, J)=EO(I, J)/RHO(I, J)-0.5*(U(I, J)**2+V(I, J)**2)
    T(I, J)=FT(RHO(I, J), E(I, J))
    AMW(I, J)=FAMW(RHO(I, J), T(I, J))
    P(I, J)=RHO(I, J)*(RG/AMW(I, J))*T(I, J)
*
*  UPDATING DELTAU(I, J)
*
    CO=SQRT(FCO2(P(I, J), RHO(I, J), T(I, J), E(I, J), AMW(I, J)))
    CX=SQRT(SAIX(I, J)**2+SAIY(I, J)**2)
    CY=SQRT(ETAX(I, J)**2+ETAY(I, J)**2)
    CX=(UN(I, J)+CX*CO)
    CY=(VN(I, J)+CY*CO)
    EIGNN=ABS(CX)
    IF(EIGNN.LE.ABS(CY)) EIGNN=ABS(CY)
    DELTAU(I, J)=ITIME*CFE/EIGNN+(1-ITIME)*DELTAE(I, J)
90  CONTINUE
*
*  CENTERLINE BOUNDARY CONDITIONS
*
  CALL CLBC(I)
*
*  WALL BOUNDARY CONDITIONS
*
  IF(IVISC.EQ.1) CALL WALLBC(I)
80  CONTINUE
  RETURN
  END
  SUBROUTINE COEFY(I)
*****
*
*  SETTING COEFFICIENTS FOR LY-OPERATOR

```

\*  
\*\*\*\*\*

```

PARAMETER (IZ=60,JZ=40)
COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
> G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
> U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
> ZMU(JZ),ZMUT(JZ),ZK(JZ)
COMMON /COORD/ SAIK(IZ,JZ),SAIJ(IZ,JZ),ETAX(IZ,JZ),
> ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
> DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
> A4(IZ,JZ)
COMMON /CONS/ EXI,EYI,THETA,CFL,CELL,OMEGAX,OMEGAY,AIN,AEX,
> RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
> PO,TO,TWALL,PB,SUM(4)
COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
> IVISC,IWALL,IWRT
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
DIMENSION IN(4),EE(4,4,JZ),EL(4,JZ),W(4,JZ)
DIMENSION AM(4,4),BM(4,4),CM(4,4),DM(4)
DIMENSION AL(4,4),BE(4),DTEMP(4),ISUB(JZ)
DIMENSION B(4,4),BL1(4,4),D(4,4),A(4,4),AJM(4,4)
DATA ISUB /JZ*0/

```

\*\*\*\*\*

\*  
\* CHECK THE SONIC POINT AT DOWNSTREAM END  
\*

```

IF(IVISC.NE.1) GO TO 5
IF(I.NE.IL) GO TO 5
DO 10 J=1,JL
CO=SQRT(FCO2(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J)))
CONTRA=UN(I,J)-SQRT(SAIK(I,J)**2+SAIJ(I,J)**2)*CO
IF(CONTRA.LT.0.0) THEN
    ISUB(J)=1
ELSE
    ISUB(J)=0
END IF
IF(PB.EQ.0.0) ISUB(J)=0
10 CONTINUE
5 CONTINUE

```

\*  
\* ON THE CENTER LINE OF THE NOZZLE AT J=1  
\*

```

J=1
CALL SZERO(4,AM)
CALL SZERO(4,BM)
DO 15 M=1,4
DM(M)=0.
BM(M,M)=BM(M,M)+1.0
15 CONTINUE
CALL SZERO(4,CM)
CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)

```

\*  
\* INTERIOR NODS

```

*
DO 20 J=2,JL1
TAUD=0.50*DELTAU(I,J)*THETA/EYI
TAUD2=2.*TAUD
JM1=J-1
JP1=J+1
CALL JCBAB(2,0,B,I,JM1)
CALL SMM(4,TAUD,B,AM)
CALL SZERO(4,BM)
DO 25 M=1,4
  BM(M,M)=BM(M,M)+1.
25 CONTINUE
CALL JCBABFM(1,1,0,A,I,J)
CALL JCBABPM(1,2,0,AJM,I,J)
CALL JCBD(D,I,J)
DO 30 M=1,4
DO 30 N=1,4
  BM(M,N)=BM(M,N)-TAUD2*(D(M,N)-A(M,N)+AJM(M,N))
30 CONTINUE
CALL JCBAB(2,0,B,I,JP1)
CALL SMM(4,-TAUD,B,CM)
*
*   INSERT VISCOUS JACOBIAN LHS HERE
*
IF(IVISC.EQ.1) THEN
  CALL JCBMVS(A,B,D,I,J)
  DO 35 M=1,4
  DO 35 N=1,4
    AM(M,N)=AM(M,N)-DELTAU(I,J)*A(M,N)
    BM(M,N)=BM(M,N)+DELTAU(I,J)*B(M,N)
    CM(M,N)=CM(M,N)-DELTAU(I,J)*D(M,N)
35 CONTINUE
ELSE
  END IF
  DO 40 K=1,4
  DM(K)=DQ(I,J,K)
40 CONTINUE
*
*   DOWNSTREAM BOUNDARY CONDITIONS FOR VISCOUS FLOW
*
IF(IVISC.EQ.1.AND.(I.EQ.IL.AND.ISUB(J).EQ.1)) THEN
  CALL TMPM(1,0,BL1,I,J)
  DO 45 K=1,4
  BL1(4,K)=0.
45 CONTINUE
CALL MMM(4,BL1,AM,A)
CALL MMM(4,BL1,BM,B)
CALL MMM(4,BL1,CM,D)
DO 50 M=1,4
DO 50 N=1,4
  AM(M,N)=A(M,N)
  BM(M,N)=B(M,N)
  CM(M,N)=D(M,N)
50 CONTINUE
DO 55 M=1,4

```

```

        DTEMP(M)=0.
        DO 55 K=1,4
        DTEMP(M)=DTEMP(M)+BL1(M,K)*DM(K)
55      CONTINUE
        DO 60 M=1,4
        DM(M)=DTEMP(M)
60      CONTINUE
        AR=FAR(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J))
        AE=FAE(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J))
        AER=AE/RHO(I,J)
        DPDR=AR+AER*(-EO(I,J)/RHO(I,J)+(U(I,J)**2+V(I,J)**2))
        DPDU=-AER*U(I,J)
        DPDV=-AER*V(I,J)
        DPDE=AER
        BM(4,1)=DPDR/Y(I,J)
        BM(4,2)=DPDU/Y(I,J)
        BM(4,3)=DPDV/Y(I,J)
        BM(4,4)=DPDE/Y(I,J)
        IF(PB.NE.O.O) THEN
            DM(4)=(PB-P(I,J))/RJ(I,J)
        ELSE
            DM(4)=0.
        END IF
    ELSE
        END IF
    CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
120 CONTINUE
*
*      WALL BOUNDARY CONDITIONS FOR INVISCID FLOW, EULER EQS.
*
        J=JL
        TAUD=THETA*DELTAU(I,J)/EYI
        IF(IVISC.EQ.1) GO TO 65
        CALL SZERO(4,AM)
        CALL JCBAB(2,0,B,I,J-1)
        CALL JCBABPM(1,1,0,A,I,J)
        CALL JCBABPM(1,2,0,AJM,I,J)
        CALL TMFM(2,0,BL1,I,J)
        DO 70 M=1,3
        DO 70 N=1,4
        DO 70 K=1,4
        AM(M,N)=AM(M,N)+TAUD*BL1(M,K)*B(K,N)
70      CONTINUE
        CALL SZERO(4,BM)
        CALL JCBAB(2,0,B,I,J)
        CALL JCBBD(D,I,J)
        DO 75 M=1,3
        DO 75 N=1,4
        BM(M,N)=BM(M,N)+BL1(M,N)
        DO 75 K=1,4
        BM(M,N)=BM(M,N)
        >      +TAUD*BL1(M,K)*(B(K,N)+A(K,N)-D(K,N)-AJM(K,N))
75      CONTINUE
        BM(4,1)=-VN(I,J)
        BM(4,2)=ETAX(I,J)

```

```

      BM(4,3)=ETAY(1,J)
      BM(4,4)=0.
      CALL SZERO(4,CM)
      DO 80 M=1,3
      DM(M)=0.
      DO 80 K=1,4
      DM(M)=DM(M)+BL1(M,K)*DQ(I,J,K)
80  CONTINUE
      DM(4)=0.
      GO TO 85
65  CONTINUE
      CALL SZERO(4,AM)
      CALL SZERO(4,BM)
      CALL SZERO(4,CM)
      DO 90 M=1,4
      DM(M)=0.
90  BM(M,M)=1.0
85  CONTINUE
      CALL EEL(J,4,JL,EE,EL,AM,BM,CM,DM,IN,AL,BE)
*
*      SOLVE 4*4 BLOCK TRIDIAGONAL MATRICES
*
      CALL SOLU(W,JL,4,EE,EL)
      DO 95 J=1,JL
      DO 95 K=1,4
      DQ(I,J,K)=W(K,J)
95  CONTINUE
      RETURN
      END
      SUBROUTINE BC
*****
*
*      SUBROUTINE FOR BOUNDARY CONDITIONS
*
*****
      PARAMETER (IZ=60,JZ=40)
      COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
      >      G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
      >      U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
      >      ZMU(JZ),ZMUT(JZ),ZK(JZ)
      COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
      >      ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
      >      DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
      >      A4(IZ,JZ)
      COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
      >      RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
      >      PO,TO,TWALL,PB,SUM(4)
      COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
      >      IVISC,IWALL,IWRT
      DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
      EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),
      >      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
*****
      ENTRY CLBC(II)
*****

```

```

*
* CENTER LINE BOUNDARY CONDITIONS
*
  I=II
*
* THE QUANTITIES EXTRAPOLATED ARE U, RHO, EO AND LET V=0
*
  SY=SAIY(I,1)
  EY=ETAY(I,1)
  DENOM=SY-1.5*EY
  IF(I.EQ.1) THEN
    UIM1=0.
    RHOIM1=0.
    EOIM1=0.
  ELSE
    UIM1=U(I-1,1)
    RHOIM1=RHO(I-1,1)
    EOIM1=EO(I-1,1)
  END IF
  U(I,1)=(SY*UIM1-0.5*EY*(4.*U(I,2)-U(I,3)))/DENOM
  V(I,1)=0.
  UN(I,1)=SAIX(I,1)*U(I,1)
  VN(I,1)=ETAX(I,1)*U(I,1)
  RHO(I,1)=(SY*RHOIM1-0.5*EY*(4.*RHO(I,2)-RHO(I,3)))/DENOM
  EO(I,1)=(SY*EOIM1-0.5*EY*(4.*EO(I,2)-EO(I,3)))/DENOM
  E(I,1)=EO(I,1)/RHO(I,1)-0.5*(U(I,1)**2+V(I,1)**2)
  T(I,1)=FT(RHO(I,1),E(I,1))
  AMW(I,1)=FAMW(RHO(I,1),T(I,1))
  P(I,1)=RHO(I,1)*(RG/AMW(I,1))*T(I,1)
  RHOV(I,1)=RHO(I,1)*U(I,1)
  RHOV(I,1)=RHO(I,1)*V(I,1)
  RETURN
*****
  ENTRY WALLBC(II)
*****
*
* WALL BOUNDARY CONDITIONS FOR VISCOUS FLOW
*
  I=II
  J=JL
  CC1=ETAX(I,J)*SAIX(I,J)+ETAY(I,J)*SAIY(I,J)
  CC2=ETAX(I,J)**2+ETAY(I,J)**2
  IF(I.NE.IL) THEN
    AM=-0.5*CC1
    BM=1.5*CC2
    CM=0.5*CC1
    DM=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
  ELSE
    AM=-CC1
    BM=CC1+1.5*CC2
    CM=0.
    DM=CC2*(2.*P(I,J-1)-0.5*P(I,J-2))
  END IF
  IP1=I+1
  IF(I.EQ.IL) IP1=IL

```

```

*****
*
*   LAMINAR VISCOSITY CALCULATION
*
*   I=I I
*
*   USE SUTHELAND LAW
*
*   DO 10 J=1,JL
*   TOS=TREF+SCONST
*   TT=T(I,J)
*   TTS=TT+SCONST
*   ZMU(J)=ZMUO*TOS/TTS*(TT/TREF)**1.5
*
*   USE CONSTANT VISCOSITY
*
*   ZMU(J)=ZMUO
*
*   USE EXPONENTIAL VISCOSITY LAW
*
*   ZMU(J)=ZMUO*(TT/TREF)**OMEGA
*
*   USE DATA
*
*   ZMU(J)=FZMU(RHO(I,J),E(I,J))
10 CONTINUE
RETURN
*****
ENTRY MUTUR(II)
*****
*
*   BALDWIN - LOMAX TURBULENCE MODEL
*
*   I=I I
*   FYMAX=0.0
*   YMAX=0.0
*   UDIF=0.
*   YVERT(JL)=0.0
*   TAUW=ZMU(JL)*ABS(ETAY(I,JL)*(U(I,JL)-U(I,JL-1))
>   -ETAX(I,JL)*(V(I,JL)-V(I,JL-1)))
*   CYP=SQRT(RHO(I,JL)*TAUW)/ZMU(JL)
*
*   DO 20 KK=2,JL1
*   K=JL+1-KK
*   YVER=YVERT(K+1)+1.0/SQRT(ETAX(I,K)**2+ETAY(I,K)**2)
*   OMG=ABS(ETAY(I,K)*(U(I,K+1)-U(I,K-1))*.5
>   +SAIY(I,K)*(U(I,K)-U(I-1,K))
>   -ETAX(I,K)*(V(I,K+1)-V(I,K-1))*.5
>   -SAIX(I,K)*(V(I,K)-V(I-1,K)))
*   YPLUS=CYP*YVER
*   CEXP=YPLUS/AP
*   IF(CEXP.GT.500.) CEXP=500.
*   TURLEN=VKCON*YVER*(1.00-EXP(-CEXP))
*   ZMUI(K)=RHO(I,K)*OMG*TURLEN**2
*   FY=TURLEN/VKCON*OMG

```

```

      UTOTAL=SQRT(U(I,K)**2+V(I,K)**2)
      IF(UTOTAL.GE.UDIF) UDIF=UTOTAL
      IF(FY.LT.FYMAX) GO TO 20
      FYMAX=FY
      YMAX=YVER
20  YVERT(K)=YVER
*
      VXDIF=UDIF
      FWAKE1=YMAX*FYMAX
      FWAKE2=CWK*YMAX*VXDIF**2/FYMAX
      FWAKE=AMIN1(FWAKE1,FWAKE2)
*
      DO 30 KK=2, JL1
      K=JL+1-KK
      FKLEB=(CKLEB*YVERT(K)/YMAX)**6
      FKLEB=1./(1.0+5.5*FKLEB)
      ZMUO=XK*CCP*RHO(I,K)*FWAKE*FKLEB
      IF(ZMUI(K).GT.ZMUO) THEN
        ZMUTUR=ZMUO
      ELSE
        ZMUTUR=ZMUI(K)
      END IF
      ZMUT(K)=ZMUTUR
      ZMU(K)=ZMU(K)+ZMUTUR
      WRITE (77,500) K,Y(I,K),YVERT(K),U(I,K),ZMUI(K),ZMUO,ZMU(K)
500  FORMAT(2X,I3,6(2X,D13.6))
      30 CONTINUE
*
      ZMUT(1)=0.
      ZMUT(JL)=0.
      RETURN
*****
      ENTRY KLAM(II)
*****
      I=II
      DO 40 J=1,JL
      ZK(J)=FZK(RHO(I,J),E(I,J))
40  CONTINUE
      RETURN
*****
      ENTRY KTUR(II)
*****
      I=II
      DO 50 J=1,JL
      CPT=RG/AMW(I,J)+E(I,J)/T(I,J)
      ZKT=CPT/PRNT*ZMUT(J)
      ZK(J)=ZK(J)+ZKT
50  CONTINUE
      RETURN
      END
      SUBROUTINE MCONST
*****
*
*  SUBROUTINE FOR CALCULATING METRIC TERMS AT THE MIDPOINT
*  (I,J+1/2), (FOR THE VISCOUS VECTOR DMVS/DETA)

```

```

*
*
*      4      2      2
*      A1(I,J)=(-ETA  +ETA  )
*              3      X      Y
*
*
*      1
*      A2(I,J)=-ETA  *ETA
*              3      X      Y
*
*
*      2 4      2
*      A3(I,J)=(ETA  +-ETA  )
*              X      3      Y
*
*
*      2      2
*      A4(I,J)=(ETA  +ETA  )
*              X      Y
*
*
*****
PARAMETER (IZ=60,JZ=40)
COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
>      G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
>      U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
>      ZMU(JZ),ZMUT(JZ),ZK(JZ)
COMMON /COORD/ SAIK(IZ,JZ),SAIJ(IZ,JZ),ETAK(IZ,JZ),
>      ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
>      DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
>      A4(IZ,JZ)
COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
>      RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
>      PO,TO,TWALL,PB,SUM(4)
COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
>      IVISC,IWALL,IWRT
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
>      (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
DATA FD3,OD3 /1.333333333333,0.333333333333/
*****
DO 10 I=2,IL
DO 10 J=1,JL1
IF(I.EQ.IL) THEN
    XSAI=0.5*(X(I,J)+X(I,J+1)-X(I-1,J)-X(I-1,J+1))
    YSAI=0.5*(Y(I,J)+Y(I,J+1)-Y(I-1,J)-Y(I-1,J+1))
ELSE
    YSAI=0.25*(Y(I+1,J+1)+Y(I+1,J)-Y(I-1,J+1)-Y(I-1,J))
    XSAI=0.25*(X(I+1,J+1)+X(I+1,J)-X(I-1,J+1)-X(I-1,J))
END IF
YETA=Y(I,J+1)-Y(I,J)
XETA=X(I,J+1)-X(I,J)
RJJ=1./(XSAI*YETA-XETA*YSAI)
A1(I,J)=RJJ*RJJ*(FD3*YSAI**2+XSAI**2)
A2(I,J)=-RJJ*RJJ*OD3*XSAI*YSAI
A3(I,J)=RJJ*RJJ*(YSAI**2+FD3*XSAI**2)
A4(I,J)=RJJ*RJJ*(XSAI**2+YSAI**2)
10 CONTINUE

```

RETURN

END

```

SUBROUTINE AVERAGE( IA, IROE, CXM, CYM, RHOM, UM, VM, EOM, PM, UCNM,
> EM, TM, AMWM, I, J)

```

\*\*\*\*\*

\*

\*

SUBROUTINE FOR AVERAGING FLOW PROPERTIES

\*

\*

IF IA=1, AVERAGING OF Q FOR A MATRIX

\*

IF IA=2, AVERAGING OF Q FOR B MATRIX

\*

IF IROE=0, MEAN VALUE AVERAGING

\*

IF IROE=1, ROE AVERAGING

\*

\*\*\*\*\*

PARAMETER (IZ=60, JZ=40)

COMMON /VECTOR/ DQ(IZ, JZ, 4), Q(IZ, JZ, 4), F(IZ, JZ, 4),

&gt; G(IZ, JZ, 4), P(IZ, JZ), T(IZ, JZ), E(IZ, JZ), AMW(IZ, JZ),

&gt; U(IZ, JZ), V(IZ, JZ), UN(IZ, JZ), VN(IZ, JZ),

&gt; ZMU(JZ), ZMUT(JZ), ZK(JZ)

COMMON /COORD/ SAIX(IZ, JZ), SAIY(IZ, JZ), ETAX(IZ, JZ),

&gt; ETAY(IZ, JZ), RJ(IZ, JZ), X(IZ, JZ), Y(IZ, JZ),

&gt; DELTAU(IZ, JZ), A1(IZ, JZ), A2(IZ, JZ), A3(IZ, JZ),

&gt; A4(IZ, JZ)

COMMON /CONS/ EXI, EYI, THETA, CFL, CFL1, OMEGAX, OMEGAY, AIN, AEX,

&gt; RL, RG, AMWO, GAMMAO, REN, PRN, PRNT, TREF, ZMUO, OMEGA,

&gt; PO, TO, TWALL, PB, SUM(4)

DIMENSION RHO(IZ, JZ), RHOU(IZ, JZ), RHOV(IZ, JZ), EO(IZ, JZ)

EQUIVALENCE (Q(1, 1, 1), RHO(1, 1)), (Q(1, 1, 2), RHOU(1, 1)),

&gt; (Q(1, 1, 3), RHOV(1, 1)), (Q(1, 1, 4), EO(1, 1))

\*\*\*\*\*

IROE=1

IF(IA.EQ.1) THEN

I1=I

J1=J

I2=I+1

J2=J

CXM=0.5\*(SAIX(I1, J1)+SAIX(I2, J2))

CYM=0.5\*(SAIY(I1, J1)+SAIY(I2, J2))

END IF

IF(IA.EQ.2) THEN

I1=I

J1=J

I2=I

J2=J+1

CXM=0.5\*(ETAX(I1, J1)+ETAX(I2, J2))

CYM=0.5\*(ETAY(I1, J1)+ETAY(I2, J2))

END IF

IF(IROE.EQ.0) THEN

RHOM=0.5\*(RHO(I1, J1)+RHO(I2, J2))

UM=0.5\*(U(I1, J1)+U(I2, J2))

VM=0.5\*(V(I1, J1)+V(I2, J2))

EOM=0.5\*(EO(I1, J1)+EO(I2, J2))

PM=0.5\*(P(I1, J1)+P(I2, J2))

IF(IA.EQ.1) UCNM=0.5\*(UN(I1, J1)+UN(I2, J2))

IF(IA.EQ.2) UCNM=0.5\*(VN(I1, J1)+VN(I2, J2))

```

      UCNM=CXM*UM+CYM*VM
      EM=EOM/RHOM-0.5*(UM**2+VM**2)
      TM=FT(RHOM,EM)
      AMWM=FAMW(RHOM, TM)
END IF
IF(IROE.EQ.1) THEN
  SQRHO1=SQRT(RHO(I1,J1))
  SQRHO2=SQRT(RHO(I2,J2))
  DENOM=SQRHO1+SQRHO2
  RHOM=(RHO(I1,J1)*SQRHO1+RHO(I2,J2)*SQRHO2)/DENOM
  UM=(U(I1,J1)*SQRHO1+U(I2,J2)*SQRHO2)/DENOM
  VM=(V(I1,J1)*SQRHO1+V(I2,J2)*SQRHO2)/DENOM
  HT1=(EO(I1,J1)+P(I1,J1))/RHO(I1,J1)
  HT2=(EO(I2,J2)+P(I2,J2))/RHO(I2,J2)
  HTM=(HT1*SQRHO1+HT2*SQRHO2)/DENOM
* ARITHMETIC AVERAGING OF "REAL GAS GAMMA"
  G1=1.+(RG/AMW(I1,J1))/(E(I1,J1)/T(I1,J1))
  G2=1.+(RG/AMW(I2,J2))/(E(I2,J2)/T(I2,J2))
  GM=0.5*(G1+G2)
  PM=(GM-1.)/GM*(RHOM*HTM-0.5*RHOM*(UM**2+VM**2))
  EOM=RHOM*HTM-PM
  UCNM=CXM*UM+CYM*VM
  EM=EOM/RHOM-0.5*(UM**2+VM**2)
  TM=FT(RHOM,EM)
  AMWM=FAMW(RHOM, TM)

```

```

END IF

```

```

RETURN

```

```

END

```

```

SUBROUTINE JCBCL

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*****

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```

* SUBROUTINE FOR JACOBIANS CALCULATIONS

```

```

*

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```

*****

```

```

  PARAMETER (IZ=60,JZ=40)

```

```

  COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),

```

```

> G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),

```

```

> U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),

```

```

> ZMU(JZ),ZMUT(JZ),ZK(JZ)

```

```

  COMMON /COORD/ SAIK(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),

```

```

> ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),

```

```

> DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),

```

```

> A4(IZ,JZ)

```

```

  COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,

```

```

> RL, RG, AMWO, GAMMAO, REN, PRN, PRNT, TREF, ZMUO, OMEGA,

```

```

> PO, TO, TWALL, PB, SUM(4)

```

```

  COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,

```

```

> IVISC,IWALL,IWRT

```

```

  DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)

```

```

  EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),

```

```

> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))

```

```

  DIMENSION A(4,4),B(4,4),C(4,4),AA(4,4),BB(4,4),DIAG(4),

```

```

> D(4,4)

```

```

*****

```

```

  ENTRY JCBAB(IA,IMID,A,I,J)

```

```

*****
*
*   JACOBIAN A OR B MATRIX CALCULATIONS
*   A=DE/DQ, B=DF/DQ
*
*   IF IA=1, ACAP MATRIX
*   IF IA=2, BCAP MATRIX
*
*****
  IF ( ( IA.EQ.1.AND.IMID.EQ.0 ).OR.
>    ( IA.EQ.1.AND.IMID.EQ.1.AND.I.EQ.IL ) ) THEN
    CX=SAIX(I,J)
    CY=SAIY(I,J)
    QRHO=RHO(I,J)
    QU=U(I,J)
    QV=V(I,J)
    QEO=EO(I,J)
    QP=P(I,J)
    QCN=UN(I,J)
    QE=E(I,J)
    QT=T(I,J)
    QAMW=AMW(I,J)
  END IF
  IF ( ( IA.EQ.2.AND.IMID.EQ.0 ).OR.
>    ( IA.EQ.2.AND.IMID.EQ.1.AND.J.EQ.JL ) ) THEN
    CX=ETAX(I,J)
    CY=ETAY(I,J)
    QRHO=RHO(I,J)
    QU=U(I,J)
    QV=V(I,J)
    QEO=EO(I,J)
    QP=P(I,J)
    QCN=VN(I,J)
    QE=E(I,J)
    QT=T(I,J)
    QAMW=AMW(I,J)
  END IF
  IF (IA.EQ.1.AND.IMID.EQ.1.AND.I.NE.IL) THEN
    CALL AVERAGE( IA, IROE, CX, CY, QRHO, QU, QV, QEO, QP, QCN,
>    QE, QT, QAMW, I, J )
  END IF
  IF (IA.EQ.2.AND.IMID.EQ.1.AND.J.NE.JL) THEN
    CALL AVERAGE( IA, IROE, CX, CY, QRHO, QU, QV, QEO, QP, QCN,
>    QE, QT, QAMW, I, J )
  END IF
  AR=FAR(QP, QRHO, QT, QE, QAMW)
  AE=FAE(QP, QRHO, QT, QE, QAMW)
  AER=AE/QRHO
  DPDR=AR+AER*( -QEO/QRHO+(QU**2+QV**2) )
  DPDU=-AER*QU
  DPDV=-AER*QV
  DPDE=AER
  A(1,1)=0.0
  A(1,2)=CX
  A(1,3)=CY

```

```

A(1,4)=0.0
A(2,1)=-QU*QCN+CX*DPDR
A(2,2)=QCN+CX*(QU+DPDU)
A(2,3)=CY*QU+CX*DPDV
A(2,4)=CX*DPDE
A(3,1)=-QV*QCN+CY*DPDR
A(3,2)=CX*QV+CY*DPDU
A(3,3)=QCN+CY*(QV+DPDV)
A(3,4)=CY*DPDE
A(4,1)=QCN*(DPDR-(QEO+QP)/QRHO)
A(4,2)=QCN*DPDU+CX*(QEO+QP)/QRHO
A(4,3)=QCN*DPDV+CY*(QEO+QP)/QRHO
A(4,4)=QCN*(1.+DPDE)

```

RETURN

\*\*\*\*\*

ENTRY JCBABPM(IA,IB,IMID,A,I,J)

\*\*\*\*\*

\*  
\* SPLITTED JACOBIAN A-PLUS, A-MINUS, B-PLUS, OR B-MINUS  
\* + -1 -1 + - -1 -1 -

\* A =T \*P \*(LAMBDA) \*P\*T, A =T \*P \*(LAMBDA) \*P\*T  
\*

\* + -1 -1 + - -1 -1 -  
\* B =T \*P \*(LAMBDA) \*P\*T, B =T \*P \*(LAMBDA) \*P\*T  
\*

\* IF IA=1 IB=1 - A-PLUS MATRIX  
\* IF IA=1 IB=2 - A-MINUS MATRIX  
\* IF IA=2 IB=1 - B-PLUS MATRIX  
\* IF IA=2 IB=2 - B-MINUS MATRIX  
\* IF IMID=0 - JACOBIAN CALCULATED IN POINT (I,J)  
\* IF IMID=1 IA=1 - JACOBIAN CALCULATED IN POINT (I+1/2,J)  
\* IF IMID=1 IA=2 - JACOBIAN CALCULATED IN POINT (I,J+1/2)  
\*

\*\*\*\*\*

IF((IA.EQ.1.AND.IMID.EQ.0).OR.

> (IA.EQ.1.AND.IMID.EQ.1.AND.I.EQ.IL)) THEN

```

CX=SAIX(I,J)
CY=SAIY(I,J)
QRHO=RHO(I,J)
QU=U(I,J)
QV=V(I,J)
QEO=EO(I,J)
QP=P(I,J)
QCN=UN(I,J)
QE=E(I,J)
QT=T(I,J)
QAMW=AMW(I,J)

```

END IF

IF((IA.EQ.2.AND.IMID.EQ.0).OR.

> (IA.EQ.2.AND.IMID.EQ.1.AND.J.EQ.JL)) THEN

```

CX=ETAX(I,J)
CY=ETAY(I,J)
QRHO=RHO(I,J)
QU=U(I,J)
QV=V(I,J)

```

```

      QEO=EO(I,J)
      QF=P(I,J)
      QCN=VN(I,J)
      QE=E(I,J)
      QT=T(I,J)
      QAMW=AMW(I,J)
    END IF
    IF(IA.EQ.1.AND.IMID.EQ.1.AND.I.NE.IL) THEN
      CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
>      QE,QT,QAMW,I,J)
    END IF
    IF(IA.EQ.2.AND.IMID.EQ.1.AND.J.NE.JL) THEN
      CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
>      QE,QT,QAMW,I,J)
    END IF
    CO=SQRT(FCO2(QP,QRHO,QT,QE,QAMW))
    CQ=SQRT(CX**2+CY**2)
    CQCO=CQ*CO
    EIG4=QCN-CQCO
    IF(IB.EQ.1) THEN
      DIAG(1)=QCN
      DIAG(2)=QCN
      DIAG(3)=QCN+CQCO
      DIAG(4)=0.
      IF(EIG4.GE.0.0) DIAG(4)=EIG4
    END IF
    IF(IB.EQ.2) THEN
      DIAG(1)=0.
      DIAG(2)=0.
      DIAG(3)=0.
      DIAG(4)=0.
      IF(EIG4.LT.0.0) DIAG(4)=EIG4
    END IF
    CALL TMPM(IA,IMID,AA,I,J)
    DO 30 II=1,4
    DO 30 JJ=1,4
    BB(JI,JJ)=DIAG(II)*AA(II,JJ)
30 CONTINUE
    CALL PPTP(IA,IMID,AA,I,J)
    CALL MMM(4,AA,BB,A)
    RETURN
*****
    ENTRY JCBD(D,I,J)
*****
*
*   SOURCE TERM JACOBIAN MATRIX, D=DH'/DQ
*
*   H(1)=0.
*   H(2)=0.
*   H(3)=(P-4./3.*MU*V/Y)/J
*   H(4)=0.
*
*****
    CALL SZERO(4,D)
    IF(IVISC.EQ.0) THEN

```

ZMU(J)=0.

DMUDR=0.

DMUDU=0.

DMUDV=0.

DMUDE=0.

ELSE

CR=FDMUDRE(RHO(I,J),E(I,J))

CE=FDMUDER(RHO(I,J),E(I,J))

CER=CE/RHO(I,J)

DMUDR=CR+CER\*(-EO(I,J)/RHO(I,J)+(U(I,J)\*\*2+V(I,J)\*\*2))

DMUDU=-CER\*U(I,J)

DMUDV=-CER\*V(I,J)

DMUDE=CER

END IF

AR=FAR(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J))

AE=FAE(P(I,J),RHO(I,J),T(I,J),E(I,J),AMW(I,J))

AER=AE/RHO(I,J)

DPDR=AR+AER\*(-EO(I,J)/RHO(I,J)+(U(I,J)\*\*2+V(I,J)\*\*2))

DPDU=-AER\*U(I,J)

DPDV=-AER\*V(I,J)

DPDE=AER

RY=4./3./Y(I,J)\*\*2

D(3,1)=DPDR/Y(I,J)

&gt; +IVISC\*(-V(I,J)\*DMUDR+ZMU(J)\*V(I,J)/RHO(I,J))\*RY

D(3,2)=DPDU/Y(I,J)

&gt; +IVISC\*(-V(I,J)\*DMUDU)\*RY

D(3,3)=DPDV/Y(I,J)

&gt; +IVISC\*(-V(I,J)\*DMUDV-ZMU(J)/RHO(I,J))\*RY

D(3,4)=DPDE/Y(I,J)

&gt; +IVISC\*(-V(I,J)\*DMUDE)\*RY

RETURN

\*\*\*\*\*

ENTRY JCBMVS(A,B,C,I,J)

\*\*\*\*\*

\*

\* VISCOUS JACOBIAN MATRIX, MVS=-D(DSVS'/DETA+H'')/DQ

\*

\* H(1)=0.

\*

\* 1 2

\* H(2)=-\*(--\*ETA \*D(MU\*V)/DETA)

\* J 3 X

\*

\* 1 2

\* H(3)=-\*(--\*ETA \*MU\*DU/DETA--\*ETA \*V\*D(MU)/DETA)

\* J 3 X 3 Y

\*

\* 1 2

\* H(4)=-\*(--\*ETA \*D(MU\*U\*V)/DETA--\*ETA \*D(MU\*V\*V)/DETA)

\* J 3 X 3 Y

\*

\*\*\*\*\*

JP1=J+1

JM1=J-1

YJP1 = Y(I,JP1)/RJ(I,JP1)

```

YJP      = 0.5*(Y(I,J)/RJ(I,J)+Y(I,JP1)/RJ(I,JP1))
YJ       = Y(I,J)/RJ(I,J)
YJM      = 0.5*(Y(I,J)/RJ(I,J)+Y(I,JM1)/RJ(I,JM1))
YJM1     = Y(I,JM1)/RJ(I,JM1)
EXJ      = 1./3.*ETAX(I,J)/RJ(I,J)
EYJ      = 1./3.*ETAY(I,J)/RJ(I,J)
RHOP     = 0.5*(RHO(I,J)+RHO(I,JP1))
RHOM     = 0.5*(RHO(I,J)+RHO(I,JM1))
UP       = 0.5*(U(I,J)+U(I,JP1))
UM       = 0.5*(U(I,J)+U(I,JM1))
VP       = 0.5*(V(I,J)+V(I,JP1))
VM       = 0.5*(V(I,J)+V(I,JM1))
EP       = 0.5*(E(I,J)+E(I,JP1))
EM       = 0.5*(E(I,J)+E(I,JM1))
ORP1     = 1./RHO(I,JP1)
OR       = 1./RHO(I,J)
ORM1     = 1./RHO(I,JM1)
UORP1    = U(I,JP1)/RHO(I,JP1)
UOR      = U(I,J)/RHO(I,J)
UORM1    = U(I,JM1)/RHO(I,JM1)
VORP1    = V(I,JP1)/RHO(I,JP1)
VOR      = V(I,J)/RHO(I,J)
VORM1    = V(I,JM1)/RHO(I,JM1)
U2P1     = U(I,JP1)**2
U2P      = (0.5*(U(I,J)+U(I,JP1)))*2
U2       = U(I,J)**2
U2M      = (0.5*(U(I,J)+U(I,JM1)))*2
U2M1     = U(I,JM1)**2
V2P1     = V(I,JP1)**2
V2P      = (0.5*(V(I,J)+V(I,JP1)))*2
V2       = V(I,J)**2
V2M      = (0.5*(V(I,J)+V(I,JM1)))*2
V2M1     = V(I,JM1)**2
UVP1     = U(I,JP1)*V(I,JP1)
UV       = U(I,J)*V(I,J)
UVM1     = U(I,JM1)*V(I,JM1)
U2ORP1   = U2P1*ORP1
U2OR     = U2*OR
U2ORM1   = U2M1*ORM1
V2ORP1   = V2P1*ORP1
V2OR     = V2*OR
V2ORM1   = V2M1*ORM1
UVORP1   = UVP1*ORP1
UVOR     = UV*OR
UVORM1   = UVM1*ORM1
ZMUP     = 0.5*(ZMU(J)+ZMU(JP1))
ZMUM     = 0.5*(ZMU(J)+ZMU(JM1))
YJZMUP   = YJP*ZMUP
YJZMUM   = YJM*ZMUM
ZKP      = 0.5*(ZK(J)+ZK(JP1))
ZKM      = 0.5*(ZK(J)+ZK(JM1))
YJZKP    = YJP*ZKP
YJZKM    = YJM*ZKM
EOORP1   = EO(I,JP1)/RHO(I,JP1)
EOORP    = 0.5*(EO(I,J)/RHO(I,J)+EO(I,JP1)/RHO(I,JP1))

```

```

EOOR  = EO(I,J)/RHO(I,J)
EOORM = 0.5*(EO(I,J)/RHO(I,J)+EO(I,JM1)/RHO(I,JM1))
EOORM1 = EO(I,JM1)/RHO(I,JM1)

```

\*

```

BR=FDTDRE(RHO(I,JP1),E(I,JP1))
BE=FDTDER(RHO(I,JP1),E(I,JP1))
BER=BE/RHO(I,JP1)
DTDRP1=BR+BER*(-EOORP1+(U2P1+V2P1))
DTDUP1=-BER*U(I,JP1)
DTDVP1=-BER*V(I,JP1)
DTDEP1=BER
BR=FDTDRE(RHO(I,J),E(I,J))
BE=FDTDER(RHO(I,J),E(I,J))
BER=BE/RHO(I,J)
DTDR=BR+BER*(-EOOR+(U2+V2))
DTDU=-BER*U(I,J)
DTDV=-BER*V(I,J)
DTDE=BER
BR=FDTDRE(RHO(I,JM1),E(I,JM1))
BE=FDTDER(RHO(I,JM1),E(I,JM1))
BER=BE/RHO(I,JM1)
DTDRM1=BR+BER*(-EOORM1+(U2M1+V2M1))
DTDUM1=-BER*U(I,JM1)
DTDVM1=-BER*V(I,JM1)
DTDEM1=BER

```

\*

```

CR=FDMUDRE(RHO(I,JP1),E(I,JP1))
CE=FDMUDER(RHO(I,JP1),E(I,JP1))
CER=CE/RHO(I,JP1)
DMUDRP1=CR+CER*(-EOORP1+(U2P1+V2P1))
DMUDUP1=-CER*U(I,JP1)
DMUDVP1=-CER*V(I,JP1)
DMUDEP1=CER
CR=FDMUDRE(RHOP,EP)
CE=FDMUDER(RHOP,EP)
CER=CE/RHOP
DMUDRP=CR+CER*(-EOORP+(U2P+V2P))
DMUDUP=-CER*UP
DMUDVP=-CER*VP
DMUDEP=CER
CR=FDMUDRE(RHO(I,J),E(I,J))
CE=FDMUDER(RHO(I,J),E(I,J))
CER=CE/RHO(I,J)
DMUDR=CR+CER*(-EOOR+(U2+V2))
DMUDU=-CER*U(I,J)
DMUDV=-CER*V(I,J)
DMUDE=CER
CR=FDMUDRE(RHOM,EM)
CE=FDMUDER(RHOM,EM)
CER=CE/RHOM
DMUDRM=CR+CER*(-EOORM+(U2M+V2M))
DMUDUM=-CER*UM
DMUDVM=-CER*VM
DMUDEM=CER
CR=FDMUDRE(RHO(I,JM1),E(I,JM1))

```

```

CE=FDMUDER(RHO(I,JM1),E(I,JM1))
CER=CE/RHO(I,JM1)
DMUDRM1=CR+CER*(-EOORM1+(U2M1+V2M1))
DMUDUM1=-CER*U(I,JM1)
DMUDVM1=-CER*V(I,JM1)
DMUDEM1=CER

```

\*

```

DR=FDKDRE(RHOP,EP)
DE=FDKDER(RHOP,EP)
DER=DE/RHOP
DKDRP=DR+DER*(-EOORP+(U2P+V2P))
DKDUP=-DER*UP
DKDVP=-DER*VP
DKDEP=DER
DR=FDKDRE(RHOM,EM)
DE=FDKDER(RHOM,EM)
DER=DE/RHOM
DKDRM=DR+DER*(-EOORM+(U2M+V2M))
DKDUM=-DER*UM
DKDVM=-DER*VM
DKDEM=DER

```

\*

\*

\*

```

COMPUTE -M=-(DSVS'/DQ)/DETA

```

```

IF(JM1.EQ.1) THEN

```

```

    CALL SZERO(4,A)

```

```

ELSE

```

```

    A(1,1)=0.

```

```

    A(1,2)=0.

```

```

    A(1,3)=0.

```

```

    A(1,4)=0.

```

```

    A(2,1)=-DMUDRM*(A1(I,JM1)*U(I,JM1)+A2(I,JM1)*V(I,JM1))
    +YJZMUM*(A1(I,JM1)*UORM1+A2(I,JM1)*VORM1)/YJM1

```

```

>    A(2,2)=-DMUDUM*(A1(I,JM1)*U(I,JM1)+A2(I,JM1)*V(I,JM1))
>    -YJZMUM*A1(I,JM1)*ORM1/YJM1

```

```

>    A(2,3)=-DMUDVM*(A1(I,JM1)*U(I,JM1)+A2(I,JM1)*V(I,JM1))
>    -YJZMUM*A2(I,JM1)*ORM1/YJM1

```

```

    A(2,4)=-DMUDEM*(A1(I,JM1)*U(I,JM1)+A2(I,JM1)*V(I,JM1))

```

```

    A(3,1)=-DMUDRM*(A3(I,JM1)*V(I,JM1)+A2(I,JM1)*U(I,JM1))
    +YJZMUM*(A3(I,JM1)*VORM1+A2(I,JM1)*UORM1)/YJM1

```

```

>    A(3,2)=-DMUDUM*(A3(I,JM1)*V(I,JM1)+A2(I,JM1)*U(I,JM1))
>    -YJZMUM*A2(I,JM1)*ORM1/YJM1

```

```

>    A(3,3)=-DMUDVM*(A3(I,JM1)*V(I,JM1)+A2(I,JM1)*U(I,JM1))
>    -YJZMUM*A3(I,JM1)*ORM1/YJM1

```

```

    A(3,4)=-DMUDEM*(A3(I,JM1)*V(I,JM1)+A2(I,JM1)*U(I,JM1))

```

```

    A(4,1)=-DMUDRM*(0.5*A1(I,JM1)*U2M1+A2(I,JM1)*UVM1

```

```

>    +0.5*A3(I,JM1)*V2M1)

```

```

>    +YJZMUM*(A1(I,JM1)*U2ORM1+2.0*A2(I,JM1)*UVORM1

```

```

>    +A3(I,JM1)*V2ORM1)/YJM1

```

```

>    -DKDRM*A4(I,JM1)*T(I,JM1)

```

```

>    -YJZKM*A4(I,JM1)*DTDRM1/YJM1

```

```

    A(4,2)=-DMUDUM*(0.5*A1(I,JM1)*U2M1+A2(I,JM1)*UVM1

```

```

>    +0.5*A3(I,JM1)*V2M1)

```

```

>    -YJZMUM*(A1(I,JM1)*UORM1+A2(I,JM1)*VORM1)/YJM1

```

```

>    -DKDUM*A4(I,JM1)*T(I,JM1)

```

```

> -YJZKM*A4(I,JM1)*DTDUM1/YJM1
A(4,3)=-DMUDVM*(0.5*A1(I,JM1)*U2M1+A2(I,JM1)*UVM1
+0.5*A3(I,JM1)*V2M1)
> -YJZMUM*(A2(I,JM1)*UORM1+A3(I,JM1)*VORM1)/YJM1
> -DKDVM*A4(I,JM1)*T(I,JM1)
> -YJZKM*A4(I,JM1)*DTDVM1/YJM1
A(4,4)=-DMUDEM*(0.5*A1(I,JM1)*U2M1+A2(I,JM1)*UVM1
+0.5*A3(I,JM1)*V2M1)
> -DKDEM*A4(I,JM1)*T(I,JM1)
> -YJZKM*A4(I,JM1)*DTDEM1/YJM1
END IF
C(1,1)=0.
C(1,2)=0.
C(1,3)=0.
C(1,4)=0.
C(2,1)=-DMUDRP*(A1(I,J)*U(I,JP1)+A2(I,J)*V(I,JP1))
> +YJZMUP*(A1(I,J)*UORP1+A2(I,J)*VORP1)/YJP1
C(2,2)=-DMUDUP*(A1(I,J)*U(I,JP1)+A2(I,J)*V(I,JP1))
> -YJZMUP*A1(I,J)*ORP1/YJP1
C(2,3)=-DMUDVP*(A1(I,J)*U(I,JP1)+A2(I,J)*V(I,JP1))
> -YJZMUP*A2(I,J)*ORP1/YJP1
C(2,4)=-DMUDEP*(A1(I,J)*U(I,JP1)+A2(I,J)*V(I,JP1))
C(3,1)=-DMUDRP*(A3(I,J)*V(I,JP1)+A2(I,J)*U(I,JP1))
> +YJZMUP*(A3(I,J)*VORP1+A2(I,J)*UORP1)/YJP1
C(3,2)=-DMUDUP*(A3(I,J)*V(I,JP1)+A2(I,J)*U(I,JP1))
> -YJZMUP*A2(I,J)*ORP1/YJP1
C(3,3)=-DMUDVP*(A3(I,J)*V(I,JP1)+A2(I,J)*U(I,JP1))
> -YJZMUP*A3(I,J)*ORP1/YJP1
C(3,4)=-DMUDEP*(A3(I,J)*V(I,JP1)+A2(I,J)*U(I,JP1))
C(4,1)=-DMUDRP*(0.5*A1(I,J)*U2P1+A2(I,J)*UVP1
> +0.5*A3(I,J)*V2P1)
> +YJZMUP*(A1(I,J)*U2ORP1+2.0*A2(I,J)*UVORP1
> +A3(I,J)*V2ORP1)/YJP1
> -DKDRP*A4(I,J)*T(I,JP1)
> -YJZKP*A4(I,J)*DTDRP1/YJP1
C(4,2)=-DMUDUP*(0.5*A1(I,J)*U2P1+A2(I,J)*UVP1
> +0.5*A3(I,J)*V2P1)
> -YJZMUP*(A1(I,J)*UORP1+A2(I,J)*VORP1)/YJP1
> -DKDUP*A4(I,J)*T(I,JP1)
> -YJZKP*A4(I,J)*DTDUP1/YJP1
C(4,3)=-DMUDVP*(0.5*A1(I,J)*U2P1+A2(I,J)*UVP1
> +0.5*A3(I,J)*V2P1)
> -YJZMUP*(A2(I,J)*UORP1+A3(I,J)*VORP1)/YJP1
> -DKDVP*A4(I,J)*T(I,JP1)
> -YJZKP*A4(I,J)*DTDVP1/YJP1
C(4,4)=-DMUDEP*(0.5*A1(I,J)*U2P1+A2(I,J)*UVP1
> +0.5*A3(I,J)*V2P1)
> -DKDEP*A4(I,J)*T(I,JP1)
> -YJZKP*A4(I,J)*DTDEP1/YJP1
B(1,1)=0.
B(1,2)=0.
B(1,3)=0.
B(1,4)=0.
B(2,1)=(DMUDRP*A1(I,J)+DMUDRM*A1(I,JM1))*U(I,J)
> +(DMUDRP*A2(I,J)+DMUDRM*A2(I,JM1))*V(I,J)

```

```

>      -(YJZMUP*A1(I,J)+YJZMUM*A1(I,JM1))*UOR/YJ
>      -(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*VOR/YJ
B(2,2)=(DMUDUP*A1(I,J)+DMUDUM*A1(I,JM1))*U(I,J)
>      +(DMUDUP*A2(I,J)+DMUDUM*A2(I,JM1))*V(I,J)
>      +(YJZMUP*A1(I,J)+YJZMUM*A1(I,JM1))*OR/YJ
B(2,3)=(DMUDVP*A1(I,J)+DMUDVM*A1(I,JM1))*U(I,J)
>      +(DMUDVP*A2(I,J)+DMUDVM*A2(I,JM1))*V(I,J)
>      +(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*OR/YJ
B(2,4)=(DMUDEP*A1(I,J)+DMUDEM*A1(I,JM1))*U(I,J)
>      +(DMUDEP*A2(I,J)+DMUDEM*A2(I,JM1))*V(I,J)
B(3,1)=(DMUDRP*A3(I,J)+DMUDRM*A3(I,JM1))*V(I,J)
>      +(DMUDRP*A2(I,J)+DMUDRM*A2(I,JM1))*U(I,J)
>      -(YJZMUP*A3(I,J)+YJZMUM*A3(I,JM1))*VOR/YJ
>      -(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*UOR/YJ
B(3,2)=(DMUDUP*A3(I,J)+DMUDUM*A3(I,JM1))*V(I,J)
>      +(DMUDUP*A2(I,J)+DMUDUM*A2(I,JM1))*U(I,J)
>      +(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*OR/YJ
B(3,3)=(DMUDVP*A3(I,J)+DMUDVM*A3(I,JM1))*V(I,J)
>      +(DMUDVP*A2(I,J)+DMUDVM*A2(I,JM1))*U(I,J)
>      +(YJZMUP*A3(I,J)+YJZMUM*A3(I,JM1))*OR/YJ
B(3,4)=(DMUDEP*A3(I,J)+DMUDEM*A3(I,JM1))*V(I,J)
>      +(DMUDEP*A2(I,J)+DMUDEM*A2(I,JM1))*U(I,J)
B(4,1)=0.5*(DMUDRP*A1(I,J)+DMUDRM*A1(I,JM1))*U2
>      +(DMUDRP*A2(I,J)+DMUDRM*A2(I,JM1))*UV
>      +0.5*(DMUDRP*A3(I,J)+DMUDRM*A3(I,JM1))*V2
>      -(YJZMUP*A1(I,J)+YJZMUM*A1(I,JM1))*U2OR/YJ
>      -2.0*(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*UVOR/YJ
>      -(YJZMUP*A3(I,J)+YJZMUM*A3(I,JM1))*V2OR/YJ
>      +(DKDRP*A4(I,J)+DKDRM*A4(I,JM1))*T(I,J)
>      +(YJZKP*A4(I,J)+YJZKM*A4(I,JM1))*DTDR/YJ
B(4,2)=0.5*(DMUDUP*A1(I,J)+DMUDUM*A1(I,JM1))*U2
>      +(DMUDUP*A2(I,J)+DMUDUM*A2(I,JM1))*UV
>      +0.5*(DMUDUP*A3(I,J)+DMUDUM*A3(I,JM1))*V2
>      +(YJZMUP*A1(I,J)+YJZMUM*A1(I,JM1))*UOR/YJ
>      +(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*VOR/YJ
>      +(DKDUP*A4(I,J)+DKDUM*A4(I,JM1))*T(I,J)
>      +(YJZKP*A4(I,J)+YJZKM*A4(I,JM1))*DTDU/YJ
B(4,3)=0.5*(DMUDVP*A1(I,J)+DMUDVM*A1(I,JM1))*U2
>      +(DMUDVP*A2(I,J)+DMUDVM*A2(I,JM1))*UV
>      +0.5*(DMUDVP*A3(I,J)+DMUDVM*A3(I,JM1))*V2
>      +(YJZMUP*A2(I,J)+YJZMUM*A2(I,JM1))*UOR/YJ
>      +(YJZMUP*A3(I,J)+YJZMUM*A3(I,JM1))*VOR/YJ
>      +(DKDVP*A4(I,J)+DKDVM*A4(I,JM1))*T(I,J)
>      +(YJZKP*A4(I,J)+YJZKM*A4(I,JM1))*DTDV/YJ
B(4,4)=0.5*(DMUDEP*A1(I,J)+DMUDEM*A1(I,JM1))*U2
>      +(DMUDEP*A2(I,J)+DMUDEM*A2(I,JM1))*UV
>      +0.5*(DMUDEP*A3(I,J)+DMUDEM*A3(I,JM1))*V2
>      +(DKDEP*A4(I,J)+DKDEM*A4(I,JM1))*T(I,J)
>      +(YJZKP*A4(I,J)+YJZKM*A4(I,JM1))*DTDE/YJ

```

```

*
*  COMPUTE -D'--DH' /DQ
*  AND ADD TO PREVIOUS RESULTS
*

```

```

IF(JM1.EQ.1) THEN
  CALL SZERO(4,A)

```

ELSE

```

A(2,1)=A(2,1)-EXJ*(V(I,JM1)*DMUDRM1-ZMU(JM1)*VORM1)/YJM1
A(2,2)=A(2,2)-EXJ*V(I,JM1)*DMUDUM1/YJM1
A(2,3)=A(2,3)-EXJ*(V(I,JM1)*DMUDVM1+ZMU(JM1)*ORM1)/YJM1
A(2,4)=A(2,4)-EXJ*V(I,JM1)*DMUDEM1/YJM1
A(3,1)=A(3,1)+EXJ*DMUDR/YJ*U(I,JM1)
> -EXJ*ZMU(J)*UORM1/YJM1
> +EYJ*VOR/YJ*ZMU(JM1)
> -EYJ*V(I,J)*DMUDRM1/YJM1
A(3,2)=A(3,2)+EXJ*DMUDU/YJ*U(I,JM1)
> +EXJ*ZMU(J)*ORM1/YJM1
> -EYJ*V(I,J)*DMUDUM1/YJM1
A(3,3)=A(3,3)+EXJ*DMUDV/YJ*U(I,JM1)
> -EYJ*OR/YJ*ZMU(JM1)
> -EYJ*V(I,J)*DMUDVM1/YJM1
A(3,4)=A(3,4)+EXJ*DMUDE/YJ*U(I,JM1)
> -EYJ*V(I,J)*DMUDEM1/YJM1
A(4,1)=A(4,1)-EXJ*(DMUDRM1-2.0*ZMU(JM1)*ORM1)*UVM1/YJM1
> -EYJ*(DMUDRM1-2.0*ZMU(JM1)*ORM1)*V2M1/YJM1
A(4,2)=A(4,2)-EXJ*(DMUDUM1*UVM1+ZMU(JM1)*VORM1)/YJM1
> -EYJ*(DMUDUM1*V2M1)/YJM1
A(4,3)=A(4,3)-EXJ*(DMUDVM1*UVM1+ZMU(JM1)*UORM1)/YJM1
> -EYJ*(DMUDVM1*V2M1+2.0*ZMU(JM1)*VORM1)/YJM1
A(4,4)=A(4,4)-EXJ*DMUDEM1*UVM1/YJM1
> -EYJ*DMUDEM1*V2M1/YJM1

```

END IF

```

C(2,1)=C(2,1)+EXJ*(V(I,JP1)*DMUDRP1-ZMU(JP1)*VORP1)/YJP1
C(2,2)=C(2,2)+EXJ*V(I,JP1)*DMUDUP1/YJP1
C(2,3)=C(2,3)+EXJ*(V(I,JP1)*DMUDVP1+ZMU(JP1)*ORP1)/YJP1
C(2,4)=C(2,4)+EXJ*V(I,JP1)*DMUDEP1/YJP1
C(3,1)=C(3,1)-EXJ*DMUDR/YJ*U(I,JP1)
> +EXJ*ZMU(J)*UORP1/YJP1
> -EYJ*VOR/YJ*ZMU(JP1)
> +EYJ*V(I,J)*DMUDRP1/YJP1
C(3,2)=C(3,2)-EXJ*DMUDU/YJ*U(I,JP1)
> -EXJ*ZMU(J)*ORP1/YJP1
> +EYJ*V(I,J)*DMUDUP1/YJP1
C(3,3)=C(3,3)-EXJ*DMUDV/YJ*U(I,JP1)
> +EYJ*OR/YJ*ZMU(JP1)
> +EYJ*V(I,J)*DMUDVP1/YJP1
C(3,4)=C(3,4)-EXJ*DMUDE/YJ*U(I,JP1)
> +EYJ*V(I,J)*DMUDEP1/YJP1
C(4,1)=C(4,1)+EXJ*(DMUDRP1-2.0*ZMU(JP1)*ORP1)*UVP1/YJP1
> +EYJ*(DMUDRP1-2.0*ZMU(JP1)*ORP1)*V2P1/YJP1
C(4,2)=C(4,2)+EXJ*(DMUDUP1*UVP1+ZMU(JP1)*VORP1)/YJP1
> +EYJ*DMUDUP1*V2P1/YJP1
C(4,3)=C(4,3)+EXJ*(DMUDVP1*UVP1+ZMU(JP1)*UORP1)/YJP1
> +EYJ*(DMUDVP1*V2P1+2.0*ZMU(JP1)*VORP1)/YJP1
C(4,4)=C(4,4)+EXJ*DMUDEP1*UVP1/YJP1
> +EYJ*DMUDEP1*V2P1/YJP1

```

RETURN

END

SUBROUTINE EIGMTX

\*\*\*\*\*  
 \*

## \* SUBROUTINE FOR EIGENVECTOR MATRIX CALCULATION

\*

\*\*\*\*\*

PARAMETER (IZ=60,JZ=40)

COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),

&gt; G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),

&gt; U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),

&gt; ZMU(JZ),ZMUT(JZ),ZK(JZ)

COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),

&gt; ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),

&gt; DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),

&gt; A4(IZ,JZ)

COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,

&gt; RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,

&gt; PO,TO,TWALL,PB,SUM(4)

COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,

&gt; IVISC,IWALL,IWRT

DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)

EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOV(1,1)),

&gt; (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))

DIMENSION A(4,4)

\*\*\*\*\*

ENTRY TMPM(IA,IMID,A,I,J)

\*\*\*\*\*

\*

\*

-1 -1

\*

CALCULATION OF T \*P MATRIX

\*

\* IF IA=1 IMID=0 - XI MATRIX CALCULATED IN POINT (I,J)

\* IF IA=2 IMID=0 - ETA MATRIX CALCULATED IN POINT (I,J)

\* IF IA=1 IMID=1 - XI MATRIX CALCULATED IN POINT (I+1/2,J)

\* IF IA=2 IMID=1 - ETA MATRIX CALCULATED IN POINT (I,J+1/2)

\*

\*\*\*\*\*

IF((IA.EQ.1.AND.IMID.EQ.0).OR.

&gt; (IA.EQ.1.AND.IMID.EQ.1.AND.I.EQ.IL)) THEN

CX=SAIX(I,J)

CY=SAIY(I,J)

QRHO=RHO(I,J)

QU=U(I,J)

QV=V(I,J)

QEO=EO(I,J)

QP=P(I,J)

QCN=UN(I,J)

QE=E(I,J)

QT=T(I,J)

QAMW=AMW(I,J)

END IF

IF((IA.EQ.2.AND.IMID.EQ.0).OR.

&gt; (IA.EQ.2.AND.IMID.EQ.1.AND.J.EQ.JL)) THEN

CX=ETAX(I,J)

CY=ETAY(I,J)

QRHO=RHO(I,J)

QU=U(I,J)

QV=V(I,J)

```

      QEO=EO(I,J)
      QP=P(I,J)
      QCN=VN(I,J)
      QE=E(I,J)
      QT=T(I,J)
      QAMW=AMW(I,J)
    END IF
    IF (IA.EQ.1.AND.IMID.EQ.1.AND.I.NE.IL) THEN
      CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
>      QE,QT,QAMW,I,J)
    END IF
    IF (IA.EQ.2.AND.IMID.EQ.1.AND.J.NE.JL) THEN
      CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
>      QE,QT,QAMW,I,J)
    END IF
    SQ2=SQRT(2.0)
    C=SQRT(FCO2(QP,QRHO,QT,QE,QAMW))
    AR=FAR(QP,QRHO,QT,QE,QAMW)
    AE=FAE(QP,QRHO,QT,QE,QAMW)
    AER=AE/QRHO
    DPDR=AR+AER*(-QEO/QRHO+(QU**2+QV**2))
    DPDU=-AER*QU
    DPDV=-AER*QV
    DPDE=AER
    C1=CX/SQRT(CX**2+CY**2)
    C2=CY/SQRT(CX**2+CY**2)
    A(1,1)=1.-DPDR/C**2
    A(1,2)=-DPDU/C**2
    A(1,3)=-DPDV/C**2
    A(1,4)=-DPDE/C**2
    A(2,1)=-(C2*QU-C1*QV)/QRHO
    A(2,2)=C2/QRHO
    A(2,3)=-C1/QRHO
    A(2,4)=0.
    A(3,1)=-((C1*QU+C2*QV)+DPDR/C)/SQ2/QRHO
    A(3,2)=(C1+DPDU/C)/SQ2/QRHO
    A(3,3)=(C2+DPDV/C)/SQ2/QRHO
    A(3,4)=DPDE/C/SQ2/QRHO
    A(4,1)=((C1*QU+C2*QV)+DPDR/C)/SQ2/QRHO
    A(4,2)=(-C1+DPDU/C)/SQ2/QRHO
    A(4,3)=(-C2+DPDV/C)/SQ2/QRHO
    A(4,4)=DPDE/C/SQ2/QRHO
    RETURN

```

\*\*\*\*\*

ENTRY PPTP(IA,IMID,A,I,J)

\*\*\*\*\*

\*

\*

CALCULATION OF P\*T MATRIX

\*

\* IF IA=1 IMID=0 - XI MATRIX CALCULATED IN POINT (I,J)

\* IF IA=2 IMID=0 - ETA MATRIX CALCULATED IN POINT (I,J)

\* IF IA=1 IMID=1 - XI MATRIX CALCULATED IN POINT (I+1/2,J)

\* IF IA=2 IMID=1 - ETA MATRIX CALCULATED IN POINT (I,J+1/2)

\*

\*\*\*\*\*

```

IF((IA.EQ.1.AND.IMID.EQ.0).OR.
> (IA.EQ.1.AND.IMID.EQ.1.AND.I.EQ.IL)) THEN
  CX=SAIX(I,J)
  CY=SAIY(I,J)
  QRHO=RHO(I,J)
  QU=U(I,J)
  QV=V(I,J)
  QEO=EO(I,J)
  QP=P(I,J)
  QCN=UN(I,J)
  QE=E(I,J)
  QT=T(I,J)
  QAMW=AMW(I,J)
END IF
IF((IA.EQ.2.AND.IMID.EQ.0).OR.
> (IA.EQ.2.AND.IMID.EQ.1.AND.J.EQ.JL)) THEN
  CX=ETAX(I,J)
  CY=ETAY(I,J)
  QRHO=RHO(I,J)
  QU=U(I,J)
  QV=V(I,J)
  QEO=EO(I,J)
  QP=P(I,J)
  QCN=VN(I,J)
  QE=E(I,J)
  QT=T(I,J)
  QAMW=AMW(I,J)
END IF
IF(IA.EQ.1.AND.IMID.EQ.1.AND.I.NE.IL) THEN
  CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
> QE,QT,QAMW,I,J)
END IF
IF(IA.EQ.2.AND.IMID.EQ.1.AND.J.NE.JL) THEN
  CALL AVERAGE(IA,IROE,CX,CY,QRHO,QU,QV,QEO,QP,QCN,
> QE,QT,QAMW,I,J)
END IF
SQ2=1./SQRT(2.0)
C=SQRT(FCO2(QP,QRHO,QT,QE,QAMW))
AR=FAR(QP,QRHO,QT,QE,QAMW)
AE=FAE(QP,QRHO,QT,QE,QAMW)
AER=AE/QRHO
DPDR=AR+AER*(-QEO/QRHO+(QU**2+QV**2))
DPDU=-AER*QU
DPDV=-AER*QV
DPDE=AER
CXCX=1./SQRT(CX**2+CY**2)
C1=CX*CXCX
C2=CY*CXCX
A(1,1)=1.
A(1,2)=0.
A(1,3)=QRHO*SQ2/C
A(1,4)=A(1,3)
A(2,1)=QU
A(2,2)=QRHO*C2
A(2,3)=SQ2*QRHO*(QU/C+C1)

```

```

A(2,4)=SQ2*QRHO*(QU/C-C1)
A(3,1)=QV
A(3,2)=-QRHO*C1
A(3,3)=SQ2*QRHO*(QV/C+C2)
A(3,4)=SQ2*QRHO*(QV/C-C2)
A(4,1)=QEO/QRHO-QRHO*AR/AE
A(4,2)=QRHO*(QU*C2-QV*C1)
TEMP1=SQ2*QRHO**2*C/AE
TEMP2=SQ2*QRHO*(QU*C1+QV*C2)
A(4,3)=A(4,1)*QRHO*SQ2/C+TEMP1+TEMP2
A(4,4)=A(4,1)*QRHO*SQ2/C+TEMP1-TEMP2
RETURN
END
SUBROUTINE FLXCL

```

\*\*\*\*\*

\*

\* SUBROUTINE FOR FLUX VECTOR CALCULATION

\*

\*\*\*\*\*

```

PARAMETER (IZ=60,JZ=40)
COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
> G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
> U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
> ZMU(JZ),ZMUT(JZ),ZK(JZ)
COMMON /COORD/ SAIY(IZ,JZ),SAIX(IZ,JZ),ETAX(IZ,JZ),
> ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
> DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
> A4(IZ,JZ)
COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
> RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
> PO,TO,TWALL,PB,SUM(4)
COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
> IVISC,IWALL,IWRT
DIMENSION RHO(IZ,JZ),RHOV(IZ,JZ),RHOX(IZ,JZ),RHOY(IZ,JZ)
EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOX(1,1)),
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),RHOY(1,1))
DIMENSION A(4,4)

```

\*\*\*\*\*

ENTRY FLXE(II)

\*\*\*\*\*

\*

\* COMPUTE CONVECTIVE FLUX VECTOR E

\*

\*\*\*\*\*

```

I=II
DO 10 J=1,JL
F(I,J,1)=RHO(I,J)*UN(I,J)/RJ(I,J)*Y(I,J)
F(I,J,2)=(RHOX(I,J)*UN(I,J)+SAIX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
F(I,J,3)=(RHOV(I,J)*UN(I,J)+SAIY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
F(I,J,4)=(EO(I,J)+P(I,J))*UN(I,J)/RJ(I,J)*Y(I,J)
10 CONTINUE

```

RETURN

\*\*\*\*\*

ENTRY FLXF(II)

\*\*\*\*\*

```

*
*   COMPUTE CONVECTIVE FLUX VECTOR F
*
*****
  I=II
  DO 20 J=1,JL
    G(I,J,1)=RHO(I,J)*VN(I,J)/RJ(I,J)*Y(I,J)
    G(I,J,2)=(RHO(I,J)*VN(I,J)+ETAX(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
    G(I,J,3)=(RHO(I,J)*VN(I,J)+ETAY(I,J)*P(I,J))/RJ(I,J)*Y(I,J)
    G(I,J,4)=(EO(I,J)+P(I,J))*VN(I,J)/RJ(I,J)*Y(I,J)
  20 CONTINUE
  RETURN
*****
  ENTRY FLXEP(II,IMID)
*****
*
*   +
*   E FLUX VECTOR (IMID=0)
*
*   + +
*   DE =A (I+1/2,J)*(Q(I+1,J)-Q(I,J)) (IMID=1)
*
*****
  I=II
  IF(IMID.EQ.0) THEN
    DO 30 J=1,JL
      CALL JCBABPM(1,1,0,A,I,J)
      DO 31 K=1,4
        F(I,J,K)=0.
      DO 31 JJ=1,4
        F(I,J,K)=F(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
    31 CONTINUE
  30 CONTINUE
  END IF
  IF(IMID.EQ.1.AND.I.NE.IL) THEN
    DO 35 J=1,JL
      CALL JCBABPM(1,1,1,A,I,J)
      DO 36 K=1,4
        F(I,J,K)=0.
      DO 36 JJ=1,4
        YM=0.5*(Y(I,J)+Y(I+1,J))
        RJM=0.5*(RJ(I,J)+RJ(I+1,J))
        F(I,J,K)=F(I,J,K)+A(K,JJ)*(Q(I+1,J,JJ)-Q(I,J,JJ))/RJM*YM
    36 CONTINUE
  35 CONTINUE
  END IF
  IF(IMID.EQ.1.AND.I.EQ.IL) THEN
    DO 37 J=1,JL
      CALL JCBABPM(1,1,0,A,I,J)
      DO 38 K=1,4
        F(I,J,K)=0.
      DO 38 JJ=1,4
        YM=Y(I,J)
        RJM=RJ(I,J)
        F(I,J,K)=F(I,J,K)+A(K,JJ)*(Q(I,J,JJ)-Q(I-1,J,JJ))/RJM*YM
    38 CONTINUE
  37 CONTINUE
  END IF

```

38 CONTINUE

37 CONTINUE

END IF

RETURN

\*\*\*\*\*

ENTRY FLXEM(II,IMID)

\*\*\*\*\*

\*

\*

E FLUX VECTOR (IMID=0)

\*

\*

DE =A (I+1/2,J)\*(Q(I+1,J)-Q(I,J)) (IMID=1)

\*

\*\*\*\*\*

I=II

IF(IMID.EQ.0) THEN

DO 40 J=1,JL

CALL JCBABPM(1,2,0,A,I,J)

DO 41 K=1,4

G(I,J,K)=0.

DO 41 JJ=1,4

G(I,J,K)=G(I,J,K)+A(K,JJ)\*Q(I,J,JJ)/RJ(I,J)\*Y(I,J)

41 CONTINUE

40 CONTINUE

END IF

IF(IMID.EQ.1.AND.I.NE.IL) THEN

DO 45 J=1,JL

CALL JCBABPM(1,2,1,A,I,J)

DO 46 K=1,4

G(I,J,K)=0.

DO 46 JJ=1,4

YM=0.5\*(Y(I,J)+Y(I+1,J))

RJM=0.5\*(RJ(I,J)+RJ(I+1,J))

G(I,J,K)=G(I,J,K)+A(K,JJ)\*(Q(I+1,J,JJ)-Q(I,J,JJ))/RJM\*YM

46 CONTINUE

45 CONTINUE

END IF

IF(IMID.EQ.1.AND.I.EQ.IL) THEN

DO 47 J=1,JL

CALL JCBABPM(1,2,0,A,I,J)

DO 48 K=1,4

G(I,J,K)=0.

DO 48 JJ=1,4

YM=Y(I,J)

RJM=RJ(I,J)

G(I,J,K)=G(I,J,K)+A(K,JJ)\*(Q(I,J,JJ)-Q(I-1,J,JJ))/RJM\*YM

48 CONTINUE

47 CONTINUE

END IF

RETURN

\*\*\*\*\*

ENTRY FLXFP(II,IMID)

\*\*\*\*\*

\*

```

*      +
*      F  FLUX VECTOR (IMID=0)
*
*      +  +
*      DF =B (I,J+1/2)*(Q(I,J+1)-Q(I,J)) (IMID=1)
*
*****
      I=II
      IF(IMID.EQ.0) THEN
        DO 50 J=1,JL
          CALL JCBABPM(2,1,0,A,I,J)
          DO 51 K=1,4
            F(I,J,K)=0.
          DO 51 JJ=1,4
            F(I,J,K)=F(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
51      CONTINUE
50      CONTINUE
      END IF
      IF(IMID.EQ.1.AND.J.NE.JL) THEN
        DO 55 J=1,JL1
          CALL JCBABPM(2,1,1,A,I,J)
          DO 56 K=1,4
            F(I,J,K)=0.
          DO 56 JJ=1,4
            YM=0.5*(Y(I,J)+Y(I,J+1))
            RJM=0.5*(RJ(I,J)+RJ(I,J+1))
            F(I,J,K)=F(I,J,K)+A(K,JJ)*(Q(I,J+1,JJ)-Q(I,J,JJ))/RJM*YM
56      CONTINUE
55      CONTINUE
      END IF
      IF(IMID.EQ.1.AND.J.EQ.JL) THEN
        CALL JCBABPM(2,1,0,A,I,J)
        DO 58 K=1,4
          F(I,J,K)=0.
        DO 58 JJ=1,4
          YM=Y(I,J)
          RJM=RJ(I,J)
          F(I,J,K)=F(I,J,K)+A(K,JJ)*(Q(I,J,JJ)-Q(I,J-1,JJ))/RJM*YM
58      CONTINUE
      END IF
      RETURN
*****
      ENTRY FLXFM(II,IMID)
*****
*      -
*      F  FLUX VECTOR (IMID=0)
*
*      -  -
*      DF =B (I,J+1/2)*(Q(I,J+1)-Q(I,J))
*
*****
      I=II
      IF(IMID.EQ.0) THEN
        DO 60 J=1,JL

```

```

        CALL JCBABPM(2,2,0,A,I,J)
        DO 61 K=1,4
          C(I,J,K)=0.
        DO 61 JJ=1,4
          G(I,J,K)=G(I,J,K)+A(K,JJ)*Q(I,J,JJ)/RJ(I,J)*Y(I,J)
61      CONTINUE
60      CONTINUE
      END IF
      IF(IMID.EQ.1.AND.J.NE.JL) THEN
        DO 65 J=1,JL1
          CALL JCBABPM(2,2,1,A,I,J)
          DO 66 K=1,4
            G(I,J,K)=0.
          DO 66 JJ=1,4
            YM=0.5*(Y(I,J)+Y(I,J+1))
            RJM=0.5*(RJ(I,J)+RJ(I,J+1))
            G(I,J,K)=C(I,J,K)+A(K,JJ)*(Q(I,J+1,JJ)-Q(I,J,JJ))/RJM*YM
66      CONTINUE
65      CONTINUE
        END IF
        IF(IMID.EQ.1.AND.J.EQ.JL) THEN
          CALL JCBABPM(2,2,0,A,I,J)
          DO 68 K=1,4
            G(I,J,K)=0.
          DO 68 JJ=1,4
            YM=Y(I,J)
            RJM=RJ(I,J)
            G(I,J,K)=G(I,J,K)+A(K,JJ)*(Q(I,J,JJ)-Q(I,J-1,JJ))/RJM*YM
68      CONTINUE
        END IF
      RETURN
*****
      ENTRY FLXSVS(II)
*****
*
*   VISCOUS FLUX VECTOR, (DSVS'/DETA)+H' '
*
*****
*
*   VISCOUS FLUX VECTOR DSVS'/DETA
*
      I=II
      DO 70 J=2,JL1
        JP1=J+1
        JM1=J-1
        YJP=0.5*(Y(I,J)/RJ(I,J)+Y(I,JP1)/RJ(I,JP1))
        YJM=0.5*(Y(I,J)/RJ(I,J)+Y(I,JM1)/RJ(I,JM1))
        ZMUP=0.5*(ZMU(J)+ZMU(JP1))
        ZMUM=0.5*(ZMU(J)+ZMU(JM1))
        ZKP=0.5*(ZK(J)+ZK(JP1))
        ZKM=0.5*(ZK(J)+ZK(JM1))
        DUP=U(I,JP1)-U(I,J)
        DUM=U(I,J)-U(I,JM1)
        DVP=V(I,JP1)-V(I,J)
        DVM=V(I,J)-V(I,JM1)

```

```

DU2P=U(I,JP1)**2-U(I,J)**2
DU2M=U(I,J)**2-U(I,JM1)**2
DV2P=V(I,JP1)**2-V(I,J)**2
DV2M=V(I,J)**2-V(I,JM1)**2
DUVP=U(I,JP1)*V(I,JP1)-U(I,J)*V(I,J)
DUVM=U(I,J)*V(I,J)-U(I,JM1)*V(I,JM1)
DTP=T(I,JP1)-T(I,J)
DTM=T(I,J)-T(I,JM1)
ZMUA1P=ZMUP*A1(I,J)
ZMUA1M=ZMUM*A1(I,JM1)
ZMUA2P=ZMUP*A2(I,J)
ZMUA2M=ZMUM*A2(I,JM1)
ZMUA3P=ZMUP*A3(I,J)
ZMUA3M=ZMUM*A3(I,JM1)
ZKA4P=ZKP*A4(I,J)
ZKA4M=ZKM*A4(I,JM1)
G(I,J,1)=0.
G(I,J,2)=YJP*(ZMUA1P*DUP+ZMUA2P*DVP)
> -YJM*(ZMUA1M*DUM+ZMUA2M*DVM)
G(I,J,3)=YJP*(ZMUA3P*DVP+ZMUA2P*DUP)
> -YJM*(ZMUA3M*DVP+ZMUA2M*DUM)
G(I,J,4)=YJP*(0.5*ZMUA1P*DU2P+ZMUA2P*DUVP+0.5*ZMUA3P*DV2P
> +ZKA4P*DTP)
> -YJM*(0.5*ZMUA1M*DU2M+ZMUA2M*DUVM+0.5*ZMUA3M*DV2M
> +ZKA4M*DTM)

```

```

*
*   INSERT THE EXTRA FIRST ORDER TERMS IN CYLINDRICAL
*   COORDINATE SYSTEMS, VECTOR H''

```

```

*   H(1)=0.

```

```

*   1 2
*   H(2)=-*(--*ETA *D(MU*V)/DETA
*   J 3 X

```

```

*   1 2 2
*   H(3)=-*(-*ETA *MU*DU/DETA --*V*ETA *DMU/DETA)
*   J 3 X 3 Y

```

```

*   1 2 2
*   H(4)=-*(-*ETA *D(MU*U*V)/DETA --*ETA *D(MU*V*V)/DETA)
*   J 3 X 3 Y

```

```

*   EXJ=1./3.*ETAX(I,J)/RJ(I,J)
*   EYJ=1./3.*ETAY(I,J)/RJ(I,J)
*   G(I,J,2)=G(I,J,2)-EXJ*(ZMU(JP1)*V(I,JP1)-ZMU(JM1)*V(I,JM1))
*   G(I,J,3)=G(I,J,3)+EXJ*ZMU(J)*(U(I,JP1)-U(I,JM1))
> -EYJ*V(I,J)*(ZMU(JP1)-ZMU(JM1))
*   G(I,J,4)=G(I,J,4)-EXJ*(ZMU(JP1)*U(I,JP1)*V(I,JP1)
> -ZMU(JM1)*U(I,JM1)*V(I,JM1))
> -EYJ*(ZMU(JP1)*V(I,JP1)**2
> -ZMU(JM1)*V(I,JM1)**2)

```

```

70 CONTINUE
RETURN
END

```

SUBROUTINE RHSCLE

\*\*\*\*\*

\*

\* RIGHT HAND SIDE CALCULATION

\*

\*\*\*\*\*

PARAMETER (IZ=60,JZ=40)

COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),

> G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),

> U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),

> ZMU(JZ),ZMUT(JZ),ZK(JZ)

COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),

> ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),

> DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),

> A4(IZ,JZ)

COMMON /CONS/ EX1,EY1,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,

> RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,

> PO,TO,TWALL,PB,SUM(4)

COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,

> IVISC,IWALL,IWRT

DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)

EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),

> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))

\*\*\*\*\*

ENTRY RHSEF(II)

\*\*\*\*\*

\*

\* RIGHT HAND SIDE CONVECTIVE EULER TERMS E, F

\*

\* NOTE - SEE ALSO ENTRY RHSH FOR SOURCE CONVECTIVE TERM OF H'

\*

\*\*\*\*\*

I=Ii

DO 10 J=1,JL

DO 10 K=1,4

DQ(I,J,K)=0.

10 CONTINUE

\*

\* COMPUTE E(I-1,J), E(I+1,J), F(I,J-1), F(I,J+1) - 1ST ORDER

\*

CALL FLXE(I-1)

IF(I.NE.IL) THEN

CALL FLXE(I+1)

ELSE

CALL FLXE(I)

CALL FLXE(I-2)

END IF

CALL FLXF(I)

DO 20 J=2,JL

DO 20 K=1,4

IF(J.NE.JL) THEN

IF(I.NE.IL) THEN

DQ(I,J,K)=DQ(I,J,K)+0.5\*(F(I+1,J,K)-F(I-1,J,K))

+0.5\*(G(I,J+1,K)-G(I,J-1,K))

ELSE

```

      DQ(I,J,K)=DQ(I,J,K)+(F(I,J,K)-F(I-1,J,K))
      >          +0.5*(G(I,J+1,K)-G(I,J-1,K))
      >          +0.5*(F(I,J,K)-2.0*F(I-1,J,K)+F(I-2,J,K))
      END IF
      ELSE
      IF(I.NE.IL) THEN
      DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I+1,J,K)-F(I-1,J,K))
      >          +(G(I,J,K)-G(I,J-1,K))
      >          +0.5*(G(I,J,K)-2.0*G(I,J-1,K)+G(I,J-2,K))
      ELSE
      DQ(I,J,K)=DQ(I,J,K)+(F(I,J,K)-F(I-1,J,K))
      >          +(G(I,J,K)-G(I,J-1,K))
      >          +0.5*(F(I,J,K)-2.0*F(I-1,J,K)+F(I-2,J,K))
      >          +0.5*(G(I,J,K)-2.0*G(I,J-1,K)+G(I,J-2,K))
      END IF
      END IF
20 CONTINUE

*
*   COMPUTE D/E(I-1/2,J)/, D/E(I+1/2,J)/ - 1ST ORDER
*
      CALL FLXEP(I-1,1)
      CALL FLXEM(I-1,1)
      CALL FLXEP(I,1)
      CALL FLXEM(I,1)
      DO 30 J=2,JL
      DO 30 K=1,4
      IF(I.NE.IL) THEN
      DQ(I,J,K)=DQ(I,J,K)-0.5*(F(I,J,K)-F(I-1,J,K))
      >          +0.5*(G(I,J,K)-G(I-1,J,K))
      ELSE
      DQ(I,J,K)=DQ(I,J,K)-(F(I,J,K)-F(I-1,J,K))
      >          +(G(I,J,K)-G(I-1,J,K))
      END IF
30 CONTINUE

*
*   COMPUTE D/F(I,J-1/2)/, D/F(I,J+1/2)/ - 1ST ORDER
*
      CALL FLXEP(I,1)
      CALL FLXEM(I,1)
      DO 35 J=2,JL
      DO 35 K=1,4
      IF(J.NE.JL) THEN
      DQ(I,J,K)=DQ(I,J,K)-0.5*(F(I,J,K)-F(I,J-1,K))
      >          +0.5*(G(I,J,K)-G(I,J-1,K))
      ELSE
      DQ(I,J,K)=DQ(I,J,K)-(F(I,J,K)-F(I,J-1,K))
      >          +(G(I,J,K)-G(I,J-1,K))
      END IF
35 CONTINUE

*
*   + -
*   COMPUTE DE , DE - 2ND ORDER
*
      IF(I.GT.2.AND.I.LT.IL) THEN
      CALL FLXEP(I-2,1)

```

```

        CALL FLXEP(I-1,1)
        CALL FLXEM(I,1)
        CALL FLXEM(I+1,1)
    ELSE
    END IF
    DO 40 J=2,JL
    DO 40 K=1,4
    IF(I.EQ.2.OR.I.EQ.IL) GO TO 40
    IF(I.NE.IL-1) THEN
        DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I-1,J,K)-F(I-2,J,K))
        > -0.5*(G(I+1,J,K)-G(I,J,K))
    ELSE
        DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I-1,J,K)-F(I-2,J,K))
        > -(G(I+1,J,K)-G(I,J,K))
    END IF
40 CONTINUE

*
*      +      -
*      COMPUTE DF , DF - 2ND ORDER
*
        CALL FLXEP(I,1)
        CALL FLXEM(I,1)
        DO 45 J=2,JL
        DO 45 K=1,4
        IF(J.EQ.2.OR.J.EQ.JL) GO TO 45
        IF(J.NE.JL-1) THEN
            DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I,J-1,K)-F(I,J-2,K))
            \ -0.5*(G(I,J+1,K)-G(I,J,K))
        ELSE
            DQ(I,J,K)=DQ(I,J,K)+0.5*(F(I,J-1,K)-F(I,J-2,K))
            \ -(G(I,J+1,K)-G(I,J,K))
        END IF
45 CONTINUE
        RETURN
*****
        ENTRY RHSH(II)
*****
*
*      SOURCE VECTOR H'
*
        H(1)=0.
        H(2)=0.
        H(3)=(P-4./3.*MU*V/Y)/J
        H(4)=0.
*
*****
        I=II
        DO 50 J=2,JL
        IF(IVISC.EQ.0) THEN
            R2MY=0.
        ELSE
            R2MY=4./3.*ZMU(J)*V(I,J)/(RJ(I,J)*Y(I,J))
        END IF
        DQ(I,J,3)=DQ(I,J,3)-P(I,J)/RJ(I,J)+IVISC*R2MY
50 CONTINUE

```

RETURN

\*\*\*\*\*

ENTRY RHSVS(II)

\*\*\*\*\*

\*

\* RIGHT HAND SIDE VISCOUS TERMS

\*

\* NOTE - SEE ALSO ENTRY RHSH FOR SOURCE VISCOUS TERMS OF H'

\*

\*\*\*\*\*

I=II

CALL FLXSVS(I)

DO 90 J=2,JL1

DO 90 K=2,4

DQ(I,J,K)=DQ(I,J,K)-G(I,J,K)

90 CONTINUE

RETURN

END

SUBROUTINE SMOOTH

\*\*\*\*\*

\*

\* ADD ARTIFICIAL DISSIPATIONAL TERM FOR SAI, ETA - DIRECTION

\*

\*\*\*\*\*

PARAMETER (IZ=60,JZ=40)

COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),

> G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),

> U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),

> ZMU(JZ),ZMUT(JZ),ZK(JZ)

COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),

> ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),

> DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),

> A4(IZ,JZ)

COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,

> RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,

> PO,TO,TWALL,PB,SUM(4)

COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,

> IVISC,IWALL,IWRT

DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)

EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),

> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))

DIMENSION ADD(4)

\*\*\*\*\*

ENTRY ADDX

\*\*\*\*\*

\*

\* ADD SAI-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY

\*

COEF=0.1250\*OMEGAX

DO 70 J=1,JL

DO 70 I=1,IL

DO 70 I=2,IL

IF(I.EQ.1) GO TO 10

IF(I.EQ.2) GO TO 20

IF(I.EQ.IL1) GO TO 30

```

      IF(I.EQ.IL) GO TO 40
      DO 5 K=1,4
5     ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
      >         +6.*Q(I,J,K)-4.*Q(I-1,J,K)
      >         +Q(I-2,J,K))
      GO TO 50
10    DO 15 K=1,4
      QM=2.*Q(1,J,K)-Q(2,J,K)
      QMM=2.*QM-Q(1,J,K)
15    ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
      >         +6.*Q(I,J,K)-4.*QM+QMM)
      GO TO 50
20    DO 25 K=1,4
      QMM=2.*Q(1,J,K)-Q(2,J,K)
25    ADD(K)=COEF*(Q(I+2,J,K)-4.*Q(I+1,J,K)
      >         +6.*Q(I,J,K)-4.*Q(I-1,J,K)
      >         +QMM)
      GO TO 50
30    DO 35 K=1,4
      QPP=2.*Q(I+1,J,K)-Q(I,J,K)
35    ADD(K)=COEF*(QPP-4.*Q(I+1,J,K)+6.*Q(I,J,K)
      >         -4.*Q(I-1,J,K)+Q(I-2,J,K)
      >         )
      GO TO 50
40    DO 45 K=1,4
      QP=2.*Q(I,J,K)-Q(I-1,J,K)
      QPP=2.*QP-Q(I,J,K)
45    ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
      >         Q(I-1,J,K)+Q(I-2,J,K))
50    CONTINUE
      DO 60 K=1,4
60    DQ(I,J,K)=DQ(I,J,K)-ADD(K)/RJ(I,J)*Y(I,J)
70    CONTINUE
      RETURN
*****
      ENTRY ADDY
*****
*
*     ADD ETA-DIRECTION 4TH ORDER ARTIFICIAL VISCOSITY
*
      COEF=0.1250*OMEGAY
      DO 170 I=1,IL
      DO 170 I=2,IL
      DO 170 J=1,JL
      IF(J.EQ.1) GO TO 110
      IF(J.EQ.2) GO TO 120
      IF(J.EQ.JL1) GO TO 130
      IF(J.EQ.JL) GO TO 140
      DO 105 K=1,4
105   ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
      >         +6.*Q(I,J,K)-4.*Q(I,J-1,K)
      >         +Q(I,J-2,K))
      GO TO 150
110   DO 115 K=1,4
      QM=2.*Q(I,1,K)-Q(I,2,K)

```

```

      QMM=2.*QM-Q(I,1,K)
115  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
      > +6.*Q(I,J,K)-4.*QM+QMM)
      GO TO 150
120  DO 125 K=1,4
      QMM=2.*Q(I,1,K)-Q(I,2,K)
125  ADD(K)=COEF*(Q(I,J+2,K)-4.*Q(I,J+1,K)
      > +6.*Q(I,J,K)-4.*Q(I,J-1,K)
      > +QMM)
      GO TO 150
130  DO 135 K=1,4
      QPP=2.*Q(I,J+1,K)-Q(I,J,K)
135  ADD(K)=COEF*(QPP-4.*Q(I,J+1,K)+6.*Q(I,J,K)
      > -4.*Q(I,J-1,K)+Q(I,J-2,K)
      > )
      GO TO 150
140  DO 145 K=1,4
      QP=2.*Q(I,J,K)-Q(I,J-1,K)
      QPP=2.*QP-Q(I,J,K)
145  ADD(K)=COEF*(QPP-4.*QP+6.*Q(I,J,K)-4.*
      > Q(I,J-1,K)+Q(I,J-2,K))
150  CONTINUE
      DO 160 K=1,4
160  DQ(I,J,K)=DQ(I,J,K)-ADD(K)/RJ(I,J)*Y(I,J)
170  CONTINUE
      RETURN
      END
      SUBROUTINE UGAS3(E,RHO,ZMU)

```

INPUTS FOR SUBROUTINE :

E = SPECIFIC INTERNAL ENERGY, IN (M/S)\*\*2  
 RHO = DENSITY, IN KG/M\*\*3

OUTPUT :

ZMU = DYNAMIC VISCOSITY, IN KG/M/S

```

DATA RHOO,E0/1.243,78408.4E00/
Z=ALOG10(E/E0)
Y=ALOG10(RHO/RHOO)
IF (Z.GT.0.67E00) GO TO 10
GAS1=4.84547E-01+4.67135E-01*Z
GAS2=(5.71205E-04-1.43629E-03*Z)*Y
GAS3=(2.55110E00-2.33472E-04*Y-1.44102E00*Z)*Z*Z
GAS4=(2.53416E-04-4.72375E-04*Z+1.86899E-05*Y)*Y*Y
F=GAS1+GAS2+GAS3+GAS4
GO TO 90
10 IF (Z.GT.1.75E00) GO TO 20
GAS1=-3.71666E01+6.67883E01*Z
GAS2=(-2.43998E00+2.12309E00*Z)*Y
GAS3=(-3.69259E01-3.08426E-01*Y+7.36486E00*Z)*Z*Z
GAS4=(-1.46446E-01+7.54423E-02*Z-2.91464E-03*Y)*Y*Y
GAS5=3.61757E01-6.11102E01*Z
GAS6=(2.40531E00-2.05914E00*Z)*Y

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```

GAS7=(3.23911E01+2.79149E-01*Y-5.07640E00*Z)*Z*Z
GAS8=(1.37916E-01-6.72041E-02*Z+2.61987E-03*Y)*Y*Y
GAS9=EXP(-3.433E01-1.823E00*Y+2.499E01*Z+6.503E-01*Z*Y)
GO TO 80
20 IF (Z.GT.2.50E00) GO TO 30
GAS1=-1.65147E02+2.11028E02*Z
GAS2=(-4.70948E00+2.78258E00*Z)*Y
GAS3=(-8.78308E01-1.28671E-01*Y+1.27639E01*Z)*Z*Z
GAS4=(-3.19867E-01+1.73179E-01*Z+3.86106E-03*Y)*Y*Y
GAS5=2.30407E02-2.98055E02*Z
GAS6=(-6.18307E00+8.44595E00*Z)*Y
GAS7=(1.26933E02-2.61671E00*Y-1.77257E01*Z)*Z*Z
GAS8=(-2.30229E-02+2.25458E-02*Z-4.41072E-03*Y)*Y*Y
GAS9=EXP(-6.882E01+8.824E00*Y+3.203E01*Z-5.359E00*Z*Y)
GO TO 80
30 IF (Z.GT.2.85E00) GO TO 40
GAS1=-7.09274E03+7.13648E03*Z
GAS2=(-2.46014E02+1.65826E02*Z)*Y
GAS3=(-2.37952E03-2.75487E01*Y+2.63465E02*Z)*Z*Z
GAS4=(-3.49744E00+1.28641E00*Z-3.13711E-03*Y)*Y*Y
GAS5=5.26158E03-4.96701E03*Z
GAS6=(2.03138E02-1.32984E02*Z)*Y
GAS7=(1.52424E03+2.15081E01*Y-1.50450E02*Z)*Z*Z
GAS8=(3.32432E00-1.15997E00*Z+1.14862E-02*Y)*Y*Y
GAS9=EXP(-3.594E02-3.763E01*Y+1.319E02*Z+1.348E01*Z*Y)
F=GAS1+GAS2+GAS3+GAS4
GO TO 80
40 IF (Z.GT.3.15E00) GO TO 50
GAS1=-1.27748E03+1.29400E03*Z
GAS2=(-3.60724E01+2.63194E01*Z)*Y
GAS3=(-4.22958E02-4.38228E00*Y+4.50571E01*Z)*Z*Z
GAS4=(-4.74425E-01+2.89684E-01*Z+1.64048E-02*Y)*Y*Y
F=GAS1+GAS2+GAS3+GAS4
GO TO 90
50 IF (Y.GT.-3.80E00) GO TO 70
IF (Z.GT.3.19E00) GO TO 60
GAS1=4.55919E03-4.21057E03*Z
GAS2=(1.03001E01-2.63478E01*Z)*Y
GAS3=(1.29069E03+6.59587E00*Y-1.31413E02*Z)*Z*Z
GAS4=(-8.28137E00+1.9827E00*Z-1.7287E-01*Y)*Y*Y
F=GAS1+GAS2+GAS3+GAS4
GO TO 90
60 Z=E/E0
GAS1=-4.41792E02+9.7986E-02*Z
GAS2=(-3.03148E02+7.6065E-03*Z)*Y
GAS3=(-5.5711E-05-3.52836E-06*Y+8.86148E-09*Z)*Z*Z
GAS4=(-7.561E01-4.76816E-04*Z-6.48859E00*Y)*Y*Y
GAS5=6.72387E04+3.28398E00*Z
GAS6=(3.55009E04+2.72616E00*Z)*Y
GAS7=(2.13714E-03+3.42377E-04*Y-6.84897E-08*Z)*Z*Z
GAS8=(6.50886E03+3.8056E-01*Z+4.14116E02*Y)*Y*Y
GAS9=EXP(2.978E01+5.415E00*Y+1.713E-03*Z+3.115E-04*Y*Z)
F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
GO TO 90
70 GAS1=-6.4029E03+6.24254E03*Z

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```

GAS2=(1.03279E02-8.73181E01*Z)*Y
GAS3=(-2.02865E03+1.71878E01*Y+2.19907E02*Z)*Z*Z
GAS4=(-1.22397E01+3.57830E00*Z-1.27953E-01*Y)*Y*Y
F=GAS1+GAS2+GAS3+GAS4
GO TO 90
80 F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0+GAS9)
90 ZMU=1.748583E-05*F
RETURN
END
SUBROUTINE UGAS4(E,RHO,ZK)

INPUTS FOR SUBROUTINE :

E = SPECIFIC INTERNAL ENERGY, IN (M/S)**2
RHO = DENSITY, IN KG/M**3

OUTPUT :

ZK = COEFFICIENT OF THERMAL CONDUCTIVITY, IN J/(KELVIN*M*S)

DATA RHOO,E0/1.243E00,78408E00/
Z=ALOG10(E/E0)
Y=ALOG10(RHO/RHOO)
IF (Z.GT.0.65E00) GO TO 10
GAS1=1.8100369E-01+4.8126802E00*Z
GAS2=(-2.7231116E-02+1.2691337E-01*Z)*Y
GAS3=(-8.9913034E00-1.2624085E-01*Y+8.9649105E00*Z)*Z*Z
GAS4=(-4.7198236E-03+9.2328079E-03*Z-2.9488327E-04*Y)*Y*Y
F=GAS1+GAS2+GAS3+GAS4
GO TO 200
10 IF (Y.GT.-1.00E00) GO TO 130
IF (Y.GT.-3.00E00) GO TO 70
IF (Z.GT.1.25E00) GO TO 20
GAS1=-1.05935E04+2.31470E04*Z
GAS2=(-7.41294E02+1.21724E03*Z)*Y
GAS3=(-1.67601E04-4.43184E02*Y+4.06631E03*Z)*Z*Z
GAS4=(1.35105E01+4.94914E00*Z+1.55386E00*Y)*Y*Y
GAS5=1.06032E04-2.31560E04*Z
GAS6=(7.46951E02-1.22465E03*Z)*Y
GAS7=(1.67604E04+4.45919E02*Y-4.06258E03*Z)*Z*Z
GAS8=(-1.28615E01-5.32398E00*Z-1.52956E00*Y)*Y*Y
GAS9=EXP(-4.219E01-4.687E00*Y+2.812E01*Z+3.125E00*Y*Z)
F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
GO TO 200
20 IF (Z.GT.1.775E00) GO TO 30
GAS1=3.79375E03-7.40351E03*Z
GAS2=(3.29698E02-3.55916E02*Z)*Y
GAS3=(4.77122E03+1.00241E02*Y-1.00740E03*Z)*Z*Z
GAS4=(1.97061E01-8.42554E00*Z+4.80494E-01*Y)*Y*Y
GAS5=-4.53603E03+9.05605E03*Z
GAS6=(-4.95870E02+6.33563E02*Z)*Y
GAS7=(-5.95317E03-2.05442E02*Y+1.28945E03*Z)*Z*Z
GAS8=(-2.00087E01+1.18851E01*Z-1.71735E-01*Y)*Y*Y
GAS9=EXP(-3.318E01+3.158E-01*Y+1.863E01*Z-1.035E00*Y*Z)
GO TO 190

```

```

30 IF (Z.GT.1.93E00) GO TO 40
   GAS1=2.06651875E05-3.165645E05*Z
   GAS2=(-3.07322021E02+4.57036377E02*Z)*Y
   GAS3=(1.61824937E05-1.55508453E02*Y-2.7603957E04*Z)*Z*Z
   GAS4=(1.92260265E00-2.24788094E00*Z-3.06226015E-01*Y)*Y*Y
   GAS5=-2.06564312E05+3.18191312E05*Z
   GAS6=(2.17542285E03-2.46670776E03*Z)*Y
   GAS7=(-1.63597062E05+7.16753174E02*Y+2.80926367E04*Z)*Z*Z
   GAS8=(3.39526825E01-7.33816645E00*Z+1.91214371E00*Y)*Y*Y
   GAS9=EXP(-3.924E02-5.206E01*Y+2.054E02*Z+2.679E01*Y*Z)
   GO TO 190
40 IF (Z.GT.2.60E00) GO TO 50
   GAS1=7.1572625E04-9.2471625E04*Z
   GAS2=(1.9646323E03-2.0280527E03*Z)*Y
   GAS3=(3.9446105E04+4.5673853E02*Y-5.5728672E03*Z)*Z*Z
   GAS4=(-9.2131958E01+1.2724541E01*Z-5.0568476E00*Y)*Y*Y
   GAS5=-3.2910781E04+4.2551211E04*Z
   GAS6=(1.4566331E03-2.2653745E03*Z)*Y
   GAS7=(-1.9476277E04+8.4370288E02*Y+3.2389702E03*Z)*Z*Z
   GAS8=(-1.3324594E02+1.0591533E02*Z+5.8639469E00*Y)*Y*Y
   GAS9=EXP(4.917E01+2.415E01*Y-2.455E01*Z-1.181E01*Y*Z)
   GO TO 190
50 IF (Z.GT.2.69E00) GO TO 60
   GAS1=1.145683E06-1.237525E06*Z
   GAS2=(1.4024508E04-9.3467227E03*Z)*Y
   GAS3=(4.4593056E05+1.533074E03*Y-5.3608352E04*Z)*Z*Z
   GAS4=(2.8485107E02-1.0968916E02*Z-1.0955791E00*Y)*Y*Y
   GAS5=-1.752087E06+1.79675E06*Z
   GAS6=(-1.3278737E05+9.8215562E04*Z)*Y
   GAS7=(-6.0791744E05-1.811943E04*Y+6.7709875E04*Z)*Z*Z
   GAS8=(-1.3384084E03+5.2707324E02*Z+2.5904894E00*Y)*Y*Y
   GAS9=EXP(-1.798E02+7.371E00*Y+6.731E01*Z-3.205E00*Y*Z)
   GO TO 190
60 GAS1=-8.5499625E04+1.1739656E05*Z
   GAS2=(6.4563168E04-3.9551203E04*Z)*Y
   GAS3=(-4.8170254E04+6.0816055E03*Y+6.2052031E03*Z)*Z*Z
   GAS4=(2.3473167E-01+1.8871567E01*Z+4.0757723E00*Y)*Y*Y
   GAS5=5.8546883E04-9.4634875E04*Z
   GAS6=(-6.6513812E04+4.0899945E04*Z)*Y
   GAS7=(4.2127227E04-6.3717305E03*Y-5.7495195E03*Z)*Z*Z
   GAS8=(-1.0260344E00-5.343277E01*Z-1.1017392E01*Y)*Y*Y
   GAS9=EXP(5.411E00+1.162E01*Y-1.082E00*Z-3.391E00*Y*Z)
   F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
   GO TO 200
70 IF (Z.GT.1.29E00) GO TO 80
   GAS1=-1.22493E04+2.41071E04*Z
   GAS2=(-1.61829E03+2.22535E03*Z)*Y
   GAS3=(-1.59261E04-7.53213E02*Y+3.53376E03*Z)*Z*Z
   GAS4=(1.98026E00+5.18483E00*Z+1.47851E00*Y)*Y*Y
   GAS5=1.22486E04-2.41023E04*Z
   GAS6=(1.61810E03-2.22571E03*Z)*Y
   GAS7=(1.59235E04+7.53746E02*Y-3.53168E03*Z)*Z*Z
   GAS8=(-2.15482E00-5.05115E00*Z-1.48795E00*Y)*Y*Y
   GAS9=EXP(-3.111E01-4.444E00*Y+1.944E01*Z+2.778E00*Y*Z)
   F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)

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```

GO TO 200
80 IF (Z.GT.1.85E00) GO TO 90
  GAS1=3.18060E03-6.69664E03*Z
  GAS2=(4.33382E01-2.14649E02*Z)*Y
  GAS3=(4.41377E03+9.41359E01*Y-9.29758E02*Z)*Z*Z
  GAS4=(-3.62190E01+1.15538E01*Z-2.14621E00*Y)*Y*Y
  GAS5=-5.98764E03+1.29243E04*Z
  GAS6=(-2.72261E02+5.42378E02*Z)*Y
  GAS7=(-9.03293E03-2.11787E02*Y+2.07831E03*Z)*Z*Z
  GAS8=(2.74179E01-5.68578E00*Z+1.91217E00*Y)*Y*Y
  GAS9=EXP(-1.854E01+7.11E00*Y+1.068E01*Z-5.449E00*Y*Z)
  GO TO 190
90 IF (Z.GT.2.0E00) GO TO 100
  GAS1=5.14024E04-7.52733E04*Z
  GAS2=(-3.30889E02+3.11550E02*Z)*Y
  GAS3=(3.66539E04-7.41227E01*Y-5.93015E03*Z)*Z*Z
  GAS4=(-4.84164E01+2.23133E01*Z-9.19118E-01*Y)*Y*Y
  GAS5=-1.80898E05+2.82532E05*Z
  GAS6=(-1.01053E03+9.75576E02*Z)*Y
  GAS7=(-1.47220E05-2.33631E02*Y+2.55940E04*Z)*Z*Z
  GAS8=(3.28681E00-1.76588E00*Z-1.54962E-01*Y)*Y*Y
  GAS9=EXP(-4.104E01+6.507E01*Y+2.083E01*Z-3.472E01*Z*Y)
  GO TO 190
100 IF (Z.GT.2.58E00) GO TO 110
  GAS1=5.1131824E04-6.664875E04*Z
  GAS2=(2.02171E03-1.9306292E03*Z)*Y
  GAS3=(2.8762395E04+4.3353467E02*Y-4.1064609E03*Z)*Z*Z
  GAS4=(-8.4970047E01+1.7925919E01*Z-6.2576542E00*Y)*Y*Y
  GAS5=-6.2768156E04+8.6015875E04*Z
  GAS6=(-1.0002036E03+6.2537280E02*Z)*Y
  GAS7=(-3.957827E04-3.8467377E01*Y+6.12953E03*Z)*Z*Z
  GAS8=(-1.0591702E02+7.636142E01*Z+5.938859E00*Y)*Y*Y
  GAS9=EXP(-3.901E00+2.418E01*Y+1.374E00*Z-1.145E01*Y*Z)
  GO TO 190
110 IF (Z.GT.2.73E00) GO TO 120
  GAS1=1.0088046E06-1.086321E06*Z
  GAS2=(1.3844801E04-9.7268516E03*Z)*Y
  GAS3=(3.8985325E05+1.7091665E03*Y-4.6621066E04*Z)*Z*Z
  GAS4=(1.4840726E02-5.2645004E01*Z-1.5477133E-01*Y)*Y*Y
  GAS5=-1.073351E06+1.14571E06*Z
  GAS6=(-1.9343957E04+1.3366211E04*Z)*Y
  GAS7=(-4.0670987E05-2.2955198E03*Y+4.7999871E04*Z)*Z*Z
  GAS8=(-4.1016724E02+1.4994148E02*Z-1.9779787E00*Y)*Y*Y
  GAS9=EXP(-1.026E02+6.302E01*Y+3.819E01*Z-2.431E01*Y*Z)
  GO TO 190
120 GAS1=-9.6638500E04+1.3206488E04*Z
  GAS2=(-4.7458105E04+2.3596875E04*Z)*Y
  GAS3=(1.8602773E04-2.306802E03*Y-4.0413552E03*Z)*Z*Z
  GAS4=(-5.3564258E03+2.2433904E03*Z+2.5188145E02*Y)*Y*Y
  GAS5=1.0962581E05-2.990116E04*Z
  GAS6=(4.7883496E04-2.3785383E04*Z)*Y
  GAS7=(-1.1753969E04+2.2905522E03*Y+3.1304399E03*Z)*Z*Z
  GAS8=(5.473418E03-2.3208018E03*Z-2.6570068E02*Y)*Y*Y
  GAS9=EXP(-3.107E01+1.082E01*Y+1.047E01*Z-3.047E00*Y*Z)
  F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)

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GO TO 200
130 IF (Z.GT.1.40E00) GO TO 140
GAS1=-1.58386E03+3.49223E03*Z
GAS2=(-8.39834E02+1.09565E03*Z)*Y
GAS3=(-2.56175E03-3.56197E02*Y+6.25145E02*Z)*Z*Z
GAS4=(-1.22407E01+7.65634E00*Z+2.58235E-01*Y)*Y*Y
GAS5=1.58025E03-3.47664E03*Z
GAS6=(8.39588E02-1.09490E03*Z)*Y
GAS7=(2.54682E03+3.55674E02*Y-6.18504E02*Z)*Z*Z
GAS8=(1.20843E01-7.44857E00*Z-2.91202E-01*Y)*Y*Y
GAS9=EXP(-2.171E01-4.342E00*Y+1.316E01*Z+2.632E00*Y*Z)
F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0-GAS9)
GO TO 200
140 IF (Z.GT.1.91E00) GO TO 150
GAS1=7.89255E02-1.91743E03*Z
GAS2=(3.59227E02-4.44070E02*Z)*Y
GAS3=(1.39463E03+1.34083E02*Y-3.13446E02*Z)*Z*Z
GAS4=(1.90681E01-1.09285E01*Z+4.24933E-02*Y)*Y*Y
GAS5=-1.31401E03+3.13134E03*Z
GAS6=(-5.18755E02+6.80268E02*Z)*Y
GAS7=(-2.32493E03-2.21393E02*Y+5.52563E02*Z)*Z*Z
GAS8=(-3.32001E01+2.11819E01*Z-4.75163E-01*Y)*Y*Y
GAS9=EXP(-5.025E01-8.412E00*Y+2.982E01*Z+3.509E00*Y*Z)
GO TO 190
150 IF (Z.GT.2.05E00) GO TO 160
GAS1=3.58691E04-5.16852E04*Z
GAS2=(-6.30189E02+6.63314E02*Z)*Y
GAS3=(2.47471E04-1.73538E02*Y-3.93167E03*Z)*Z*Z
GAS4=(-4.23871E01+2.08048E01*Z-1.05512E00*Y)*Y*Y
GAS5=-1.10522E05+1.67591E05*Z
GAS6=(4.61877E03-4.94930E03*Z)*Y
GAS7=(-8.46558E04+1.32441E03*Y+1.42438E04*Z)*Z*Z
GAS8=(2.25065E01-1.10316E01*Z+9.62887E-01*Y)*Y*Y
GAS9=EXP(-1.681E02+7.063E01*Y+8.75E01*Z-3.75E01*Y*Z)
GO TO 190
160 IF (Z.GT.2.57E00) GO TO 170
GAS1=3.1899562E04-4.2186664E04*Z
GAS2=(2.3055603E03-1.9897017E03*Z)*Y
GAS3=(1.849998E04+4.2561816E02*Y-2.6808696E03*Z)*Z*Z
GAS4=(-1.6195114E01+5.8640623E00*Z-3.6172504E00*Y)*Y*Y
GAS5=-5.7594039E04+7.9328437E04*Z
GAS6=(-1.9275989E03+1.6730544E03*Z)*Y
GAS7=(-3.6473008E04-3.6100732E02*Y+5.597543E03*Z)*Z*Z
GAS8=(-7.920808E01+4.0542084E01*Z+2.1495867E00*Y)*Y*Y
GAS9=EXP(-5.733E01+2.088E01*Y+2.592E01*Z-9.793E00*Y*Z)
GO TO 190
170 IF (Z.GT.2.75E00) GO TO 180
GAS1=7.0838087E05-7.5619919E05*Z
GAS2=(3.9503091E03-2.7381802E03*Z)*Y
GAS3=(2.6888181E05+4.7728687E02*Y-3.183816E04*Z)*Z*Z
GAS4=(-1.2532251E02+4.7734787E01*Z-4.0148029E00*Y)*Y*Y
GAS5=-2.5216325E05+2.1727769E05*Z
GAS6=(9.2882383E03-7.780918E03*Z)*Y
GAS7=(-5.6539297E04+1.6120212E03*Y+3.9419248E03*Z)*Z*Z
GAS8=(1.8537296E02-7.1010757E01*Z+1.1307096E00*Y)*Y*Y

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      GAS9=EXP(-1.786E02+2.18E-01*Y+6.714E01*Z-4.739E-01*Y*Z)
      GO TO 190
180  GAS1=3.1855037E05-3.3041156E05*Z
      GAS2=(2.2983352E04-1.6623461E04*Z)*Y
      GAS3=(1.13848E05+3.0098223E03*Y-1.3020133E04*Z)*Z*Z
      GAS4=(-1.8599039E02+6.9840683E01*Z-7.7371645E00*Y)*Y*Y
      F=GAS1+GAS2+GAS3+GAS4
      GO TO 200
190  F=GAS1+GAS2+GAS3+GAS4+(GAS5+GAS6+GAS7+GAS8)/(1.0+GAS9)
200  ZK=1.87915E-02*F
      RETURN
      END
      FUNCTION FAMW(R,T)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
>                  X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
>                  X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
>                  X7(9),Y7(9),F7(9,9)
      IF(R.LT.X1(1)) II=1
      IF(R.GT.X1(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X1(I).AND.R.LE.X1(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
1  CONTINUE
2  CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X1(1),X1(9)
500  FORMAT(/2X,'R IS OUT OF BOUNDARIES, CALLED FROM FAMW'/
> 2X,'R=',E12.5,2X,'X1(1)=' ,E12.5,2X,'X1(9)=' ,E12.5)
        STOP
      ELSE
      END IF
      IF(T.LT.Y1(1)) JJ=1
      IF(T.GT.Y1(8)) JJ=8
      DO 3 J=1,8
      IF(T.GE.Y1(J).AND.T.LE.Y1(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
3  CONTINUE
4  CONTINUE
      IF(JJ.EQ.0) THEN
        WRITE (6,501) T,Y1(1),Y1(9)
501  FORMAT(/2X,'T IS OUT OF BOUNDARIES, CALLED FROM FAMW'/
> 2X,'T=',E12.5,2X,'Y1(1)=' ,E12.5,2X,'Y1(9)=' ,E12.5)
        STOP
      ELSE
      END IF
      I=II
      J=JJ
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1

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      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
      AMW1=F1(I,J)
>      +(F1(I+1,J)-F1(I,J))/(X1(I+1)-X1(I))*(R-X1(I))
      AMW2=F1(I,J+1)
>      +(F1(I+1,J+1)-F1(I,J+1))/(X1(I+1)-X1(I))*(R-X1(I))
      AMW=AMW1+(AMW2-AMW1)/(Y1(J+1)-Y1(J))*(T-Y1(J))
      FAMW=AMW
      RETURN
      END
      FUNCTION FE(R,T)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
>      X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
>      X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
>      X7(9),Y7(9),F7(9,9)
      IF(R.LT.X4(1)) II=0
      IF(R.GT.X4(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X4(I).AND.R.LE.X4(I+1)) THEN
        II=I
        GO TO 2
      ELSE
        END IF
1      CONTINUE
2      CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X4(1),X4(9)
500      FORMAT(/2X,'R IS OUT OF BOUNDARIES, CALLED FROM FE'/
>      2X,'R=',E12.5,2X,'X4(1)=' ,E12.5,2X,'X4(9)=' ,E12.5)
        STOP
      ELSE
        END IF
      IF(T.LT.Y4(1)) JJ=0
      IF(T.GT.Y4(9)) JJ=8
      DO 3 J=1,8
      IF(T.GE.Y4(J).AND.T.LE.Y4(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
        END IF
3      CONTINUE
4      CONTINUE
      IF(JJ.EQ.0) THEN
        WRITE (6,501) T,Y4(1),Y4(9)
501      FORMAT(/2X,'T IS OUT OF BOUNDARIES, CALLED FROM FE'/
>      2X,'T=',E12.5,2X,'Y4(1)=' ,E12.5,2X,'Y4(9)=' ,E12.5)
        STOP
      ELSE
        END IF
      I=II
      J=JJ
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1

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E1=F4(I,J)
> +(F4(I+1,J)-F4(I,J))/(X4(I+1)-X4(I))*(R-X4(I))
IF(E1.LT.F4(1,J)) E1=F4(1,J)
IF(E1.GT.F4(9,J)) E1=F4(9,J)
E2=F4(I,J+1)
> +(F4(I+1,J+1)-F4(I,J+1))/(X4(I+1)-X4(I))*(R-X4(I))
IF(E2.LT.F4(1,J+1)) E2=F4(1,J+1)
IF(E2.GT.F4(9,J+1)) E2=F4(9,J+1)
E=E1+(E2-E1)/(Y4(J+1)-Y4(J))*(T-Y4(J))
IF(E.LT.F4(I,1)) E=F4(I,1)
IF(E.GT.F4(I,9)) E=F4(I,9)
FE=E
RETURN
END
FUNCTION FT(R,E)
COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
> X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
> X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
> X7(9),Y7(9),F7(9,9)
IF(R.LT.X5(1)) II=0
IF(R.GT.X5(9)) II=8
DO 1 I=1,8
IF(R.GE.X5(I).AND.R.LE.X5(I+1)) THEN
II=I
GO TO 2
ELSE
END IF
1 CONTINUE
2 CONTINUE
IF(II.EQ.0) THEN
WRITE (6,500) R,X5(1),X5(9)
500 FORMAT(/2X,'R IS OUT OF BOUNDARIES, CALLED FROM FT'/
> 2X,'R=' ,E12.5,2X,'X5(1)=' ,E12.5,2X,'X5(9)=' ,E12.5)
STOP
ELSE
END IF
IF(E.LT.Y5(1)) JJ=0
IF(E.GT.Y5(9)) JJ=8
DO 3 J=1,8
IF(E.GE.Y5(J).AND.E.LE.Y5(J+1)) THEN
JJ=J
GO TO 4
ELSE
END IF
3 CONTINUE
4 CONTINUE
IF(JJ.EQ.0) THEN
WRITE (6,501) E,Y5(1),Y5(9)
501 FORMAT(/2X,'E IS OUT OF BOUNDARIES, CALLED FROM FT'/
> 2X,'E=' ,E12.5,2X,'Y5(1)=' ,E12.5,2X,'Y5(9)=' ,E12.5)
STOP
ELSE
END IF
I=II
J=JJ

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      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
      T1=F5(I,J)
>    +(F5(I+1,J)-F5(I,J))/(X5(I+1)-X5(I))*(R-X5(I))
      T2=F5(I,J+1)
>    +(F5(I+1,J+1)-F5(I,J+1))/(X5(I+1)-X5(I))*(R-X5(I))
      T=T1+(T2-T1)/(Y5(J+1)-Y5(J))*(E-Y5(J))
      FT=T
      RETURN
      END
      FUNCTION FZMU(R,E)
      CALL UGAS3(E,R,ZMU)
      FZMU=ZMU
      RETURN
      END
      FUNCTION FZK(R,E)
      CALL UGAS4(E,R,ZK)
      FZK=ZK
      RETURN
      END
      FUNCTION FDMVRT(R,T)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
>                  X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
>                  X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
>                  X7(9),Y7(9),F7(9,9)
      IF(R.LT.X2(1)) II=0
      IF(R.GT.X2(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X2(I).AND.R.LE.X2(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
1    CONTINUE
2    CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X2(1),X2(9)
500   FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FDMVRT'/
> 2X,'R=',E12.5,2X,'X2(1)=' ,E12.5,2X,'X2(9)=' ,E12.5)
        STOP
      ELSE
      END IF
      IF(T.LT.Y2(1)) JJ=0
      IF(T.GT.Y2(9)) JJ=8
      DO 3 J=1,8
      IF(T.GE.Y2(J).AND.T.LE.Y2(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
3    CONTINUE
4    CONTINUE
      IF(JJ.EQ.0) THEN

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      WRITE (6,501) T,Y2(1),Y2(9)
501  FORMAT(//2X,'T IS OUT OF BOUNDARIES, CALLED FROM FDMDRT'/
> 2X,'T=' ,E12.5,2X,'Y2(1)=' ,E12.5,2X,'Y2(9)=' ,E12.5)
      STOP
      ELSE
      END IF
      I=II
      J=JJ
      IF(II.EQ.0) I=II+1
      IF(II.EQ.8) I=II-1
      IF(JJ.EQ.0) J=JJ+1
      IF(JJ.EQ.8) J=JJ-1
      DMDRT1=F2(I,J)
>  +(F2(I+1,J)-F2(I,J))/(X2(I+1)-X2(I))*(R-X2(I))
      DMDRT2=F2(I,J+1)
>  +(F2(I+1,J+1)-F2(I,J+1))/(X2(I+1)-X2(I))*(R-X2(I))
      DMDRT=DMDRT1+(DMDRT2-DMDRT1)/(Y2(J+1)-Y2(J))*(T-Y2(J))
      FDMDRT=DMDRT
      RETURN
      END
      FUNCTION FDMDTR(R,T)
      COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
> X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
> X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
> X7(9),Y7(9),F7(9,9)
      IF(R.LT.X3(1)) II=0
      IF(R.GT.X3(9)) II=8
      DO 1 I=1,8
      IF(R.GE.X3(I).AND.R.LE.X3(I+1)) THEN
        II=I
        GO TO 2
      ELSE
      END IF
      1 CONTINUE
      2 CONTINUE
      IF(II.EQ.0) THEN
        WRITE (6,500) R,X3(1),X3(9)
500  FORMAT(//2X,'R IS OUT OF BOUNDARIES, CALLED FROM FDMDTR'/
> 2X,'R=' ,E12.5,2X,'X3(1)=' ,E12.5,2X,'X3(9)=' ,E12.5)
        STOP
      ELSE
      END IF
      IF(T.LT.Y3(1)) JJ=0
      IF(T.GT.Y3(9)) JJ=8
      DO 3 J=1,8
      IF(T.GE.Y3(J).AND.T.LE.Y3(J+1)) THEN
        JJ=J
        GO TO 4
      ELSE
      END IF
      3 CONTINUE
      4 CONTINUE
      IF(JJ.EQ.0) THEN
        WRITE (6,501) T,Y3(1),Y3(9)
501  FORMAT(//2X,'T IS OUT OF BOUNDARIES, CALLED FROM FDMDTR'/

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> 2X, 'T-', E12.5, 2X, 'Y3(1)=' , E12.5, 2X, 'Y3(9)=' , E12.5)
  STOP
ELSE
END IF
I=II
J=JJ
IF(II.EQ.0) I=II+1
IF(II.EQ.8) I=II-1
IF(JJ.EQ.0) J=JJ+1
IF(JJ.EQ.8) J=JJ-1
DMDTR1=F3(I,J)
> +(F3(I+1,J)-F3(I,J))/(X3(I+1)-X3(I))*(R-X3(I))
DMDTR2=F3(I,J+1)
> +(F3(I+1,J+1)-F3(I,J+1))/(X3(I+1)-X3(I))*(R-X3(I))
DMDTR=DMDTR1+(DMDTR2-DMDTR1)/(Y3(J+1)-Y3(J))*(T-Y3(J))
FDMDTR=DMDTR
RETURN
END
FUNCTION FDTDRE(R,E)
COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
> X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
> X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
> X7(9),Y7(9),F7(9,9)
IF(R.LT.X6(1)) II=0
IF(R.GT.X6(9)) II=8
DO 1 I=1,8
IF(R.GE.X6(I).AND.R.LE.X6(I+1)) THEN
  II=I
  GO TO 2
ELSE
END IF
1 CONTINUE
2 CONTINUE
IF(II.EQ.0) THEN
  WRITE (6,500) R,X6(1),X6(9)
500 FORMAT(/2X,'R IS OUT OF BOUNDARIES, CALLED FROM FDTDRE'/
> 2X,'R=' ,E12.5,2X,'X6(1)=' ,E12.5,2X,'X6(9)=' ,E12.5)
  STOP
ELSE
END IF
IF(E.LT.Y6(1)) JJ=0
IF(E.GT.Y6(9)) JJ=8
DO 3 J=1,8
IF(E.GE.Y6(J).AND.E.LE.Y6(J+1)) THEN
  JJ=J
  GO TO 4
ELSE
END IF
3 CONTINUE
4 CONTINUE
IF(JJ.EQ.0) THEN
  WRITE (6,501) E,Y6(1),Y6(9)
501 FORMAT(/2X,'E IS OUT OF BOUNDARIES, CALLED FROM FDTDRE'/
> 2X,'E=' ,E12.5,2X,'Y6(1)=' ,E12.5,2X,'Y6(9)=' ,E12.5)
  STOP

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ELSE
END IF
I=II
J=JJ
IF(II.EQ.0) I=II+1
IF(II.EQ.8) I=II-1
IF(JJ.EQ.0) J=JJ+1
IF(JJ.EQ.8) J=JJ-1
DTDRE1=F6(I,J)
> +(F6(I+1,J)-F6(I,J))/(X6(I+1)-X6(I))*(R-X6(I))
DTDRE2=F6(I,J+1)
> +(F6(I+1,J+1)-F6(I,J+1))/(X6(I+1)-X6(I))*(R-X6(I))
DTDRE=DTDRE1+(DTDRE2-DTDRE1)/(Y6(J+1)-Y6(J))*(E-Y6(J))
FDTDRE=DTDRE
RETURN
END
FUNCTION FDTDER(R,E)
COMMON /INPL/ X1(9),Y1(9),F1(9,9),X2(9),Y2(9),F2(9,9),
> X3(9),Y3(9),F3(9,9),X4(9),Y4(9),F4(9,9),
> X5(9),Y5(9),F5(9,9),X6(9),Y6(9),F6(9,9),
> X7(9),Y7(9),F7(9,9)
IF(R.LT.X7(1)) II=0
IF(R.GT.X7(9)) II=8
DO 1 I=1,8
IF(R.GE.X7(I).AND.R.LE.X7(I+1)) THEN
II=I
GO TO 2
ELSE
END IF
1 CONTINUE
2 CONTINUE
IF(II.EQ.0) THEN
WRITE (6,500) R,X7(1),X7(9)
500 FORMAT(/2X,'R IS OUT OF BOUNDARIES, CALLED FROM FDTDER'/
> 2X,'R=',E12.5,2X,'X7(1)=' ,E12.5,2X,'X7(9)=' ,E12.5)
STOP
ELSE
END IF
IF(E.LT.Y7(1)) JJ=0
IF(E.GT.Y7(9)) JJ=8
DO 3 J=1,8
IF(E.GE.Y7(J).AND.E.LE.Y7(J+1)) THEN
JJ=J
GO TO 4
ELSE
END IF
3 CONTINUE
4 CONTINUE
IF(JJ.EQ.0) THEN
WRITE (6,501) E,Y7(1),Y7(9)
501 FORMAT(/2X,'E IS OUT OF BOUNDARIES, CALLED FROM FDTDER'/
> 2X,'E=' ,E12.5,2X,'Y7(1)=' ,E12.5,2X,'Y7(9)=' ,E12.5)
STOP
ELSE
END IF

```

```

I=II
J=JJ
IF(II.EQ.0) I=II+1
IF(II.EQ.8) I=II-1
IF(JJ.EQ.0) J=JJ+1
IF(JJ.EQ.8) J=JJ-1
DTDER1=F7(I,J)
> +(F7(I+1,J)-F7(I,J))/(X7(I+1)-X7(I))*(R-X7(I))
DTDER2=F7(I,J+1)
> +(F7(I+1,J+1)-F7(I,J+1))/(X7(I+1)-X7(I))*(R-X7(I))
DTDER=DTDER1+(DTDER2-DTDER1)/(Y7(J+1)-Y7(J))*(E-Y7(J))
FDTDER=DTDER
RETURN
END
FUNCTION EDMUDRE(R,E)
DR=0.01*R
CALL UGAS3(E,R-DR/2.,ZMU1)
CALL UGAS3(E,R+DR/2.,ZMU2)
DMUDRE=(ZMU2-ZMU1)/DR
EDMUDRE=DMUDRE
RETURN
END
FUNCTION EDMUDER(R,E)
DE=0.01*E
CALL UGAS3(E-DE/2.,R,ZMU1)
CALL UGAS3(E+DE/2.,R,ZMU2)
DMUDER=(ZMU2-ZMU1)/DE
EDMUDER=DMUDER
RETURN
END
FUNCTION FDKDRE(R,E)
DR=0.01*R
CALL UGAS4(E,R-DR/2.,ZK1)
CALL UGAS4(E,R+DR/2.,ZK2)
DKDRE=(ZK2-ZK1)/DR
FDKDRE=DKDRE
RETURN
END
FUNCTION FDKDER(R,E)
DE=0.01*E
CALL UGAS4(E-DE/2.,R,ZK1)
CALL UGAS4(E+DE/2.,R,ZK2)
DKDER=(ZK2-ZK1)/DE
FDKDER=DKDER
RETURN
END
FUNCTION FAR(P,R,T,E,AMW)
DMDRT=FDMDRT(R,T)
DMDTR=FDMDTR(R,T)
DTDRE=FDTDRE(R,E)
BR=1.-R/AMW*DMDRT
BT=1.-T/AMW*DMDTR
FAR=P/R*BR+P/T*BT*DTDRE
RETURN
END

```

```
FUNCTION FAE(P,R,T,E,AMW)
```

```
DMDRT=FDMDRT(R,T)
```

```
DMDTR=FDMDTR(R,T)
```

```
DTDER=FDTDER(R,E)
```

```
BR=1.-R/AMW*DMDRT
```

```
BT=1.-T/AMW*DMDTR
```

```
FAE=P/T*BT*DTDER
```

```
RETURN
```

```
END
```

```
FUNCTION FCO2(P,R,T,E,AMW)
```

```
COMPUTING OF SPEED OF SOUND - C**2
```

```
P - PRESSURE
```

```
R - DENSITY
```

```
T - TEMPERATURE
```

```
E - INTERNAL ENERGY
```

```
AMW - MOLECULAR WEIGHT
```

```
DMDRT=FDMDRT(R,T)
```

```
DMDTR=FDMDTR(R,T)
```

```
DTDRE=FDTDRE(R,E)
```

```
DTDER=FDTDER(R,E)
```

```
BR=1.-R/AMW*DMDRT
```

```
BT=1.-T/AMW*DMDTR
```

```
FCO2=P/R*BR+P/T*BT*(DTDRE+P/R**2*DTDER)
```

```
RETURN
```

```
END
```

```
SUBROUTINE SUPPLY
```

```
*****
```

```
*
```

```
* SERVICE SUBROUTINE
```

```
*
```

```
*****
```

```
PARAMETER (IZ=60,JZ=40)
```

```
COMMON /VECTOR/ DQ(IZ,JZ,4),Q(IZ,JZ,4),F(IZ,JZ,4),
```

```
> G(IZ,JZ,4), P(IZ,JZ),T(IZ,JZ),E(IZ,JZ),AMW(IZ,JZ),
```

```
> U(IZ,JZ),V(IZ,JZ),UN(IZ,JZ),VN(IZ,JZ),
```

```
> ZMU(JZ),ZMUT(JZ),ZK(JZ)
```

```
COMMON /COORD/ SAIX(IZ,JZ),SAIY(IZ,JZ),ETAX(IZ,JZ),
```

```
> ETAY(IZ,JZ),RJ(IZ,JZ),X(IZ,JZ),Y(IZ,JZ),
```

```
> DELTAU(IZ,JZ),A1(IZ,JZ),A2(IZ,JZ),A3(IZ,JZ),
```

```
> A4(IZ,JZ)
```

```
COMMON /CONS/ EXI,EYI,THETA,CFL,CFL1,OMEGAX,OMEGAY,AIN,AEX,
```

```
> RL,RG,AMWO,GAMMAO,REN,PRN,PRNT,TREF,ZMUO,OMEGA,
```

```
> PO,TO,TWALL,PB,SUM(4)
```

```
COMMON /INTEG/ IL,JL,IL1,JL1,NBEG,NEND,NADV,NORD,ITIME,
```

```
> IVISC,IWALL,IWRT
```

```
DIMENSION RHO(IZ,JZ),RHOU(IZ,JZ),RHOV(IZ,JZ),EO(IZ,JZ)
```

```
EQUIVALENCE (Q(1,1,1),RHO(1,1)),(Q(1,1,2),RHOU(1,1)),
```

```
> (Q(1,1,3),RHOV(1,1)),(Q(1,1,4),EO(1,1))
```

```
DIMENSION SS(4),A(4,4)
```

```
*****
```

```
ENTRY CHECK
```

```
*****
```

```
DO 10 K=1,4
```

```
10 SS(K)=0.
```

```
DO 20 I=2,IL
```

```

DO 20 J=2,JL
DO 20 K=1,4
QQ=Q(I,J,K)
IF(K.EQ.3) QQ=Q(I,J,2)
IF(QQ.EQ.0.0) GO TO 20
SS(K)=SS(K)+(DQ(I,J,K)*RJ(I,J)/Y(I,J)/QQ)**2
20 CONTINUE
DO 30 K=1,4
30 SS(K)=SQRT(SS(K))/(IL*JL)
WRITE (6,500) NADV,(SS(K),K=1,4)
500 FORMAT(2X,'NADV=',I4,4X,'SS(1)=' ,1X,E12.7,
> 2X,'SS(2)=' ,1X,E12.7,2X,'SS(3)=' ,1X,E12.7,
> 2X,'SS(4)=' ,1X,E12.7)
WRITE (10,501) NADV,(SS(K),K=1,4)
501 FORMAT(I5,3X,4(1X,E14.7))
RETURN
*****
ENTRY MASS
*****
PI=ACOS(-1.0)
I=1
FLRT=0.
DO 41 J=1,JL1
DR=SQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
CXCY1=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)
CXCY2=SQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
FLRT=FLRT+0.5*PI*(Y(I,J)+Y(I,J+1))*DR*
> (RHO(I,J)*UN(I,J)/CXCY1+RHO(I,J+1)*UN(I,J+1)/CXCY2)
41 CONTINUE
WRITE (6,502) I,FLRT
WRITE (4,503) I,FLRT
DO 40 I=1,IL1
FLRT=0.
DO 50 J=1,JL1
DR1=SQRT((X(I,J+1)-X(I,J))**2+(Y(I,J+1)-Y(I,J))**2)
DR2=SQRT((X(I+1,J+1)-X(I+1,J))**2+(Y(I+1,J+1)-Y(I+1,J))**2)
DR=0.5*(DR1+DR2)
*
* 1ST ORDER
*
CXCY11=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)
CXCY12=SQRT(SAIX(I+1,J)**2+SAIY(I+1,J)**2)
CXCY1=0.5*(CXCY11+CXCY12)
CXCY21=SQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
CXCY22=SQRT(SAIX(I+1,J+1)**2+SAIY(I+1,J+1)**2)
CXCY2=0.5*(CXCY21+CXCY22)
RHOUN1=0.5*(RHO(I,J)*UN(I,J)/CXCY11
> +RHO(I+1,J)*UN(I+1,J)/CXCY12)
RHOUN2=0.5*(RHO(I,J+1)*UN(I,J+1)/CXCY21
> +RHO(I+1,J+1)*UN(I+1,J+1)/CXCY22)
IF(I.EQ.IL1) GO TO 59
CALL JCBABPM(1,1,1,A,I,J)
AQ1=0.
DO 51 JJ=1,4
51 AQ1=AQ1+A(1,JJ)*(Q(I+1,J,JJ)-Q(I,J,JJ))

```

```

CALL JCBABPM(1,1,1,A,I,J+1)
AQ2=0.
DO 52 JJ=1,4
52 AQ2=AQ2+A(1,JJ)*(Q(I+1,J+1,JJ)-Q(I,J+1,JJ))
   RHOUN1=RHOUN1-0.5*AQ1/CXCY1
   RHOUN2=RHOUN2-0.5*AQ2/CXCY2
   CALL JCBABPM(1,2,1,A,I,J)
   AQ1=0.
   DO 53 JJ=1,4
53 AQ1=AQ1+A(1,JJ)*(Q(I+1,J,JJ)-Q(I,J,JJ))
   CALL JCBABPM(1,2,1,A,I,J+1)
   AQ2=0.
   DO 54 JJ=1,4
54 AQ2=AQ2+A(1,JJ)*(Q(I+1,J+1,JJ)-Q(I,J+1,JJ))
   RHOUN1=RHOUN1+0.5*AQ1/CXCY1
   RHOUN2=RHOUN2+0.5*AQ2/CXCY2
*
* 2ND ORDER
*
IF(I.GT.1.AND.I.LT.IL1) THEN
  CXCY11=SQRT(SAIX(I-1,J)**2+SAIY(I-1,J)**2)
  CXCY12=SQRT(SAIX(I,J)**2+SAIY(I,J)**2)
  CXCY1=0.5*(CXCY11+CXCY12)
  CXCY21=SQRT(SAIX(I-1,J+1)**2+SAIY(I-1,J+1)**2)
  CXCY22=SQRT(SAIX(I,J+1)**2+SAIY(I,J+1)**2)
  CXCY2=0.5*(CXCY21+CXCY22)
  CALL JCBABPM(1,1,1,A,I-1,J)
  AQ1=0.
  DO 55 JJ=1,4
55 AQ1=AQ1+A(1,JJ)*(Q(I,J,JJ)-Q(I-1,J,JJ))
  CALL JCBABPM(1,1,1,A,I-1,J+1)
  AQ2=0.
  DO 56 JJ=1,4
56 AQ2=AQ2+A(1,JJ)*(Q(I,J+1,JJ)-Q(I-1,J+1,JJ))
  RHOUN1=RHOUN1+0.5*AQ1/CXCY1
  RHOUN2=RHOUN2+0.5*AQ2/CXCY2
  CXCY11=SQRT(SAIX(I+1,J)**2+SAIY(I+1,J)**2)
  CXCY12=SQRT(SAIX(I+2,J)**2+SAIY(I+2,J)**2)
  CXCY1=0.5*(CXCY11+CXCY12)
  CXCY21=SQRT(SAIX(I+1,J+1)**2+SAIY(I+1,J+1)**2)
  CXCY22=SQRT(SAIX(I+2,J+1)**2+SAIY(I+2,J+1)**2)
  CXCY2=0.5*(CXCY21+CXCY22)
  CALL JCBABPM(1,2,1,A,I+1,J)
  AQ1=0.
  DO 57 JJ=1,4
57 AQ1=AQ1+A(1,JJ)*(Q(I+2,J,JJ)-Q(I+1,J,JJ))
  CALL JCBABPM(1,2,1,A,I+1,J+1)
  AQ2=0.
  DO 58 JJ=1,4
58 AQ2=AQ2+A(1,JJ)*(Q(I+2,J+1,JJ)-Q(I+1,J+1,JJ))
  RHOUN1=RHOUN1-0.5*AQ1/CXCY1
  RHOUN2=RHOUN2-0.5*AQ2/CXCY2
END IF
59 CONTINUE
Y1=0.5*(Y(I,J)+Y(I+1,J))

```

```

      Y2=0.5*(Y(I,J+1)+Y(I+1,J+1))
      FLRT=FLRT+0.5*PI*(Y1+Y2)*DR*(RHOUN1+RHOUN2)
50  CONTINUE
      II=I+1
      WRITE (6,502) II,FLRT
502  FORMAT(1X,'I=',I4,2X,'FLRT=',E14.7)
      WRITE (4,503) II,FLRT
503  FORMAT(1X,I8,E14.7)
      40 CONTINUE
      RETURN
*****
      ENTRY OUTPUT
*****
      IF(IWRT.EQ.0) GO TO 60
      WRITE (6,504) NEND
504  FORMAT(/4X,'NEND=',I5/)
      DO 70 I=1,IL
      WRITE (6,505) I
505  FORMAT(/2X,2HI=,I2,4X,1HX,11X,1HY,11X,1HU,11X,1HV,11X,
>      1HP,11X,1HR,11X,1HT,11X,1HE,11X,1HS,11X,1HM/)
      DO 70 J=1,JL
      RA=RHO(I,J)
      UA=RHO(I,J)/RHO(I,J)
      VA=RHOV(I,J)/RHO(I,J)
      EOA=EO(I,J)
      EA=EOA/RA-0.5*(UA**2+VA**2)
      TA=FT(RA,EA)
      AMWA=FAMW(RA,TA)
      PA=RA*(RG/AMWA)*TA
      GAMMA=1.+(RG/AMWA)/(EA/TA)
      SA=ALOG(PA)/GAMMA-ALOG(RA)
      CO=SQRT(ECO2(PA,RA,TA,EA,AMWA))
      AMACH=SQRT(UA**2+VA**2)/CO
      WRITE (6,506) J,X(I,J),Y(I,J),UA,VA,PA,RA,TA,EOA,SA,AMACH
506  FORMAT(2X,2HJ=,I2,10(1X,E11.4))
      70 CONTINUE
      60 CONTINUE
*
*   WRITING COMPUTED DATA ON TAPE
*
      WRITE (8) ((DELTAU(I,J),I=1,IL),J=1,JL)
      WRITE (8) ((RHO(I,J),RHO(I,J),RHOV(I,J),EO(I,J),
>      I=1,IL),J=1,JL)
      RETURN
      END
      SUBROUTINE EEL(J,MM,JMAX,E,EL,AM,BM,CM,DM,IN,AL,BE)
*****
*
*   LIBRARY SUBROUTINES
*
*****
      DIMENSION IN(MM),E(MM,MM,JMAX),EL(MM,JMAX)
      DIMENSION AM(MM,MM),BM(MM,MM),CM(MM,MM),DM(MM)
      DIMENSION AL(MM,MM),BE(MM)
      DO 1 M=1,MM

```

```

      TP=0.00
      DO 2 N=1,MM
      T1=0.00
      IF(J.EQ.1) GO TO 3
      TP=TP+AM(M,N)*EL(N,J-1)
      DO 4 K=1,MM
      T1=T1+AM(M,K)*E(K,N,J-1)
4     CONTINUE
3     CONTINUE
      AL(M,N)=BM(M,N)-T1
2     CONTINUE
      EL(M,J)=DM(M)+TP
1     CONTINUE
      DO 5 M=1,MM
      DO 6 N=1,MM
      E(M,N,J)=CM(M,N)
6     CONTINUE
5     CONTINUE
      CALL AXB(MM,MM,AL,E(1,1,J),BE,0,IN)
      CALL AXB(MM,1,AL,EL(1,J),BE,1,IN)
      RETURN
      END
      SUBROUTINE SOLU(W,JMAX,MM,E,EL)

```

```

*****

```

```

*

```

```

*     LIBRARY SUBROUTINES

```

```

*

```

```

*****

```

```

      DIMENSION W(MM,JMAX),E(MM,MM,JMAX),EL(MM,JMAX)
      DO 1 M=1,MM
      W(M,JMAX)=EL(M,JMAX)
1     CONTINUE
      DO 2 J1=2,JMAX
      J=JMAX+1-J1
      DO 3 M=1,MM
      SUM=0.00
      DO 4 K=1,MM
      SUM=SUM+E(N,K,J)*W(K,J+1)
4     CONTINUE
      W(M,J)=SUM+EL(M,J)
3     CONTINUE
2     CONTINUE
      RETURN
      END
      SUBROUTINE AXB(N,M,A,B,X,INIT,IPS)

```

```

*****

```

```

*

```

```

*     LIBRARY SUBROUTINES

```

```

*

```

```

*****

```

```

      DIMENSION A(N,N),B(N,M),IPS(N),X(N)
      IF(INIT.EQ.0) CALL DECOMP(N,A,IPS)
      DO 1 I=1,M
      CALL SOLV(N,A,B(1,I),X,IPS)
1     CONTINUE

```

```

RETURN
END
SUBROUTINE DECOMP(N,UL,IPS)
*****
*
*   LIBRARY SUBROUTINES
*
*****
    DIMENSION UL(N,N),IPS(N)
    DO 1 I=1,N
        IPS(I)=I
    1 CONTINUE
    NM1=N-1
    DO 2 K=1,NM1
        BIG=0.00
        DO 3 I=K,N
            IP=IPS(I)
            SIZE=ABS(UL(IP,K))
            IF(SIZE-BIG) 3,3,4
        4 BIG=SIZE
            IDXPIV=I
        3 CONTINUE
        IF(IDXPIV-K) 5,6,5
    5 J=IPS(K)
        IPS(K)=IPS(IDXPIV)
        IPS(IDXPIV)=J
    6 KP=IPS(K)
        PIVOT=UL(KP,K)
        KP1=K+1
        DO 7 I=KP1,N
            IP=IPS(I)
            EM=-UL(IP,K)/PIVOT
            UL(IP,K)=-EM
            DO 7 J=KP1,N
                UL(IP,J)=UL(IP,J)+EM*UL(KP,J)
        7 CONTINUE
    2 CONTINUE
    RETURN
END
SUBROUTINE SOLV(N,UL,B,X,IPS)
*****
*
*   LIBRARY SUBROUTINES
*
*****
    DIMENSION UL(N,N),B(N),X(N),IPS(N)
    NP1=N+1
    IP=IPS(1)
    X(1)=B(IP)
    DO 1 I=2,N
        IP=IPS(I)
        IM1=I-1
        SUM=0.00
        DO 2 J=1,IM1
            SUM=SUM+UL(IP,J)*X(J)

```

```

2 CONTINUE
  X(I)=B(IP)-SUM
1 CONTINUE
  IP=IPS(N)
  B(N)=X(N)/UL(IP,N)
  DO 3 IBACK=2,N
    I=NP1-IBACK
    IP=IPS(I)
    IP1=I+1
    SUM=0.00
    DO 4 J=IP1,N
      SUM=SUM+UL(IP,J)*B(J)
4 CONTINUE
  B(I)=(X(I)-SUM)/UL(IP,I)
3 CONTINUE
  RETURN
END
SUBROUTINE SZERO(M,A)
*****
*
*   LIBRARY SUBROUTINES
*
*****
  SET ZERO FOR MATRIC (M,M)
  DIMENSION A(M,M)
  DO 1 I=1,M
    DO 1 J=1,M
      A(I,J)=0.00
1 CONTINUE
  RETURN
END
SUBROUTINE SMM(M,C,A,B)
*****
*
*   LIBRARY SUBROUTINES
*
*****
  SCALAR*METRIC (M,M)
  DIMENSION A(M,M),B(M,M)
  DO 1 I=1,M
    DO 1 J=1,M
      B(I,J)=C*A(I,J)
1 CONTINUE
  RETURN
END
SUBROUTINE MMM(M,A,B,C)
*****
*
*   LIBRARY SUBROUTINES
*
*****
  METRIX*METRIX (M*M)
  DIMENSION A(M,M),B(M,M),C(M,M)
  DO 1 I=1,M
    DO 1 J=1,M

```

FILE: NPROG11 FOR A1 VM/SP CMS 4-8602 (02/02/88) -- THE PENNSYLVANIA STAT

C(I,J)=0.00