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SUMMARY

An improved two-dimensional/viscous characteristics analysis program is presented in this report. The program is built upon the foundation of a FORTRAN program in NASA CR-112223 entitled "Analysis of Supersonic Combustion Flow Fields With Embedded Subsonic Regions." The major improvements are described and a listing of the new program is provided. The subroutines and their functions are given as well as the input required for the program.

Additionally, several applications of the new program to real problems are qualitatively described. Similarly, three runs obtained in the investigation of a real problem are presented to provide insight for the input and output of the program.

This new program has greatly extended the viscous characteristics analysis of NASA CR-112223 and has transformed it into a useful combustor design tool. None of the problems described in this paper could be solved with the program capability of NASA CR-112223.

INTRODUCTION

Current investigations of the hydrogen-fueled supersonic combustion ramjet (scramjet) engine have delineated several technological problem areas. References 1 to 4 provide evaluations of the scramjet concept. One area, the analysis of the injection, turbulent mixing, and combustion of hydrogen, has been addressed by references 5 and 6.

The analysis and computer program of references 5 and 6, respectively, are specifically designed to analyze the parallel injection of an underexpanded hydrogen jet in supersonic flow. However, the viscous characteristics theory of these references has general applicability to two-dimensional and axisymmetric flows. Unfortunately, the program of reference 6 is limited in its ability to handle all the possible flow situations which may exist in these type flows.

The present work was undertaken to extend the applicability of the computer program of reference 6. Specifically, it was intended to make the program a practical design tool for two-dimensional and axisymmetric supersonic combustors.

SYMBOLS

Temperatures and pressures are given in SI units. Calculations were made in the U.S. Customary Units, and the computer program was written with U.S. Customary Units.

K	empirical constant
M_∞	free-stream Mach number
P	static pressure
r_j	jet radius or reference length
T	static temperature
u	velocity
x	axial distance divided by r_j
y	radial distance divided by r_j
z	mixing-zone width in viscosity model
$\alpha_{H,ref}$	stoichiometric mass fraction of hydrogen (0.02915)
$\alpha_{H,total}$	sum of mass fractions of atomic and diatomic hydrogen
θ	flow angle
μ	absolute viscosity
ρ_{local}	density

Subscript:

ϕ	center line

PROGRAM

The original program was designed to analyze the flow field resulting from underexpanded injection of hydrogen into a supersonic flow. The program was for a single supersonic hydrogen jet exhausting parallel to the main flow.

The basic governing equations the program solves are the "viscous-inviscid" equations with finite-rate chemistry terms included. In addition, the Rankine-Hugoniot and Prandtl-Meyer relations are used to compute shock and expansion conditions. Since the equations and numerical application are presented in references 7 to 9, they will not be repeated here. The chemistry package, unchanged from reference 6, has a 7-species 8-mechanism hydrogen-air reaction scheme.

In addition to streamlining the analysis for computational efficiency, the following major modifications have been made to the program of reference 6:

(1) The original Ferri-Kleinstein ($\mu = \mu(x)$) viscosity model (refs. 10 and 11) was replaced by the Eggers z-difference ($\mu = \mu(x,y)$) model (ref. 12).

The importance of allowing μ to vary radially has been discussed along with the model in reference 12. In equation form the viscosity is given as

$$\mu = Kzu_{\ell}\rho_{local}$$

The empirical constant K is 0.01 and z is the radial distance between the points where the local velocities u_1 and u_2 are given by the equations

$$u_1 = u_a + 0.95(u_{\ell} - u_a)$$

and

$$u_2 = u_a + 0.50(u_{\ell} - u_a)$$

where u_a is the stream velocity external to the jet.

Additionally, the laminar viscosity is computed if the velocities of the stream and jet do not differ by more than 15 percent, and the viscosity for each distinct cross-stream region is computed independently.

(2) The original method for computing the Prandtl-Meyer expansion fan at the injector lip has been replaced.

Originally, the program computed the expansion in steps, and then assigned the varied properties (T, P, θ, u, and μ) to different radial locations at the zero axial location. This approach produced a distorted profile since the origin of the expansion fan was spread over a small area of the injector exit. The present method computes the expansion in one operation, steps downstream to the 0.03 axial locations, and then computes the physical axial and radial locations and the corresponding properties for the first and last Mach lines in the expansion fan. (The value 0.03 was chosen to give good resolution without slowing the computations.) This procedure limits the origin of the fan to the edge of the injector lip, while computing the actual properties of the fan.

(3) The code for computing ideal conical jet flow has been included. This capability allows detailed computation inside the hydrogen potential core where the flow-field details are determined by the conical hydrogen injector.

(4) The ability to compute negative-running shock waves has been added. Even though the program had part of the code necessary for computing such shocks, it could not be applied because of numerical difficulty. The numerical difficulties resulting from the vanishing radial distance between the data point on the shock and the adjacent point as the program marches downstream were removed by an averaging process which allows the removal of the adjacent point.

(5) The code necessary for computing reflection of shock waves at the wall and center line has been included. This reflection technique does not account for shock–boundary-layer interaction.

(6) The number of shock waves that the program can handle simultaneously has been increased from 4 to 20. Up to 10 each of positive-running or negative-running shocks are allowed.

(7) The instructions for the interaction of shock waves of opposite families have been added.

(8) The instructions for the coalescing of two shock waves of the same family have been included.

(9) The capability of inputting the wall or center-body geometry in six or less sections has been added. The sections are prescribed in equational form and the last section can have up to a parabolic shape. All other sections are constrained to a shape of linear form. Successive parabolic-shaped sections can be run by restarting the calculations at the end of the preceding section.

(10) Since the geometry changes allowed under change (9) can produce shocks and expansions, the code to compute and insert shock waves and discrete expansion waves at geometric breaks has been added. The program checks the direction of the new section and determines whether a shock or an expansion is needed.

The many improvements to NASA CR-112223 (program of ref. 6) have been made concurrent with reducing the memory requirement from $151\ 000_8$ to $117\ 700_8$.

While these modifications are not all that are possible or desirable, they have greatly extended the usefulness of the program. The improved version of the program is listed in appendix A. Similarly, the various program subroutines and functions are given in appendix B. The input required by the program is described in appendix C.

RESULTS OF CALCULATIONS

The improved program has been applied to several problems pertinent to the Langley-developed scramjet engine. In particular, the flow field of a single underexpanded hydrogen jet, the internal flow of a gas sampling probe, the fuel-injector strut shape, and the combustor shape have been examined. For the first problem, the results have been published in reference 13. With only the first four major modifications mentioned in the previous section, the program was able to predict very near-field pitot data accurately.

The other three problems involve ongoing research and have not been published. Preliminary results indicate that gas samples taken with probes of different designs (see refs. 14 and 15 for two typical designs) may be inaccurate due to reaction internal to the probe. It appeared that the probes quenched the sample as designed; however, the recompression which occurs in the probe may have restarted the reaction. Thus the composition reaching the sample bottle, or mass spectrometer, may have been different from that entering the probe.

The fuel-injector strut-shape investigation by the author, showed that the shape of the strut downstream of the injection point was very important. Autoignition and combustion efficiency are greatly influenced by the trailing shape of the strut. Calculations by the author indicate that the present Langley-

developed scramjet (see ref. 16) would gain in performance by parabolizing the strut trailing shape.

Changing from a qualitative problem discussion, the problem is stated and actual calculations are now presented. The two-dimensional divergent combustor is of nondimensional length 38, based on a strut gap of 7.62 mm (the average strut for the Langley-developed subscale scramjet). The combustor, which has 12° of divergence, is illustrated in figure 1. The flow entering the combustor is uniform and parallel and has a Mach number of 1.9, a static temperature of 2140 K, a static pressure of 58.414 kPa, and the following composition:

Species	Mass fraction
H	6.864×10^{-6}
O	3.529×10^{-4}
H_2O	1.694×10^{-1}
H_2	9.177×10^{-3}
O_2	6.758×10^{-2}
OH	3.343×10^{-3}
N_2	7.501×10^{-1}

(This composition represents a partially reacted stoichiometric mixture.)

Operation of the combustor shows that the combustion is not complete; that is, unreacted hydrogen is reaching the exit of the combustor. The problem then is to modify the 12° combustor to improve the combustion. However, the exit height of the combustor and the exit flow-angle distribution should be changed as little as possible by the modifications.

The most obvious modification to the combustor is the placement of filler plates. This approach is very versatile with an almost unlimited number of variations. Three such variations are given in figures 2 to 4. In the first variation (fig. 2), the filler plate results in a combustor whose wall diverges 12° for the first 5 units of length, 4° for the next 5 units, and returns to 12° for the remainder of the combustor length. The switch from 12° to 4° produces a shock wave with a turning angle of 8°. The second variation (fig. 3) is similar to the first except the divergence is 12°, 6°, and 12°, which results in a shock-wave turning angle of 6°. The third variation (fig. 4) does not generate a shock wave to increase the combustion, but relies instead on a 4-unit length of constant-area combustion before the 12° of divergence.

The three geometric variations were evaluated by using the program to calculate the flow field of each. The computer input and output for each of the three cases is presented in appendix D. The unreacted hydrogen exit profile for each case is presented in figure 5. In this figure, the sum of the atomic and molecular hydrogen mass fractions nondimensionalized by the stoichiometric mass fraction (0.02915) is plotted against nondimensional exit height. The computed values for the unmodified combustor are also included in the figure. Figure 5 suggests that all three variations improve the combustion. However, the $4\text{-}r_j$ constant-area combustion would be the modification of choice. These

limited applications are intended to serve as an indication of the usefulness of the program.

CONCLUDING REMARKS

The improved viscous characteristics program presented in this paper is a major extension of a FORTRAN program in NASA CR-112223 entitled "Analysis of Supersonic Combustion Flow Fields With Embedded Subsonic Regions." NASA CR-112223 has been converted into a useful combustor design tool and simultaneously extends the program applicability. These improvements have been implemented concurrently with a decrease in the memory requirement of the program. The program has been successfully applied to several diverse hydrogen combustion problems.

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APPENDIX A

LISTING OF IMPROVED VISCOUS CHARACTERISTICS ANALYSIS PROGRAM

The entire modified program is contained in this appendix.

```
RVJEMVC
      PROGRAM EMVC(INPUT,OUTPUT,TAPE7,TAPE5=INPUT,TAPE6=OUTPUT)
C     MAIN PROGRAM FOR CHARACTERISTICS WITH SHEAR
      COMMON/AB/EPP,EPQ,EPT
      COMMON/AC/IBOD,PIN
      COMMON/AL/GAR,GEW
      COMMON/AX/JSUBL,JSUBU
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/BC/IOCHEM
      COMMON/BD/XMASS(55)
      COMMON/CG/AUP,BUP,CUP,DTSPRI(55),DUP,EUP,JCONV,THPRI(55),YPRI(55)
      COMMON/CK/WTMOLE(7)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/RC/R(55)
      COMMON/TW/TIN
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/DE/MM
      COMMON/DP/YN(55)
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EG/EIN,PR,XLE
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/FE/DEL
      COMMON/GE/RAD,ROO,UIN,VISINF
      COMMON/GF/DELY,IFS,KOUNTO,MMM
      COMMON/GK/DELX
      COMMON/HJ/KOUNT,LL,NPT
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     IL,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/HP/BETAN(20),IEMBED
      COMMON/OP/ALPB(7),PHI(55)
      COMMON/PD/W(55),X(55)
      COMMON/PO/ALPHN(7),IFUEL,PRES
      COMMON/PQ/JCHEM,NSP,T(55),PTZERO,IDIVERG,TH1,XE,YE,RCR,PTOJ,TOJ
     1,EM1,XMU1,Q1
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/QS/RHOP(2),WDOT(7,55),WDOTC(7),WP(2),XMUP(2)
      COMMON/RO/APO,AP1,AP2
      COMMON/RS/GPMS,PS,THS,THSL,THSU
      COMMON/ST/I13,IREGI,K ,KFIRST,KKKQ,PSTAR
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/WAVE/XBOD(5),XWALL(5),AABOD(5),BBBOD(5),CCBOD(5),EEBOD(5),
     ZFFBOD(5),GGBOD(5),LWALL,LBOD,III,JJJ
      COMMON/UV/II11,IERR,IPRESS,IPRESU,ISUB
      COMMON/VT/DACH(7,55),DTCH(55)
      COMMON/VW/ICONT,IEND,KT,THBPN,XBPN
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/XO/XOO
```

```
      COMMON/YX/ABODS,BPRESS,CPRESS
      COMMON/YZ/BPRESU,CHEMFC,CPRESU,EMSUB,RTH,XSTEP
      COMMON/ZY/ABOD,BBOD,CBOD,EBOD,FBOD,GBOD,IAVE,IPUNCH,JBOD,KKKKK
      DIMENSION XS(7),PITOT(55),VIA(55)
      DATA II1I/0/
C     ********************************   BEGIN INPUTTING PARAMETERS
      WRITE(6,400)
  112 FORMAT(I5,5X,9E13.5)
  400 FORMAT(1H1)
C     J=0 TWO DIMENSIONAL
C     J=1 AXISYMMETRIC
C     SPECIES 1 IS H
C     SPECIES 2 IS O
C     SPECIES 3 IS H2O
C     SPECIES 4 IS H2
C     SPECIES 5 IS O2
C     SPECIES 6 IS OH
C     SPECIES 7 IS N2
      WTMOLE(1)=1.008
      WTMOLE(2)=16.
      WTMOLE(3)=18.016
      WTMOLE(4)=2.016
      WTMOLE(5)=32.0
      WTMOLE(6)=17.008
      WTMOLE(7)=28.014
      FAS=WTMOLE(4)/16.
      J22=0
      X00=0.
      IDG=0
      DEL=0.
      XBOD(1)= 10000.
      XWALL(1)=10000.
      DO 8220 I=1,20
      BETAN(I)=0.
      BETB(I)=0.
      IS(I)=0
 8220 CONTINUE
      IFS=0
      NSP=7
      RO=1.987
      ROO=RO*3.087*32.2/2.205*1000.
      EPP=1.E-10
      EPQ=1.E-10
      EPT=1.E-10
      IOCHEM=1
      MM=6
      EXXX=1.E-06
      I13=0
      KFIRST=-1
```

```
      KKKQ=10000
      JCONV=0
      INPTSH=0
  363 CONTINUE
      CALL INDATA
C     ************************************    MAKE INITIAL SHEAR
      IVV=1
      IDD=IDD+1
      DO 7  IV=1,IDD
      IDUM=NPTS
      IF(IS(IV).EQ.0) GO TO   6
      IF((IV/2)*2.EQ.IV) GO TO   1
      IDUM=IS(IV)-1
      GO TO   2
    1 IDUM=IS(IV)
    2 VISD= XVIS(XBP,IVV,IDUM)
      VISD=VISD*RE
      DO  3I=IVV,IDUM
    3 VIS (I)=  VISD*RHO(I)
       IVV=IDUM+1
      GO TO 7
    6 IF(IV.EQ.IDD) GO TO   2
    7 CONTINUE
      IDD=IDD-1
      VISD=VIS (1)
      CFF=0.
      CALL SHEAR1(CFF,VISD)
 6789 CONTINUE
      CALL EMBED
      DO 99999 JSJ=1,NPTS
99999 IF(ABS(TH(JSJ)).LT.1.E-8) TH(JSJ)=0.0
      IF(IDIVERG.NE.1) GO TO 1313
      JENK=IS(4)
      DO 1300 I=1,JENK
      RJ=SQRT(Y(I)*Y(I)+(XE+X(I))**2)
      TH(I)=ATAN(Y(I)/(XE+X(I)))
      ZJ=RJ/RCR
      G1=GAM(I)-1.
      G2=GAM(I)+1.
    5 EJ=1.+G1/2.*EM(I)*EM(I)
      ZJ1=((2./G2*EJ)**(G2/(2.*G1)))/EM(I)
      ZJ2=SQRT(ZJ1)
      IF(XJ.NE.1.) ZJ2=ZJ1
      IF(ABS(ZJ2-ZJ).LE..001) GO TO 12
      IF(ZJ2-ZJ) 14,12,13
   14 EM(I)=EM(I)+.01
      GO TO 5
   13 EM(I)=EM(I)-.0011
      GO TO 5
```

```
   12 T(I)=TOJ/EJ
      P(I)=PTOJ*EJ**(-GAM(I)/G1)
      T(I)=T(I)/TIN
      Q(I)=EM(I)/EMINF/SQRT(GAR/GAM(I)/R(I)/T(I))
      P(I)=P(I)/PRES *PIN
      RHO(I)=GEW*W(I)*P(I)/T(I)
      CPX(I)=0.
      W(I)=0.
      CALL THERMO(T(I),H1,CP1)
      DO 55 J=1,NSP
      H(J,I)=H1(J)
      CP(J,I)=CP1(J)
      W(I)=W(I)+ALP(J,I)/WTMOLE(J)
      CPX(I)=CPX(I)+ALP(J,I)*CP(J,I)
   55 CONTINUE
      W(I)=1./W(I)
      R(I)=RO/W(I)
      GAM(I)=CPX(I)/(CPX(I)-R(I)/CPIN)
 1307 VIS(I)=0.
 1300 CONTINUE
 1313 CONTINUE
      DO 1200 I=1,NPTS
 1200 VIA(I)=VIS(I)*VISINF
      DO 7188 K=1,NPTS
      DO 7199 J=1,NSP
 7199 XS(J)=W(K)*ALP(J,K)/WTMOLE(J)
      FUAIR=1.008*(XS(1)+2.*XS(4)+2.*XS(3)+XS(6))/(16.*(XS(2)+XS(3)
     1+2.*XS(5)+XS(6))+28.014*XS(7))
      PHI(K)=FUAIR/.029161
 7188 CONTINUE
      IF(KOUNT.EQ.KKKKK) GO TO 407
      IF(II11.EQ.1) GO TO 407
      IF(KOUNT.EQ.KOUNTO) GO TO 407
      IF(((KOUNT/LL)*LL).NE.KOUNT)GO TO 179
  407 WRITE(6,408)KOUNT
  408 FORMAT(7H1KOUNT=I5)
      WRITE(6,5206) X(1)
 5206 FORMAT(/5H X = E13.5)
      DO 8485 I23=1,IDD
      IF(BETB(I23).EQ.0.) GO TO 8485
      IF(I23.LT.3)
     1WRITE(6,8484) I23,BETB(I23)
 8484 FORMAT(/5X,20HEMBEDDED SHOCK TYPE  ,I1,10X,7HBETA = ,E11.3)
      IF(I23.GE.3)
     1WRITE(6,2331) I23,BETB(I23)
 2331 FORMAT(/14X,11HSHOCK TYPE  ,I1,10X,7HBETA = ,E11.3)
 8485 CONTINUE
      WRITE(6,7222)(VIA(I),I=1,NPTS)
 7222 FORMAT(5X24HVISCOSITY(LB*SEC/FT**2)=(7E13.5))
```

```
      WRITE(6,5207)
5207  FORMAT(/3X,3HPT.,11X,1HY,12X,1HQ,12X,1HT,12X,1HP,11X,2HTH,11X,
     12HEM11X3HRHO10X3HGAM9X5HPITOT)
      DO 70 I=1,NPTS
      P(I)=P(I)/PIN
      TM=EM(I)*COS(TH(I))
   70 PITOT(I)=P(I)*PRES*((GAM(I)+1.)*.5*TM**2)**(GAM(I)/(GAM(I)-1.))*(2
     A.*GAM(I)/(GAM(I)+1.)*TM**2-((GAM(I)-1.)/(GAM(I)+1.)))**(1./(1.-GAM
     8(I)))
      PTO=1./PTZERO
      DO 7070 I=1,NPTS
7070  PITOT(I)=PTO*PITOT(I)
      WRITE(6,112)(I,Y(I),Q(I),T(I),P(I),TH(I),EM(I),RHO(I),GAM(I),PITOT
     1(I),I=1,NPTS)
      DO 71 I=1,NPTS
   71 P(I)=P(I)*PIN
      WRITE(6,160)
  160 FORMAT(/////3X,3HPT.,8X,                6HALP(1),7X,6HALP(2),7X,
     26HALP(3),7X,6HALP(4),7X,6HALP(5),7X,6HALP(6),7X,6HALP(7),9X,3HPHI
     2,11X,1HW)
      WRITE(6,112)(I,(ALP(J,I),J=1,7),PHI(I),W(I),I=1,NPTS)
  179 CONTINUE
      IF(KOUNT.GE.KKKKK)GO TO 1572
      IF(II11.EQ.1) GO TO 1572
      ALPHA=1.0
      BETA=0.0
      CALL STEP
      IF(II11.EQ.1) GO TO 407
      IF(KOUNT.NE.KFIRST.OR.I13.NE.1) GO TO 300
      CALL PUNCH
      DO 301 I=JSUBL,JSUBU
      Y PRI(I)=Y (I)
      THPRI(I)=TH(I)
  301 CONTINUE
  300 CONTINUE
      CALL CHEM(FAS)
8282  CONTINUE
      ICONT=0
      IEND=0
      K=1
      L=2
  887 IF(L.GE.JSUBL.AND.L.LE.JSUBU) GO TO 900
  888 K=L
      KT=L-1
      IF(IJENK.EQ.1) GO TO 67676
      IF(L.EQ.NPTS)GOTO 612
      IF(L.EQ.JSUBU.AND.ICONT.EQ.1) GO TO 1622
      DO 776 JSHOCK=1,IDD
      JJSHOCK= (JSHOCK/2)*2
```

```
      IF( JJSHOCK.EQ.JSHOCK) GO TO 11
      IF( K.NE.(IS(JSHOCK)-1)) GO TO 776
      MMM=JSHOCK
      K= IS(JSHOCK)
      KT= K
      GO TO 8232
   11 IF(  K.NE.IS(JSHOCK))                                    GO TO 22
      MMM=JSHOCK
      GO TO 8232
   22 IF( K.EQ.(IS(JSHOCK)+1))                                   GO TO 88888
  776 CONTINUE
      GO TO 8234
88888 K=K+1
      L=K
      KT=L-1
      IF(L.EQ.NPTS)GO TO 612
      GO TO 8234
 8232 L=K
 8230 IFS=1
      IPOI=1
      ALSV=ALPHA
      BESV=BETA
      KTSAV=KT
  772 CALL CPOINT
      THDE=THN(K)
      ALPHA=.5
      BETA=.5
      KT=KTSAV
 2194 CALL CPOINT
      IPOI=IPOI+1
      IF(IPOI.LT.20)GO TO 2195
      WRITE(6,9191)
      WRITE(6,2196)
 2196 FORMAT(44H ERROR IN CPOINT ITERATION FOR SHOCK IN CHARL
      STOP
 2195 ERTHD=ABS(THDE-THN(K))
      THDE=THN(K)
      KT=KTSAV
  771 IF(ERTHD.GT.EXXX)GO TO 2194
      ALPHA=ALSV
      BETA=BESV
      IFS=2
      CALL HSHOCK(MMM)
      IFS=0
      K=K+1
      L=L+1
      GO TO 887
 8234 CONTINUE
      IPOI=1
```

```
      ALSV=ALPHA
      BESV=BETA
      CALL CPOINT
      KT=L-1
      THDE=THN(K)
      ALPHA=.5
      BETA=.5
 2601 CALL CPOINT
      KT=L-1
      IPOI=IPOI+1
      IF(IPOI.LT.20)GO TO 2602
      WRITE(6,9191)
 9191 FORMAT(1H1)
      WRITE(6,2197) K
 2197 FORMAT(53H ERROR IN STANDARD CPOINT ITERATION IN CHAR AT POINT I2)
      STOP
 2602 ERTHD=ABS(THDE-THN(K))
      THDE=THN(K)
      IF(ERTHD.GT.EXXX) GO TO 2601
      ALPHA=ALSV
      BETA=BESV
C     ************************  INCREMENT COUNTERS  DO NEXT C POINT
  900 CONTINUE
      K=K+1
      IF(L.EQ.NPTS) GO TO 7676
      L=L+1
      IF(ICONT.EQ.1) GO TO 888
      GO TO 887
C   NOZZLE WALL CALCULATION
  612 CONTINUE
      IPOI=1
      ALSV=ALPHA
      BESV=BETA
      CALL LPOINT(NPTS,1.)
      K=NPTS
      THDE=THN(K)
      IF(                IPRESU.EQ.0) THDE=PN(K)
      ALPHA=.5
      BETA=.5
 2607 CALL LPOINT(NPTS,1.)
      K=NPTS
      IPOI=IPOI+1
      IF(IPOI.LT.20)GO TO 2608
      WRITE(6,9191)
      WRITE(6,2198)
 2198 FORMAT(51H ERROR IN NOZZLE WALL CALCULATION ITERATION IN CHAR)
      STOP
 2608 ERTHD=ABS(THDE-THN(K))
      IF(                IPRESU.EQ.0) ERTHD=ABS(1.-THDE/PN(K))
```

```
      THDE=THN(K)
      IF(                IPRESU.EQ.0) THDE=PN(K)
      IF(ERTHD.GT.EXXX) GO TO 2607
      ALPHA=ALSV
      BETA=BESV
C     COMPLETE FIRST POINT
      IF (JENKI.EQ.1) GO TO 1818
67676 IJENK=0
 7676 CONTINUE
      IF(JSUBL.EQ.1) GO TO 1800
      CALL LPOINT(1,0.)
      K=1
      IPOI=1
      ALSV=ALPHA
      BESV=BETA
      THDE=THN(K)
      IF(IPRESS.EQ.0                ) THDE=PN(K)
      ALPHA=.5
      BETA=.5
 2609 CALL LPOINT(1,0.)
      K=1
      IPOI=IPOI+1
      IF(IPOI.LT.20)GO TO 2610
      WRITE(6,9191)
      WRITE(6,2199)
 2199 FORMAT(39H ERROR IN FIRST POINT ITERATION IN CHAR)
      STOP
 2610 ERTHD=ABS(THDE-THN(K))
      IF(IPRESS.EQ.0                ) ERTHD=ABS(1.-THDE/PN(K))
      THDE=THN(K)
      IF(IPRESS.EQ.0                ) THDE=PN(K)
      IF(ERTHD.GT.EXXX) GO TO 2609
      ALPHA=ALSV
      BETA=BESV
 1818 JENKI=0
C     SUBSONIC PRESSURE ITERATION
 1800 CONTINUE
      IF(ISUB.EQ.0) GO TO 1622
      IF(ICONT.EQ.1) GO TO 1622
      IF(I13.NE.1.OR.KOUNT.NE.KFIRST) GO TO 1777
      CALL DPDTH(THS,JSUBU)
      CALL DPDTH(THSU,JSUBU+1)
      CALL DPDTH(THSL,JSUBU-1)
      CALL THSSS(THSS)
      AUP=Y(JSUBU)
      BUP=TAN(TH(JSUBU))
      IF(IREGI.NE.0.AND.JSUBU.EQ.J22) GO TO 8375
      CUP=THS/COS(TH(JSUBU))**3
      DUP=(THSS+3.*TAN(TH(JSUBU))*THS*THS)/COS(TH(JSUBU))**4
```

```
      EUP=-4.095
      GO TO 8376
 8375 CONTINUE
      CUP=0.
      DUP=-1.
      EUP=0.
 8376 CONTINUE
      DO 381 I=JSUBL,JSUBU
  381 CALL DPDTH(DTSPRI(I),I)
 1777 CONTINUE
      CALL SSONIC(IDG)
      IF(IDG.EQ.0) GO TO 1622
      II11=1
      IPUNCH=1
      GO TO 407
 1622 CONTINUE
      IF(ISUB.EQ.0) GO TO 359
      IF(JCONV.EQ.1) GO TO 360
      IF(KOUNT.NE.KKKQ-1) GO TO 361
      IF(INPTSH.EQ.0) NPTSH=NPTS
      INPTSH=1
      REWIND 7
      GO TO 363
  360 NPTS=NPTSH
      INPTSH=0
  359 DO 357 I=1,NPTS
      II=NPTS-I+1
      IF(EMN(II).GT.EMSUB) GO TO 357
      IF(ISUB.EQ.1) GO TO 355
      ISUB=1
      WRITE(6,354)
  354 FORMAT(37H1          SUBSONIC REGION ENCOUNTERED)
      EMST=EMSUB
      EMSUB=1.15
      AP1=0.
      IREGI=0
      GO TO 359
  355 K=II+1
      IF(IREGI.EQ.1) K=JSUBU
      GO TO 358
  357 CONTINUE
      IREGI=2
      GO TO 361
  358 CONTINUE
      IF(JCONV.EQ.0) GO TO 1417
      JCONV=0
      DO 1418 I=1,NPTS
      II=NPTS-I+1
      IF(EMN(II).GT.EMST) GO TO 1418
```

```
      GO TO 1417
 1418 CONTINUE
      IREGI=2
      I13=0
      EMSUB=EMST
      X00=XBPN
      ABOD=YN(1)
      ABODS=YN(1)
      BBOD=TAN(THN(1))
      CBOD=0.
      GO TO 361
 1417 CONTINUE
      AP0=PN(1)
      AP2=(PN(K)-PN(1)-AP1*(YN(K)-YN(1)))/(YN(K)-YN(1))**2
      DO 356 I=1,K
      PN(I)=AP0+AP1*(YN(I)-YN(1))+AP2*(YN(I)-YN(1))**2
      RHON(I)=GEW*WN(I)*PN(I)/TN(I)
      IF(I.EQ.1) GO TO 356
      XJ1=1.+XJ
      I1=I-1
      YFUN=(YN(I)**XJ1-YN(I1)**XJ1)/XJ1
      TERM=(RHON(I)*QN(I)*COS(THN(I))+RHON(I1)*QN(I1)*COS(THN(I1)))/2.
      XMASS(I)=XMASS(I1)+TERM*YFUN
  356 CONTINUE
      DS=2.*DELX/(COS(TH(K))+COS(THN(K)))
      PS=(PN(K)-P(K))/DS
      GPMS=(GAMN(K)*PN(K)*EMN(K)**2-GAM(K)*P(K)*EM(K)**2)/DS
      DS=2.*DELX/(COS(THN(1))+COS(TH(1)))
  361 CONTINUE
C     COMPUTE SHEAR
      IVV=1
      IDD=IDD+1
      DO 77 IV=1,IDD
      IDUM=NPTS
      IF(IS(IV).EQ.0) GO TO  76
      IF((IV/2)*2.EQ.IV) GO TO 701
      IDUM=IS(IV)-1
      GO TO 702
  701 IDUM=IS(IV)
  702 VISE= XVIS(XBP,IVV,IDUM)
      VISE=VISE*RE
      DO773I=IVV,IDUM
  773 VISN(I)=  VISE*RHO(I)
       IVV=IDUM+1
      GO TO 77
   76 IF(IV.EQ.IDD) GO TO 702
   77 CONTINUE
      IDD=IDD-1
      VISE=VISN(1)
```

```
      CFF=0.
      CALL SHEAR2(CFF,VISE)
C     ************************************   RESET ALPHA AND BETA
      IF(IAVE.EQ.0) GO TO 8396
      IF(BETA.GT.0.0)GO TO 8396
      ALPHA=0.5
      BETA=0.5
      GO TO 8282
 8396 CONTINUE
C     ******************************************** STEP TAKEN   OUTPUT
      J22=JSUBU
      CALL RSET
      DO 1431 I=1,IDD
 1431 BETB(I)=BETAN(I)
      KOUNT=KOUNT+1
      CALL WAVES
      GO TO 6789
 1572 IF(IPUNCH.EQ.0) STOP
      CALL PUNCH
      STOP
      END
      SUBROUTINE WAVES
      COMMON/AC/IBOD,PIN
      COMMON/RC/R(55)
      COMMON/ZY/ABOD,BBOD,CBOD,EBOD,FBOD,GBOD,IAVE,IPUNCH,JBOD,KKKKK
      COMMON/WAVE/XBOD(5),XWALL(5),AABOD(5),BBBOD(5),CCBOD(5),EEBOD(5),
     ZFFBOD(5),GGBOD(5),LWALL,LBOD
      COMMON/PD/W(55),X(55)
      COMMON/AL/GAR,GEW
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/CK/WTMOLE(7)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/PQ/JCHEM,NSP,T(55),PTZERO,IDIVERG,TH1,XE,YE,RCR,PTOJ,TOJ
     1,EM1,XMU1,Q1
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55)
      REAL NUBEGIN,NUFINAL
    1 IF( X(1)       .NE.XBOD(LBOD)) GO TO 2
      IF(BBBOD(LBOD).LT.BBOD) GO TO 3
      DELTA= ATAN(BBBOD(LBOD))-ATAN(BBOD)
      IF((IDD/2)*2.NE.IDD) GO TO 4
      IDD= IDD +1
      GO TO 5
    4 IDD= IDD +2
```

```
    5 IS(IDD)= 1
      EMSQ  = EM(      1)**2
      BB=-(EMSQ+2.)/EMSQ-GAM(      1)*SIN(DELTA)**2
      CC=(2.*EMSQ+1.)/(EMSQ**2)+((GAM(      1)+1.)**2/4.+(GAM(      1)-1
     Z.)/EMSQ)*SIN(DELTA)**2
      DD=-COS(DELTA)**2/(EMSQ**2)
      EX=(4.5*BB*CC-BB**3-13.5*DD)/SQRT((BB**2-3*CC)**3)
      EE=ACOS(EX)
      NN=4
      FF=COS((EE+NN*4.*ATAN(1.))/3.)
      GG=SQRT(-BB/3.+(2.*SQRT(BB**2-3.*CC)/3.)*FF)
      EPS=ASIN(GG)
   12 SE =(SIN(EPS)) **2
      GM =.5*(GAM(      1)-1.)
      SED =  (SIN(EPS-DELTA))**2
      EM2= SQRT((1.+GM*EMSQ*SE)/(SED*(GAM(      1)*EMSQ*SE-GM)))
      TOP =2.*GAM(      1)*EMSQ*SE-(GAM(      1)-1.)
      PP2= TOP /(GAM(      1)+1.)*P(      1)
      TT2= (TOP*((GAM(      1)-1.)*EMSQ*SE+2.)/((GAM(      1)+1.)**2*EMS
     1Q*SE))*T(1)
      BETB(IDD) = EPS + ATAN(BBOD)
      DO 333 K3=1,NPTS
      K3K= NPTS +1 -K3
      J3= K3K +2
      CALL SWITCH(J3,K3K)
  333 CONTINUE
      NPTS = NPTS +2
      DO 3333 I=1,IDD
      IF(IS(I).GT.0) IS(I) = IS(I) + 2
 3333 CONTINUE
      EM(1)=EM(2)=EM2
      XMU(1      )=XMU(2      )=ZMU(EM2)
      P(1)=P(2)=PP2
      T(1)=T(2)=TT2
      TH(1)=TH(2)=ATAN( BBBOD(LBOD) )
      W(1)=0.
      CPX(1)=0.
      CALL THERMO(T(      1),H1,CP1)
      DO 66 J=1,NSP
      H (J,      1)=H1(J)
      H (J,    2)  =H (J,      1)
      CP (J,      2)=CP (J,    1)=CP1(J)
      W(1)=W(1) + ALP(J,1)/WTMOLE(J)
      CPX(1)=CPX(1) + ALP(J,1)*CP(J,1)
      CPX(2)=CPX(1)
   66 CONTINUE
      W(2)=W(1)=1./W(1)
      R(2)=R(1)=RO/W(1)
      GAM(2)=GAM(1)=CPX(1)/(CPX(1)-R(1)/CPIN)
```

```
      RHO(2)=RHO(1)=GEW*W(1)*P(1)/T(1)
      Q(2)=Q(1)=EM(1)/EMINF/SQRT(GAR/GAM(1)/R(1)/T(1))
      ABOD= AABOD(LBOD)
      BBOD= BBBOD(LBOD)
      CBOD= CCBOD(LBOD)
      LBOD= LBOD + 1
      Y(2)=Y(3)=ABOD+ 3.E-2* TAN(BETB(IDD))
      Y(1)=  ABOD + 3.E-2*BBOD
      WRITE(6,1313) BETB(IDD),X(1),DELTA
 1313 FORMAT(1H,10H *********,//* A SHOCK WAVE BETB=*,E10.3,*HAS BEEN  I
     ZNSERTED AT X=*,E10.3,*WITH A TURNING ANGLE=*,E10.3)
      IF(XWALL(LWALL).EQ.XBOD(LBOD-1)) GO TO 9
      DO 1977 II=1,NPTS
 1977 X(II)=X(II)+3.E-2
    9 XBP=X(1)
      IDDD =IDD -1
      DO 1776 JR=1,IDDD
      L=1
      IF((JR/2)*2.NE.JR) L=-1
      IF(IS(JR).EQ.0) GO TO 1776
      Y(IS(JR)+L)=Y(IS(JR))=Y(IS(JR))+3.E-2*TAN(BETB(JR))
 1776 CONTINUE
      GO TO 2
    3 DNU    =ATAN(BBOD)-ATAN(BBBOD(LBOD))
      WRITE(6,7713) DNU,X(1)
 7713 FORMAT(1H,10H *********,// *A DISCRET EXPANSION OF DNU=*,E10.3,*HA
     ZS BEEN INSERTED AT*,E10.3)
      SQEM=SQRT(EM(1)*EM(1)-1.)
      G=SQRT((GAM(1)+1.)/(GAM(1)-1.))
      GN=SQRT((GAM(1)-1.)/(GAM(1)+1.))
      NUBEGIN=G*ATAN(GN*SQEM)-ATAN(SQEM)
      UMU= ASIN(1./EM(1))
      NUFINAL=NUBEGIN +DNU
      EMF=EM(1) + .001
    7 SQEMF= SQRT(EMF*EMF-1.)
      FINAL= G*ATAN(GN*SQEMF)-ATAN(SQEMF)
      IF(ABS(NUFINAL-FINAL).LE..0001) GO TO 16
      IF(FINAL-NUFINAL) 14,16,15
   14 EMF= EMF +.001
      GO TO 7
   15 EMF= EMF - .0001333
      GO TO 7
   16 UMUF=ASIN(1./EMF)
      FAN= DNU +UMU -UMUF
      FIRST=  UMU + ATAN(BBOD)
      FLINE= FIRST -FAN
      GR=2./(GAM(1)-1.)
      PF=P(1)*((EM(1)**2+GR)/(EMF**2+GR))**(GAM(1)/(GAM(1)-1.))
      RHOF=RHO(1)*(PF/P(1))**(1./GAM(1))
```

```
      QQ=-(2.*GAM(1)/(GAM(1)-1.))*(PF/RHOF-P(1)/RHO(1))
      QF= SQRT(Q(1)**2 +QQ)
      TF = T(1)*(PF/P(1))**((GAM(1)-1.)/GAM(1))
      IF(LBOD.LE.1) GO TO 77777
      IF((Y(2)-Y(1)).GE.(Y(4)-Y(3))*.2) GO TO 77777
      DO 71313 LR=2,NPTS
      KR3=1+LR
71313 CALL SWITCH(LR,KR3)
      NPTS=NPTS-1
      DO 19799 I=1,IDD
19799 IF(IS(I).GT.0) IS(I) = IS(I) - 1
77777 CONTINUE
      DO 1978 K3=1,NPTS
      K3K= NPTS +1 -K3
      J3= K3K +2
      CALL SWITCH(J3,K3K)
 1978 CONTINUE
      NPTS =  NPTS + 2
      DO 1979 I=1,IDD
      IF(IS(I).GT.0) IS(I) = IS(I) + 2
 1979 CONTINUE
      EM(1)=EM(2)=EMF
      XMU(1)=XMU(2)=UMUF
      P(1)=P(2)=PF
      TH(1)=TH(2)=ATAN(BBBOD(LBOD))
      T(1)=T(2)=TF
      RHO(1)=RHO(2)=RHOF
      Q(1)=Q(2)=QF
      ABOD= AABOD(LBOD)
      BBOD= BBBOD(LBOD)
      CBOD= CCBOD(LBOD)
      LBOD= LBOD + 1
      Y(3)=ABOD + 3.E-2*TAN(FIRST)
      Y(2)=ABOD + 3.E-2*TAN(FLINE)
      Y(1)=ABOD + 3.E-2*BBOD
      IF(XWALL(LWALL).EQ.XBOD(LBOD-1)) GO TO 11
      DO 1778 II=1,NPTS
 1778 X(II)=X(II)+3.E-2
   11 XBP=X(1)
      DO 1779 JR=1,IDD
      L=1
      IF((JR/2)*2.NE.JR) L=-1
      IF(IS(JR).EQ.0) GO TO 1779
      Y(IS(JR)+L)=Y(IS(JR))=Y(IS(JR))+3.E-2*TAN(BETB(JR))
 1779 CONTINUE
    2 IF(X(1).NE.XWALL(LWALL)) GO TO 901
      IF(FFBOD(LWALL).GT.FBOD) GO TO 33
      DELTA= ABS(ATAN(FBOD)-ATAN(FFBOD(LWALL)))
      IF((IDD/2)*2.EQ.IDD) GO TO 44
```

```
      IDD= IDD +1
      GO TO 555
   44 IDD= IDD +2
  555 IS(IDD)= NPTS
      EMSQ   = EM(   NPTS)**2
      BB=-(EMSQ+2.)/EMSQ-GAM(   NPTS)*SIN(DELTA)**2
      CC=(2.*EMSQ+1.)/(EMSQ**2)+((GAM(   NPTS)+1.)**2/4.+(GAM(   NPTS)-1
     Z.)/EMSQ)*SIN(DELTA)**2
      DD=-COS(DELTA)**2/(EMSQ**2)
      EX=(4.5*BB*CC-BB**3-13.5*DD)/SQRT((BB**2-3*CC)**3)
      EE=ACOS(EX)
      NN=4
      FF=COS((EE+NN*4.*ATAN(1.))/3.)
      GG=SQRT(-BB/3.+(2.*SQRT(BB**2-3.*CC)/3.)*FF)
      EPS=ASIN(GG)
 1112 SE =(SIN(EPS)) **2
      GM =.5*(GAM(   NPTS)-1.)
      SED =  (SIN(EPS-DELTA))**2
      EM2= SQRT((1.+GM*EMSQ*SE)/(SED*(GAM(   NPTS)*EMSQ*SE-GM)))
      TOP =2.*GAM(   NPTS)*EMSQ*SE-(GAM(   NPTS)-1.)
      PP2= TOP /(GAM(   NPTS)+1.)*P(   NPTS)
      TT2= (TOP*((GAM(   NPTS)-1.)*EMSQ*SE+2.)/((GAM(   NPTS)+1.)**2*EMS
     1Q*SE))*T(NPTS)
      BETB(IDD)= -(EPS-ATAN(FBOD))
      EM(1+NPTS)=EM(2+NPTS)=EM2
      XMU(1+NPTS)=XMU(2+NPTS)=ZMU(EM2)
      P(1+NPTS)=P(2+NPTS)=PP2
      T(1+NPTS)=T(2+NPTS)=TT2
      TH(1+NPTS)=TH(2+NPTS)=ATAN(FFBOD(LWALL))
      DO 90000 J=1,NSP
      ALP(J,1+NPTS)=ALP(J,NPTS)
90000 ALP(J,2+NPTS)=ALP(J,NPTS)
      W(1+NPTS)=0.
      CPX(1+NPTS)=0.
      CALL THERMO(T( NPTS+ 1),H1,CP1)
      DO 6666 J=1,NSP
      H (J, NPTS+1)=H1(J)
      H (J,NPTS+2) =H (J,NPTS+ 1)
      CP (J,NPTS+ 2)=CP (J,NPTS+1)=CP1(J)
      W(1+NPTS)=W(1+NPTS)+ ALP(J,1+NPTS)/WTMOLE(J)
      CPX(1+NPTS)=CPX(1+NPTS) + ALP(J,1+NPTS)*CP(J,1+NPTS)
      CPX(2+NPTS)=CPX(1+NPTS)
 6666 CONTINUE
      VIS(1+NPTS)=VIS(2+NPTS)=VIS(NPTS)
      W(1+NPTS)=W(2+NPTS)=1./W(1+NPTS)
      R(2+NPTS)=R(1+NPTS)=RO/W(1+NPTS)
      GAM(1+NPTS)=GAM(2+NPTS)=CPX(1+NPTS)/(CPX(1+NPTS)-R(1+NPTS)/CPIN)
      RHO(2+NPTS)=RHO(1+NPTS)=GEW*W(1+NPTS)*P(1+NPTS)/T(1+NPTS)
      Q(2+NPTS)=Q(1+NPTS)=EM(1+NPTS)/EMINF/SQRT(GAR/GAM(1+NPTS)/R(1+NPT
```

```
     ZS)/T(1+NPTS))
      EBOD=EEBOD(LWALL)
      FBOD=FFBOD(LWALL)
      GBOD=GGBOD(LWALL)
      LWALL=LWALL+ 1
      Y(1+NPTS)=Y(NPTS)=EBOD   +3.E-2* TAN(BETB(IDD))
      Y(2+NPTS)=EBOD   +3.E-2*FBOD
      NPTS = NPTS +2
      WRITE(6,1313) BETB(IDD),X(1),DELTA
      DO 1987 II=1,NPTS
1987  X(II)=X(1)+3.E-2
      XBP=X(1)
      IDDD=IDD-1
      DO 1780 JR=1,IDDD
      L=1
      IF((JR/2)*2.NE.JR) L=-1
      IF(IS(JR).EQ.0) GO TO 1780
      Y(IS(JR)+L)=Y(IS(JR))=Y(IS(JR))+3.E-2*TAN(BETB(JR))
1780  CONTINUE
      GO TO 901
   33 DNU= ATAN(FFBOD(LWALL))-ATAN(FBOD)
      WRITE(6,7713) DNU,X(1)
      SQEM=SQRT(EM(NPTS)*EM(NPTS)-1.)
      G=SQRT((GAM(NPTS)+1.)/(GAM(NPTS)-1.))
      GN=SQRT((GAM(NPTS)-1.)/(GAM(NPTS)+1.))
      NUBEGIN=G*ATAN(GN*SQEM)-ATAN(SQEM)
      UMU= ASIN(1./EM(NPTS))
      NUFINAL=NUBEGIN +DNU
      EMF=EM(NPTS)  +  .001
      IF(EM(NPTS).LT.2.) EMF=EM(NPTS)+1./EM(NPTS)
   77 SQEMF= SQRT(EMF*EMF-1.)
      FINAL= G*ATAN(GN*SQEMF)-ATAN(SQEMF)
      IF(ABS(NUFINAL-FINAL).LE..0001) GO TO 1116
      IF(FINAL-NUFINAL) 1114,1116,1115
1114  EMF= EMF +.001
      GO TO 77
1115  EMF= EMF - .0001333
      GO TO 77
1116  UMUF=ASIN(1./EMF)
      FAN= DNU +UMU -UMUF
      FIRST= -UMU + ATAN(FBOD)
      FLINE= FIRST +FAN
      GR=2./(GAM(NPTS)-1.)
      PF=P(NPTS)*((EM(NPTS)**2+GR)/(EMF**2+GR))**(GAM(NPTS)/
     Z(GAM(NPTS)-1.))
      RHOF=RHO(NPTS)*(PF/P(NPTS))**(1./GAM(NPTS))
      QQ=-(2.*GAM(NPTS)/(GAM(NPTS)-1.))*(PF/RHOF-P(NPTS)/RHO(NPTS))
      QF= SQRT(Q(NPTS)**2 +QQ)
      TF= T(NPTS)*(PF/P(NPTS))**((GAM(NPTS)-1.)/GAM(NPTS))
```

```
      EM(2+NPTS)=EM(1+NPTS)=EMF
      XMU(1+NPTS)=XMU(2+NPTS)=UMUF
      P(2+NPTS)=P(1+NPTS)=PF
      TH(2+NPTS)=TH(1+NPTS)=ATAN(FFBOD(LWALL))
      T(2+NPTS)=T(1+NPTS)=TF
      RHO(2+NPTS)=RHO(1+NPTS)=RHOF
      Q(2+NPTS)=Q(1+NPTS)=QF
      DO 90001 J=1,NSP
      ALP(J,1+NPTS)=ALP(J,NPTS)
90001 ALP(J,2+NPTS)=ALP(J,NPTS)
      W(1+NPTS)=0.
      CPX(1+NPTS)=0.
      CALL THERMO(T( NPTS+ 1),H1,CP1)
      DO 66669 J=1,NSP
      H (J, NPTS+1)=H1(J)
      H (J,NPTS+2) =H (J,NPTS+ 1)
      CP (J,NPTS+ 2)=CP (J,NPTS+1)=CP1(J)
      W(1+NPTS)=W(1+NPTS)+ ALP(J,1+NPTS)/WTMOLE(J)
      CPX(1+NPTS)=CPX(1+NPTS) + ALP(J,1+NPTS)*CP(J,1+NPTS)
      CPX(2+NPTS)=CPX(1+NPTS)
66669 CONTINUE
      W(1+NPTS)=W(2+NPTS)=1./W(1+NPTS)
      R(2+NPTS)=R(1+NPTS)=RO/W(1+NPTS)
      GAM(1+NPTS)=GAM(2+NPTS)=CPX(1+NPTS)/(CPX(1+NPTS)-R(1+NPTS)/CPIN)
      NPTS = NPTS + 2
      EBOD=EEBOD(LWALL)
      FBOD=FFBOD(LWALL)
      GBOD=GGBOD(LWALL)
      LWALL= LWALL +1
      Y(  NPTS)=EBOD     + 3.E-2* FBOD
      Y(NPTS-1)=EBOD    +  3.E-2*TAN(FLINE)
      Y(NPTS-2)=EBOD     + 3.E-2*TAN(FIRST)
      IF(Y(NPTS-2).GT.Y(NPTS-3)) GO TO 99999
      NNN=NPTS-3
      IF(Y(NPTS-2).LT.Y(NPTS-4)) NNN=NPTS-4
      DO 91313 LJ=NNN,NPTS
      KR3=1+LJ
      IF((NPTS-NNN).EQ.4) KR3=2+LJ
91313 CALL SWITCH(LJ,KR3)
      NPTS=NPTS-1
      IF((NPTS-NNN).EQ.3) NPTS=NPTS-1
99999 CONTINUE
      DO 1777 II=1,NPTS
 1777 X(II)=X(1)+3.E-2
      XBP=X(1)
      DO 1781 JR=1,IDD
      L=1
      IF((JR/2)*2.NE.JR) L=-1
      IF(IS(JR).EQ.0) GO TO 1781
```

```
      Y(IS(JR)+L)=Y(IS(JR))=Y(IS(JR))+3.E-2*TAN(BETB(JR))
 1781 CONTINUE
  901 RETURN
      END
      SUBROUTINE CROSS(K,KK,KZ)
      COMMON/AL/GAR,GEW
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/CK/WTMOLE(7)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/DP/YN(55)
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/GK/DELX
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     ZLS,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/HP/BETAN(20),IEMBED
      COMMON/PQ/JCHEM,NSP,T(55),PTZERO,IDIVERG,TH1,XE,YE,RCR,PTOJ,TOJ
     1,EM1,XMU1,Q1
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      IF((KZ/2)*2.EQ.KZ) GO TO 3
      DO 1 JR=2,IDD,2
      IF((IS(JR)-K).NE.1) GO TO 1
      YUP=Y(K)+DELX*TAN(BETB(KZ))
      YDOWN=Y(IS(JR))+DELX*TAN(BETB(JR))
      IF(YDOWN.GT.YUP) GO TO 1
      D=(Y(IS(JR))-Y(K))/(TAN(BETB(KZ))-TAN(BETB(JR)))
      YCROSS=Y(K)+TAN(BETB(KZ))*D
      DUP=ABS(TH(K)-TH(K-1))
      DDOWN=ABS(TH(IS(JR)+1)-TH(IS(JR)))
   30 DELTA=DUP
      EMSQ=EM(IS(JR)+1)**2
      BB=-(EMSQ+2.)/EMSQ-GAM(IS(JR)+1)*SIN(DELTA)**2
      CC=(2.*EMSQ+1.)/(EMSQ**2)+((GAM(IS(JR)+1)+1.)**2/4.+(GAM(IS(JR)+1)
     Z-1.)/EMSQ)*SIN(DELTA)**2
      DD=-COS(DELTA)**2/(EMSQ**2)
      EX=(4.5*BB*CC-BB**3-13.5*DD)/SQRT((BB**2-3*CC)**3)
      EE=ACOS(EX)
      NN=4
      FF=COS((EE+NN*4.*ATAN(1.))/3.)
      GG=SQRT(-BB/3.+(2.*SQRT(BB**2-3.*CC)/3.)*FF)
      EPS=ASIN(GG)
   12 SE =(SIN(EPS)) **2
      GM=.5*(GAM(IS(JR)+1)-1.)
      SED=(SIN(EPS-DUP))**2
      EM2=SQRT((1.+GM*EMSQ*SE)/(SED*(GAM(IS(JR)+1)*EMSQ*SE-GM)))
      TOP=2.*GAM(IS(JR)+1)*EMSQ*SE-(GAM(IS(JR)+1)-1.)
```

```
      PP2=TOP/(GAM(IS(JR)+1)+1.)*P(IS(JR)+1)
      TT2=(TOP*((GAM(IS(JR)+1)+1.)*EMSQ*SE+2.)/((GAM(IS(JR)+1)+1.)**2*
     ZEMSQ*SE))*T(IS(JR)+1)
      BUP=EPS-TH(IS(JR)+1)
      DELTA=DDOWN
      EMSQ=EM(K-1)**2
      BB=-(EMSQ+2.)/EMSQ-GAM(  K-  1)*SIN(DELTA)**2
      CC=(2.*EMSQ+1.)/(EMSQ**2)+((GAM(  K-  1)+1.)**2/4.+(GAM( K-   1)-1
     Z.)/EMSQ)*SIN(DELTA)**2
      DD=-COS(DELTA)**2/(EMSQ**2)
      EX=(4.5*BB*CC-BB**3-13.5*DD)/SQRT((BB**2-3*CC)**3)
      EE=ACOS(EX)
      NN=4
      FF=COS((EE+NN*4.*ATAN(1.))/3.)
      GG=SQRT(-BB/3.+(2.*SQRT(BB**2-3.*CC)/3.)*FF)
      EPS=ASIN(GG)
  112 SE =(SIN(EPS)) **2
      GM=.5*(GAM(K-1)-1.)
      SED=(SIN(EPS-DDOWN))**2
      EM3=SQRT((1.+GM*EMSQ*SE)/(SED*(GAM(K-1)*EMSQ*SE-GM)))
      TOP=2.*GAM(K-1)*EMSQ*SE-(GAM(K-1)-1.)
      PP3=TOP/(GAM(K-1)+1.)**P(K-1)
      TT3=(TOP*((GAM(K-1)-1.)*EMSQ*SE+2.)/((GAM(K-1)+1.)**2*EMSQ*SE))
     Z*T(K-1)
      BDOWN=-EPS+TH(K-1)
      AUP=TH(IS(JR)+1)+DUP
      ADOWN=TH(K-1)-DDOWN
      DIF=AUP-ADOWN
      IF(ABS(DIF).LE.1.E-4.AND.ABS(PP2-PP3).LE.1.E-3) GO TO 90
      IF(DIF.LT.0.) GO TO 91
      DUP=DUP*.9973
      DDOWN=DDOWN*1.0027
      GO TO 30
   91 DUP=DUP*1.01
      DDOWN=DDOWN*.99
      GO TO 30
   90 IS(KZ)=IS(JR)+1
      IS(JR)=K-1
      BETAN(KZ)=BUP
      BETAN(JR)=BDOWN
      K=IS(KZ)
      YN(IS(KZ))=YN(IS(KZ)-1)=YCROSS+TAN(BUP)*(DELX-D)
      YN(IS(JR))=YN(IS(JR)+1)=YCROSS+TAN(BDOWN)*(DELX-D)
      EMN(IS(KZ)-1)=EM2
      XMUN(IS(KZ)-1)=ZMU(EM2)
      PN(IS(KZ)-1)=PP2
      TN(IS(KZ)-1)=TT2
      THN(IS(KZ)-1)=AUP
      WN(IS(KZ)-1)=0.
```

```
      CPXN(IS(KZ)-1)=0.
      CALL THERMO(TN(IS(KZ)-1),H1,CP1)
      DO 66 J=1,NSP
      HN(J,IS(KZ)-1)=H1(J)
      CPN(J,IS(KZ)-1)=CP1(J)
      WN(IS(KZ)-1)=WN(IS(KZ)-1)+ALP(J,IS(KZ)-1)/WTMOLE(J)
      CPXN(IS(KZ)-1)=CPXN(IS(KZ)-1)+ALP(J,IS(KZ)-1)*CPN(J,IS(KZ)-1)
   66 CONTINUE
      WN(IS(KZ)-1)=1./WN(IS(KZ)-1)
      RN(IS(KZ)-1)=RO/WN(IS(KZ)-1)
      GAMN(IS(KZ)-1)=CPXN(IS(KZ)-1)/(CPXN(IS(KZ)-1)-RN(IS(KZ)-1)/CPIN)
      RHON(IS(KZ)-1)=GEW*WN(IS(KZ)-1)*PN(IS(KZ)-1)/TN(IS(KZ)-1)
      QN(IS(KZ)-1)=EMN(IS(KZ)-1)/EMINF/SQRT(GAR/GAMN(IS(KZ)-1)/RN(IS(KZ)
     Z-1)/TN(IS(KZ)-1))
      EMN(IS(JR)+1)=EM3
      XMUN(IS(JR)+1)=ZMU(EM3)
      PN(IS(JR)+1)=PP3
      TN(IS(JR)+1)=TT3
      THN(IS(JR)+1)=ADOWN
      WN(IS(JR)+1)=0.
      CPXN(IS(JR)+1)=0.
      CALL THERMO(TN(IS(JR)+1),H1,CP1)
      DO 666 J=1,NSP
      HN(IS(JR)+1)=H1(J)
      CPN(J,IS(JR)+1)=CP1(J)
      WN(IS(JR)+1)=WN(IS(JR)+1)+ALP(J,IS(JR)+1)/WTMOLE(J)
      CPXN(IS(JR)+1)=CPXN(IS(JR)+1)+ALP(J,IS(JR)+1)*CPN(J,IS(JR)+1)
  666 CONTINUE
      WN(IS(JR)+1)=1./WN(IS(JR)+1)
      RN(IS(JR)+1)=RO/WN(IS(JR)+1)
      GAMN(IS(JR)+1)=CPN(IS(JR)+1)/(CPXN(IS(JR)+1)-RN(IS(JR)+1)/CPIN)
      RHON(IS(JR)+1)=GEW*WN(IS(JR)+1)*PN(IS(JR)+1)/TN(IS(JR)+1)
      QN(IS(JR)+1)=EMN(IS(JR)+1)/EMINF/SQRT(GAR/GAMN(IS(JR)+1)/RN(IS(JR)
     Z+1)/TN(IS(JR)+1))
      GO TO 1313
    1 CONTINUE
      GO TO 1313
    3 L=1
      IF((KZ/2)*2.EQ.KZ) L=-1
      DO 2 J=1,IDD
      IF((IS(J )-K).NE.2) GO TO 2
      YUPPER=Y(IS(J ))+DELX*TAN(BETB(J))
      YLOWER=Y(K)+DELX*TAN(BETB(KZ))
      IF(YUPPER.GT.YLOWER) GO TO 2
      D=(Y(IS(J))-Y(K))/(TAN(BETB(KZ))-TAN(BETB(J)))
      YCROSS=Y(K)+TAN(BETB(KZ))*D
      DU=ABS(TH(IS(J)+L)-TH(IS(J)))
      DL=ABS(TH(IS(KZ)+L)-TH(IS(KZ)))
      DELTA=DU+DL
```

```
      EMSQ=EM(IS(KZ)+1-L)**2
      BB=-(EMSQ+2.)/EMSQ-GAM(IS(KZ)+1-L)*SIN(DELTA)**2
      CC=(2.*EMSQ+1.)/(EMSQ**2)+((GAM(IS(KZ)+1-L)+1.)**2/4.+(GAM(IS(KZ)+
     Z1-L)-1.)/EMSQ)*SIN(DELTA)**2
      DD=-COS(DELTA)**2/(EMSQ**2)
      EX=(4.5*BB*CC-BB**3-13.5*DD)/SQRT((BB**2-3*CC)**3)
      EE=ACOS(EX)
      NN=4
      FF=COS((EE+NN*4.*ATAN(1.))/3.)
      GG=SQRT(-BB/3.+(2.*SQRT(BB**2-3.*CC)/3.)*FF)
      EPS=ASIN(GG)
  912 SE =(SIN(EPS)) **2
      GM=.5*(GAM(IS(KZ)+1-L)-1.)
      SED=(SIN(EPS-DELTA))**2
      EM2=SQRT((1.+GM*EMSQ*SE)/(SED*(GAM(IS(KZ)+1-L)*EMSQ*SE-GM)))
      TOP=2.*GAM(IS(KZ)+1-L)*EMSQ*SE-(GAM(IS(KZ)+1-L)-1.)
      PP2=TOP/(GAM(IS(KZ)+1-L)+1.)*P(IS(KZ)+1-L)
      TT2=(TOP*((GAM(IS(KZ)+1-L)-1.)*EMSQ*SE+2.)/((GAM(IS(KZ)+1-L)+1.)**
     Z2*EMSQ*SE))*T(IS(KZ)+1-L)
      BBETB=-(EPS-TH(IS(KZ)+1-L))*L
      EMN(IS(KZ)+1)=EM2
      XMUN(IS(KZ)+1)=ZMU(EM2)
      PN(IS(KZ)+1)=PP2
      TN(IS(KZ)+1)=TT2
      THN(IS(KZ)+1)=AUP
      WN(IS(KZ)+1)=0.
      CPXN(IS(KZ)+1)=0.
      CALL THERMO(TN(IS(KZ)+1),H1,CP1)
      DO 44 JJ=1,NSP
      HN(JJ,IS(KZ)+1)=H1(JJ)
      CPN(JJ,IS(KZ)+1)=CP1(JJ)
      WN(IS(KZ)+1)=WN(IS(KZ)+1)+ALP(JJ,IS(KZ)+1)/WTMOLE(JJ)
      CPXN(IS(KZ)+1)=CPXN(IS(KZ)+1)+ALP(JJ,IS(KZ)+1)*CPN(JJ,IS(KZ)+1)
   44 CONTINUE
      WN(IS(KZ)+1)=1./WN(IS(KZ)+1)
      RN(IS(KZ)+1)=RO/WN(IS(KZ)+1)
      GAMN(IS(KZ)+1)=CPXN(IS(KZ)+1)/(CPXN(IS(KZ)+1)-RN(IS(KZ)+1)/CPIN)
      RHON(IS(KZ)+1)=GEW*WN(IS(KZ)+1)*PN(IS(KZ)+1)/TN(IS(KZ)+1)
      QN(IS(KZ)+1)=EMN(IS(KZ)+1)/EMINF/SQRT(GAR/GAMN(IS(KZ)+1)/RN(IS(KZ)
     Z+1)/TN(IS(KZ)+1))
      YN(IS(KZ)+1)=YN(IS(KZ)+1-L)=YCROSS+TAN(BBETB)*(DELX-D)
      IF(L.NE.1) GO TO 7
      JR=IS(KZ)+2
      DO 71313 LR=JR,NPTS
      KR3=2+LR
71313 CALL SWITCH(LR,KR3)
      IS(J)=0
      BETAN(J)=0.
      BETAN(KZ)=BBETB
```

```
      NPTS=NPTS-2
      KK=1
      DO 333 I=1,IDD
      IF(IS(I).GT.IS(KZ))IS(I)=IS(I)-2
  333 CONTINUE
      GO TO 2
    7 JR=IS(KZ)-1
      DO 91313 LR=JR,NPTS
      KR3=2+LR
91313 CALL SWITCH(LR,KR3)
      IS(J)=IS(KZ)
      IS(KZ)=0
      BETAN(KZ)=0.
      BETAN(J)=BBETB
      NPTS=NPTS-2
      KK=1
      DO 3333 I=1,IDD
      IF(IS(I).GT.IS(J)) IS(I)=IS(I)-2
 3333 CONTINUE
    2 CONTINUE
 1313 RETURN
      END
      SUBROUTINE EMBED
      COMMON/AC/IBOD,PIN
      COMMON/AL/GAR,GEW
      COMMON/AX/JSUBL,JSUBU
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/BD/XMASS(55)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/CK/WTMOLE(7)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/GK/DELX
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     IL,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/HP/BETAN(20),IEMBED
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/RC/R(55)
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      DATA EPPRES/1.E-04/
      IEMBED=0
```

```
      ALPHA=1.
      BETA=0.
      ALPH=1.
      BET=0.
      DELX=1.
      DO 500 M=1,2
      IF(IS(M).NE.0) GO TO 500
      IM=NPTS-2
      DO 1 I=2,IM
      IF(I.GE.JSUBL.AND.I.LT.JSUBU) GO TO 1
      I2=I
      I1=I2-1
      I3=I2+1
      I4=I2+2
      T10=Y(I1)-Y(I2)
      T11=Y(I2)-Y(I3)
      T12=Y(I3)-Y(I4)
      IF(T10.LT.1.E-04.OR.T11.LT.1.E-04.OR.T12.LT.1.E-04) GO TO 1
      DZ=Y(I+1)  -Y(I)
      IF((M/2)*2.EQ.M) GO TO 200
      XP2=XM1(ALPH ,BET ,TH(I+1),XMU(I+1),0.,0.)
      XP1=XM1(ALPH ,BET ,TH(I   ),XMU(I   ),0.,0.)
      GO TO 201
  200 CONTINUE
      XP2=XM2(ALPH ,BET ,TH(I+1),XMU(I+1),0.,0.)
      XP1=XM2(ALPH ,BET ,TH(I   ),XMU(I   ),0.,0.)
  201 DZLAM=XP1-XP2
      IF(DZLAM.LT.1.E-10) GO TO 1
      DI=DZ/DZLAM
      IF(DI) 1,1,7
    7 IF(DI.GT.10.*DELX) GO TO 1
      P1S=P(I1)*P(I1)
      P2S=P(I2)*P(I2)
      P3S=P(I3)*P(I3)
      P4S=P(I4)*P(I4)
      T1=P(I1)-P(I2)
      T2=P(I2)-P(I3)
      T3=P(I3)-P(I4)
      T4=P1S-P2S
      T5=P2S-P3S
      T6=P3S-P4S
      T7=P1S*P(I1)-P2S*P(I2)
      T8=P2S*P(I2)-P3S*P(I3)
      T9=P3S*P(I3)-P4S*P(I4)
      CALL SOLVE(T1 ,T2 ,T3 ,T4 ,T5 ,T6 ,T7 ,T8 ,T9 ,E )
      CALL SOLVE(T10,T11,T12,T4 ,T5 ,T6 ,T7 ,T8 ,T9 ,DB)
      CALL SOLVE(T1 ,T2 ,T3 ,T10,T11,T12,T7 ,T8 ,T9 ,DC)
      CALL SOLVE(T1 ,T2 ,T3 ,T4 ,T5 ,T6 ,T10,T11,T12,DD)
      B=DB/E
```

```
      C=DC/E
      D=DD/E
      A=Y(I1)+P(I1)*(-B+P(I1)*(-C-D*P(I1)))
      TRE=1./3.
      CD=1./27.
      YST=A-C*B*TRE/D+2.*C**3*CD/D**2
      IF(YST.LE.Y(I).OR.YST.GE.Y(I+1)) GO  TO 1
      YSTP=B-C*C*TRE/D
      IF(YSTP.GE.EPPRES) GO TO 1
      IS(M)  =I+1
      IF((M/2)*2.EQ.M) IS(M)=I
      XP5=XP1
      XP6=XP2
      GO TO 501
    1 CONTINUE
      GO TO 500
  501 ISM=IS(M)
      BETB(M)=(ATAN(XP5)+ATAN(XP6))/2.
      WRITE(6,506)M
  506 FORMAT(1H1,20X,19HEMBEDDED SHOCK TYPE  I2//13X,2HIS ,5X,4HBETA )
      WRITE(6,508) IS(M),BETB(M)
  508 FORMAT(10X,I5,E11.3)
      L=1
      IF((M/2)*2.EQ.M) L=-1
      ISMM=ISM-L
      ISP=ISM+L
      RAT=((Y(ISM)+Y(ISMM))/2.-Y(ISP))/(Y(ISM)-Y(ISP))
      X      (ISM)=X      (ISP)+RAT*(X      (ISM)-X      (ISP))
      Y      (ISM)=Y      (ISP)+RAT*(Y      (ISM)-Y      (ISP))
      Q      (ISM)=Q      (ISP)+RAT*(Q      (ISM)-Q      (ISP))
      P      (ISM)=P      (ISP)+RAT*(P      (ISM)-P      (ISP))
      T      (ISM)=T      (ISP)+RAT*(T      (ISM)-T      (ISP))
      DVIS(ISM)=DVIS(ISP)+RAT*(DVIS(ISM)-DVIS(ISP))
      VIS(ISM)=VIS(ISP)+RAT*(VIS(ISM)-VIS(ISP))
      TH     (ISM)=TH     (ISP)+RAT*(TH     (ISM)-TH     (ISP))
      BQ     (ISM)=BQ     (ISP)+RAT*(BQ     (ISM)-BQ     (ISP))
      TAU    (ISM)=TAU    (ISP)+RAT*(TAU    (ISM)-TAU    (ISP))
      DBQ    (ISM)=DBQ    (ISP)+RAT*(DBQ    (ISM)-DBQ    (ISP))
      DCPX   (ISM)=DCPX   (ISP)+RAT*(DCPX   (ISM)-DCPX   (ISP))
      DTAU   (ISM)=DTAU   (ISP)+RAT*(DTAU   (ISM)-DTAU   (ISP))
      XMASS  (ISM)=XMASS  (ISP)+RAT*(XMASS  (ISM)-XMASS  (ISP))
      CPX(ISM)=0.
      W(ISM)=0.
      CALL THERMO(T(ISM),H1,CP1)
      DO 100 KI=1,NSP
      J=KI
      ALP  (KI,ISM)=ALP  (KI,ISP)+RAT*(ALP  (KI,ISM)-ALP  (KI,ISP))
      DALP (KI,ISM)=DALP (KI,ISP)+RAT*(DALP (KI,ISM)-DALP (KI,ISP))
      DDALP(KI,ISM)=DDALP(KI,ISP)+RAT*(DDALP(KI,ISM)-DDALP(KI,ISP))
```

```
      H(J,ISM)=H1(J)
      CP(J,ISM)=CP1(J)
      W(ISM)=W(ISM)+ALP(J,ISM)/WTMOLE(J)
      CPX(ISM)=CPX(ISM)+ALP(J,ISM)*CP(J,ISM)
      H  N(KI,ISM)=H  (KI,ISM)
      ALPN(KI,ISM)=ALP(KI,ISM)
  100 CONTINUE
      W(ISM)=1./W(ISM)
      R(ISM)=RO/W(ISM)
      GAM(ISM)=CPX(ISM)/(CPX(ISM)-R(ISM)/CPIN)
      RHO(ISM)=P(ISM)*W(ISM)*GEW/T(ISM)
      RI=1./R(ISM)
      EM(ISM)=Q(ISM)*EMINF*SQRT(GAR/GAM(ISM)*RI/T(ISM))
      XMU(ISM)=ZMU(EM(ISM))
      Q   N(ISM)=Q  (ISM)
      R   N(ISM)=R  (ISM)
      T   N(ISM)=T  (ISM)
      P   N(ISM)=P  (ISM)
      W   N(ISM)=W  (ISM)
      VISN(ISM)=VIS(ISM)
      DVISN(ISM)=DVIS(ISM)
      TH  N(ISM)=TH (ISM)
      RHO N(ISM)=RHO(ISM)
      GAM N(ISM)=GAM(ISM)
      IF(JSUBL.GT.IS(M)) JSUBL=JSUBL+1
      IF(JSUBU.GT.IS(M)) JSUBU=JSUBU+1
      DO 101 KK=1,4
      IF(IS(KK).GT.IS(M)) IS(KK)=IS(KK)+1
  101 CONTINUE
      IEMBED=1
      CALL HSHOCK(M)
      IEMBED=0
      X(ISMM)=X(ISM)
      Y(ISMM)=Y(ISM)
      XMASS(ISMM)=XMASS(ISM)
      W  (ISMM)=W  N(ISMM)
      P  (ISMM)=P  N(ISMM)
      Q  (ISMM)=Q  N(ISMM)
      T  (ISMM)=T  N(ISMM)
      R  (ISMM)=R  N(ISMM)
      TH (ISMM)=TH N(ISMM)
      EM (ISMM)=EM N(ISMM)
      RHO(ISMM)=RHON(ISMM)
      VIS(ISMM)=VISN(ISMM)
      DVIS(ISMM)=DVISN(ISMM)
      CPX(ISMM)=CPXN(ISMM)
      GAM(ISMM)=GAMN(ISMM)
      XMU(ISMM)=XMUN(ISMM)
      DO 1313 KI=1,NSP
```

```
      H  (KI,ISMM)=H  N(KI,ISMM)
      CP (KI,ISMM)=CP N(KI,ISMM)
      ALP(KI,ISMM)=ALPN(KI,ISMM)
 1313 CONTINUE
      IBOD=0.
      RE=0.
      XBP=0.
      CALL SHEAR1(0.,0.)
  500 CONTINUE
      RETURN
      END
      SUBROUTINE SOLVE(A11,A12,A13,A21,A22,A23,A31,A32,A33,DET)
      DET=A11*(A22*A33-A32*A23)-A12*(A21*A33-A31*A23)+A13*(A21*A32-A22*A
     131)
      RETURN
      END
      SUBROUTINE HSHOCK(K)
      COMMON/AL/GAR,GEW
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/BB/S1A,S2A,S3AT
      COMMON/BO/GAMB,PB,QB,RHOB,THB,WB,XMUB,YB
      COMMON/CA/WDOTN(7,55),XN(55)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/CK/WTMOLE(7)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/ZY/ABOD,BBOD,CBOD,EBOD,FBOD,GBOD,IAVE,IPUNCH,JBOD,KKKKK
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/DP/YN(55)
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EG/EIN,PR,XLE
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/FE/DEL
      COMMON/GF/DELY,IFS,KOUNTO,MMM
      COMMON/GK/DELX
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     ILS,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/HP/BETAN(20),IEMBED
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/QS/RHOP(2),WDOT(7,55),WDOTC(7),WP(2),XMUP(2)
      COMMON/SQ/BQN(55),DALPN(7,55),DBQN(55),DCPXN(55),DDALPN(7,55),
     1DTAUN(55),TAUN(55)
      COMMON/ST/I13,IREGI,KS,KFIRST,KKKQ,PSTAR
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      COMMON/TV/ALPP(7,2),BET,BQP(2),DACHP(7,2),DALPP(7,2),DBQP(2),
     1DCPXP(2),DDALPP(7,2),DTAUP(2),DTCHP(2),GAMP(2),PP(2),QP(2),
```

```
     2TAUP(2),THP(2),TP(2),YP(2)
      COMMON/VW/ICONT,IEND,KT,THBPN,XBPN
      DIMENSION DUMM(7)
      REAL NBETB
      I=IS(K)
      IT1=1
      BET=BETB(K)
      IT11=1
      XXX=1.
      ICCC=0
      L=1
      IF((K/2)*2.NE.K) L=-1
      KSAVE=KS
      KZ=K
      KK=0
      KJ=0
      CALL CROSS(KS,KK,KZ)
      IF(KSAVE.NE.KS.OR.KK.NE.0) GO TO 1402
      IF(L.LT.0) GO TO 2
      TOE=  Y(1    )-Y(IS(K))
      KJ=IS(K)-1
      DXX= .02*TOE/(TAN(BETB(K))-BBOD)
      DELTA =ABS(TH(IS(K)+L)-ATAN(BBOD) )
      GO TO 3
    2 TOE=  Y(NPTS)-Y(IS(K))
      KJ=NPTS-IS(K)
      DXX= .2*TOE/(TAN(BETB(K))-FBOD)
      DELTA =ABS(TH(IS(K)+L)-ATAN(FBOD) )
    3 IF(DXX.GT.DELX.OR.KJ.GT.1) GO TO 1
      EMSQ  = EM(IS(K)+L)**2
      BB=-(EMSQ+2.)/EMSQ-GAM(IS(K)+L)*SIN(DELTA)**2
      CC=(2.*EMSQ+1.)/(EMSQ**2)+((GAM(IS(K)+L)+1.)**2/4.+(GAM(IS(K)+L)-1
     Z.)/EMSQ)*SIN(DELTA)**2
      DD=-COS(DELTA)**2/(EMSQ**2)
      EX=(4.5*BB*CC-BB**3-13.5*DD)/SQRT((BB**2-3*CC)**3)
      EE=ACOS(EX)
      NN=4
      FF=COS((EE+NN*4.*ATAN(1.))/3.)
      GG=SQRT(-BB/3.+(2.*SQRT(BB**2-3.*CC)/3.)*FF)
      EPS=ASIN(GG)
   12 SE =(SIN(EPS)) **2
      GM =.5*(GAM(IS(K)+L)-1.)
      SED =  (SIN(EPS-DELTA))**2
      EM2= SQRT((1.+GM*EMSQ*SE)/(SED*(GAM(IS(K)+L)*EMSQ*SE-GM)))
      TOP =2.*GAM(IS(K)+L)*EMSQ*SE-(GAM(IS(K)+L)-1.)
      PP2= TOP /(GAM(IS(K)+L)+1.)*P(IS(K)+L)
      TT2= (TOP*((GAM(IS(K)+L)-1.)*EMSQ*SE+2.)/((GAM(IS(K)+L)+1.)**2*EMS
     1Q*SE))*T(IS(K)+L)
      NBETB=L*(EPS+L*TH(IS(K)+L))
```

```
      IF((((IDD+1)/2)*2.NE.(IDD+1)).AND.(L.LT.0))GO TO 114
      IDD =IDD+1
      IS(IDD)= IS(K)+L
      BETB(IDD)= NBETB
      BETAN(IDD)=NBETB
      GO TO 115
  114 IDD= IDD+2
      IS(IDD  ) =IS(K)+L
      BETB(IDD)= NBETB
      BETAN(IDD)=NBETB
  115 Y2= Y(IS(K) ) + DXX*TAN(BETB(K))
      YN(IS(K))=YN(IS(K)+L)=Y2+(DELX-DXX)*TAN(NBETB)
      IF(L.LT.0) GO TO 22
      YN(IS(K)-L)=Y(IS(K)-L) +DELX*BBOD
      JENKI=1
      GO TO 33
   22 YN(IS(K)-L)=Y(IS(K)-L) +DELX*FBOD
      IJENK =1
   33 EMN(IS(K)-L)=EMN(IS(K))=EM2
      XMUN(IS(K)-L)=XMUN(IS(K))=ZMU(EM2)
      PN(IS(K))=PN(IS(K)-L)=PP2
      TN(IS(K))=TN(IS(K)-L)=TT2
      IF(L.LT.0) GO TO 44
      THN(IS(K))=THN(IS(K)-L)=ATAN(BBOD)
      GO TO 333
   44 THN(IS(K))=THN(IS(K)-L)=ATAN(FBOD)
  333 WN(IS(K)-L)=0.
      CPXN(IS(K)-L)=0.
      CALL THERMO(TN(IS(K)-L),H1,CP1)
      DO 66 J=1,NSP
      HN(J,IS(K)-L)=H1(J)
      HN(J,IS(K))  =HN(J,IS(K)-L)
      CPN(J,IS(K)-L)=CPN(J,IS(K))=CP1(J)
      WN(IS(K)-L)=WN(IS(K)-L) +ALP(J,IS(K)-L)/WTMOLE(J)
      CPXN(IS(K)-L)=CPXN(IS(K)-L) +ALP(J,IS(K)-L)*CPN(J,IS(K)-L)
      CPXN(IS(K))=CPXN(IS(K)-L)
   66 CONTINUE
      WN(IS(K)-L)=WN(IS(K))=1./WN(IS(K)-L)
      RN(IS(K))=RN(IS(K)-L)=RO/WN(IS(K)-L)
      GAMN(IS(K)-L)=CPXN(IS(K)-L)/(CPXN(IS(K)-L)-RN(IS(K)-L)/CPIN)
      GAMN(IS(K))=GAMN(IS(K)-L)
      RHON(IS(K))=RHON(IS(K)-L)=GEW*WN(IS(K)-L)*PN(IS(K)-L)/TN(IS(K)-L)
      QN(IS(K))  =QN(IS(K)-L)=EMN(IS(K)-L)/EMINF/SQRT(GAR/GAMN(IS(K)-L)/
     ZRN(IS(K)-L)/TN(IS(K)-L))
      WRITE(6,2002) K,IDD
 2002 FORMAT(1H,10H *********,//* SHOCK WAVE BETB(*,I3,*)*,*HAS REFLECTE
     ZD FROM THE WALL AND HAS BECOME BETB(*,I3,*)*)
      BETB(K)=0.
      BETAN(K)=0.0
```

```
      IS(K)=0
      IF(L.GT.0) LS=LS+1
      GO TO 1402
    1 CONTINUE
      M=IS(K)  +L
      IF(BETA.NE.0.) GO TO 8210
      TAUN(M)=TAU(M)
      BQN(M)=BQ(M)
      DCPXN(M)=DCPX(M)
      DTAUN(M)=DTAU(M)
      DBQN(M)=DBQ(M)
      CPXN(M)=CPX(M)
      DO 8211 J=1,NSP
      DALPN(J,M)=DALP(J,M)
      DDALPN(J,M)=DDALP(J,M)
      ALPN(J,M)=ALPN(J,I)
      WDOTC(J)=0.
      WDOTN(J,M)=0.
      WN(M)=WN(I)
 8211 CONTINUE
 8210 CONTINUE
      IF(BETA.GT.0.)BET=BETAN(K)
    4 IT=1
      CA=1.
      VT=QN(I)  *COS(BET-THN(I))
      U1=QN(I)                          *CA*SIN(BET-THN(I))
      U1=ABS(U1)
      XMS=RHON(I)  *U1
      GN=GAMN(I)
      GP1=(GN+1.)
      GM1=GN-1.
      RNI=1./RN(I)
      XM1=U1**2*EMINF**2*(GAR/GAMN(I)*RNI/TN(I))
      OXM=1./XM1
      IF(IT.EQ.1)U2=U1*(GM1*XM1+2.)/GP1*OXM
    5 RH2P=XMS/U2
      P2H=XMS*(U1-U2)+PN(I)
      V2=VT**2
      V1=V2+U1**2
      V2=V2+U2**2
      H6=0.
      DO 1400 J=1,NSP
 1400 H6=HN(J,I)*ALPN(J,I)+H6
      H2=H6+(V1-V2)/2.*EIN
      IIT1=1
      T1=TN(I)
      IF(IIT1.EQ.1)T2=T1*(2.*GN*XM1-GM1)*(GM1*XM1+2.)/(2.*GP1)*OXM
 8200 CALL THERMO(T2,H1,CP1)
      H2P=0.
```

```
      DO 8201 J=1,NSP
8201  H2P=H2P+ALPN(J,M)*H1(J)
      ERR1=(H2-H2P)/H6
      IF(ABS(ERR1).LT.1.E-08) GO TO 8202
      IIT1=IIT1+1
      IF(IIT1.GT.15) GO TO 8203
      IF(IIT1.GT.2) GO TO 8204
      ERR2=ERR1
      T22=T2
      T2=T2*1.01
      GO TO 8200
8203  WRITE(6,9191)
9191  FORMAT(1H1)
      WRITE(6,8205)
8205  FORMAT(* ERROR IN TEMPERATURE LOOP IN HSHOCK*)
      STOP
8204  DUM=T22-ERR2*(T2-T22)/(ERR1-ERR2)
      ERR2=ERR1
      T22=T2
      T2=DUM
      GO TO 8200
8202  CONTINUE
      RH2=P2H*WN(M)*GEW/T2
      ER=(RH2-RH2P)/RHO (I)
      IF(ABS(ER).LT.1.E-8)GO TO 7
      IT=IT+1
      IF(IT.GT.25) GO TO 100
      IF(IT.GT.2)GO TO 6
      ER2=ER
      U22=U2
      U2=U2*.99
      GO TO 5
 100  WRITE(6,9191)
      WRITE(6,200)
 200  FORMAT(* ERROR IN HUGONIOT LOOP IN HSHOCK*)
      STOP
   6  DUM=U22-ER2*(U2-U22)/(ER-ER2)
      ER2=ER
      U22=U2
      U2=DUM
      GO TO 5
   7  CONTINUE
      CB=COS(BET)
      SB=SIN(BET)
      IF((K/2)*2.EQ.K)U2=-U2
      QN2P=-U2*CA
      UV=VT*CB-QN2P*SB
      WV=VT*SB+QN2P*CB
      PHE2=ATAN(WV/UV)
```

```
      Q2=SQRT(UV*UV+WV*WV)
      IF(IEMBED.EQ.1) GO TO 3535
      YN(M)  =Y(M)  +.5*(TAN(BETB(K)  )+TAN(BET))*DELX
      DEL=1.
      CALL LPOINT(M,1.)
  775 DEL=0.
      S1A=0.
      S2A=0.
      S3AT=0.
      GAMB=GAMP(1)
      PB=PP(1)
      QB=QP(1)
      RHOB=RHOP(1)
      THB=THP(1)
      WB=WP(1)
      XMUB=XMUP(1)
      YB=YP(1)
      A1=F1(M)
      A2=F2(M,S1A,S2A,S3AT)
      IF(JCHEM.EQ.1) GO TO 7254
      A3=0.
      GO TO 7257
 7254 TP1=(TP(1)+T2)/2.
      DTCHP(1)=DTCHP(1)/2.
      DO 1552 J=1,NSP
 1552 DUMM(J)=DACHP(J,1)/2.
      A3=F3(TP1,DTCHP(1),TP(1),T2,THP(1),PHE2,DUMM,WP(1),WN(M))
 7257 CONTINUE
      OPT=-1.
      IF((K/2)*2.EQ.K) OPT=1.
      A4=F4(BETA,-OPT,XMUP(1),THP(1),XMUN(M),THN(M))
      A2=(A2+A3)*A4
      PSH=PP(1)+(OPT*(PHE2-THP(1))-A2*DELX)/A1
      ER3=(PSH-P2H)/P(M)
      IF(ABS(ER3).LT.1.E-3)GO TO 19
      IT1=IT1+1
      IF(IT1.GT.25)GO TO 103
      IT11=IT11+1
      IF(IT1.EQ.2) GO TO 1430
      IF(ER1*ER3.LT.0.) GO TO 14
      IF(ABS(ER1-ER3).LT.5.E-06) GO TO 1492
      IF(ABS(ER1).GT.ABS(ER3)) GO TO 1430
      IF(ICCC.EQ.1) GO TO 103
      XXX=-1.
      ICCC=1
      IT11=IT11-1
 1430 ER1=ER3
      BET1=BET
      BET=BET+.01*(IT11-1)*BET*XXX
```

```
      GO TO 15
 1492 BET2=(BET-BET1 )*20.
      ER1=ER3
      BET1=BET
      BET=BET+BET2
      GO TO 15
  103 WRITE(6,9191)
      WRITE(6,220)
  220 FORMAT(* ERROR IN SHOCK ANGLE IN HSHOCK*)
      STOP
   14 DUM=BET1-ER1*(BET-BET1)/(ER3-ER1)
      ER1=ER3
      BET1=BET
      BET=DUM
   15 YN(M)  =Y(M)  +.5*(TAN(BETB(K)  )+TAN(BET))*DELX
      I5=IS(K)
      YN(I5)  =YN(M)
      KS=IS(K)
      LS=KS
      KT=KS
      IF ((K/2)*2.EQ.K) KT= KT-1
      CALL CPOINT
      GO TO 4
   19 BETAN(K)  =BET
      YN(M)  =.5*(TAN(BETB(K)  )+TAN(BETAN(K)  ))*DELX+Y(M)
      I5=IS(K)
      YN(I5)  =YN(M)
 3535 CONTINUE
      PN(M)  =P2H
      QN(M)  =Q2
      THN(M)  =PHE2
      RHON(M)  =RH2
      TN(M)=T2
      RN(M)=RO/WN(M)
      CPXN(M)=0.
      DO 1401 J=1,NSP
      HN(J,M)=H1(J)
      CPN(J,M)=CP1(J)
 1401 CPXN(M)=CPXN(M)+ALPN(J,M)*CPN(J,M)
      GAMN(M)=CPXN(M)/(CPXN(M)-RN(M)/CPIN)
      ORM=1./RN(M)
      EMN(M)=QN(M)*EMINF*SQRT(GAR/GAMN(M)*ORM/TN(M))
      IF(EMN(M).LT.1.0001) GO TO 1402
      XMUN(M)=ZMU(EMN(M))
 1402 CONTINUE
      RETURN
      END
      SUBROUTINE SWITCH(J,K)
      COMMON/BA/ALP(7,55),EMINF,WINF
```

```
      COMMON/BD/XMASS(55)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/RC/R(55)
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      X     (J)=X     (K)
      Y     (J)=Y     (K)
      Q     (J)=Q     (K)
      P     (J)=P     (K)
      T     (J)=T     (K)
      W     (J)=W     (K)
      R     (J)=R     (K)
      EM    (J)=EM    (K)
      TH    (J)=TH    (K)
      BQ    (J)=BQ    (K)
      TAU   (J)=TAU   (K)
      DBQ   (J)=DBQ   (K)
      DVIS(J)=DVIS(K)
      VIS(J)=VIS(K)
      GAM   (J)=GAM   (K)
      RHO   (J)=RHO   (K)
      XMU   (J)=XMU   (K)
      CPX   (J)=CPX   (K)
      DCPX  (J)=DCPX  (K)
      DTAU  (J)=DTAU  (K)
      XMASS(J)=XMASS(K)
      DO 108 JJ=1,NSP
      H     (JJ,J)=H     (JJ,K)
      CP    (JJ,J)=CP    (JJ,K)
      ALP   (JJ,J)=ALP   (JJ,K)
      DALP  (JJ,J)=DALP  (JJ,K)
      DDALP(JJ,J)=DDALP(JJ,K)
  108 CONTINUE
      RETURN
      END
      SUBROUTINE PM(M,OPT)
      COMMON/AL/GAR,GEW
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/CK/WTMOLE(7)
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EG/EIN,PR,XLE
      COMMON/EP/GAMINF,H1(7),RINF
```

```
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55),PTZERO,IDIVERG,TH1,XE,YE,RCR,PTOJ,TOJ
     1,EM1,XMU1,Q1
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/RC/R(55)
      DP=ALOG(P(7)/P(2))
      H6=0.
      DO 2 J=1,NSP
    2 H6=H6+H(J,M)*ALP(J,M)
      DO 11 I=1,NPTS
   11 X(I)=3.E-2
      XBP=X(1)
      RHO1=RHO(2)*EXP(DP/GAM(2))
      G=2.*GAM(2)/(GAM(2)-1)
      VSQUARE=QQ=-G*(P(7)/RHO1-P(2)/RHO(2))
      Q1=SQRT(Q(5)**2+VSQUARE)
      H2=H6-QQ/2.*EIN
      IIT1=1
      T1=T(2)
      IF(IIT1.EQ.1) T2=T1*.99
8200  CALL THERMO(T2,H1,CP1)
      H2P=0.
      DO 4 J=1,NSP
    4 H2P=H2P+ALP(J,5)*H1(J)
      ERR1=(H2-H2P)/H6
      IF(ABS(ERR1).LT.1.E-08) GO TO 8202
      IIT1=IIT1+1
      IF(IIT1.GT.15) GO TO 8203
      IF(IIT1.GT.2) GO TO 8204
      ERR2=ERR1
      T22=T2
      T2=T2*.99
      GO TO 8200
8203  WRITE(6,9191)
9191  FORMAT(1H1)
      WRITE(6,8205)
8205  FORMAT(* ERROR IN TEMPERATURE LOOP IN PM*)
      STOP
8204  DUM=T22-ERR2*(T2-T22)/(ERR1-ERR2)
      ERR2=ERR1
      T22=T2
      T2=DUM
      GO TO 8200
8202  CONTINUE
      N=5
      T(N)=T2
      W(N)=0.
      CPX(N)=0.
```

```
      DO 5 J=1,NSP
      CP(J,N)=CP1(J)
      H(J,N)=H1(J)
      CPX(N)=CPX(N)+ALP(J,N)*CP1(J)
    5 W(N)=W(N)+ALP(J,N)/WTMOLE(J)
      W(N)=1./W(N)
      R(N)=RO/W(N)
      GAM(N)=CPX(N)/(CPX(N)-R(N)/CPIN)
      ORN=1./R(N)
      EM1=Q1*EMINF*SQRT(GAR/GAM(N)*ORN/T(N))
      XMU1=ZMU(EM1)
      TH1=TH(N)-OPT*(DP/GAM(2))*(COS(XMU1)*SIN(XMU1)
     3+COS(XMU(N)) *SIN(XMU(N)))/2.
      RETURN
      END
      SUBROUTINE CHEM(FAS)
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/CA/WDOTN(7,55),XN(55)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/DP/YN(55)
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
       COMMON/HI/DALCH(7),DTCHEM
      COMMON/OP/ALPB(7),PHI(55)
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/QS/RHOP(2),WDOT(7,55),WDOTC(7),WP(2),XMUP(2)
      COMMON/VT/DACH(7,55),DTCH(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/YZ/BPRESU,CHEMFC,CPRESU,EMSUB,RTH,XSTEP
      IF(JCHEM.EQ.0) GO TO 8351
C          ********** CHEMISTRY PACKAGE **********
      DO 8355 L=1,NPTS
      DO 89 M=1,IDD
      IF(IS(M).EQ.0) GO TO 89
      ITEST=IS(M)-1
      IF((M/2)*2.EQ.M) ITEST=IS(M)
      IF(L.EQ.ITEST.OR.L.EQ.ITEST+1) GO TO 8398
   89 CONTINUE
      FAT=ABS(PHI(L))
      IF((FAT.LT..01).OR.(FAT.GT.100.)) GO TO 8398
      K=L
      DX=SQRT((XN(L)-X(K))**2+(YN(L)-Y(K))**2)*RTH
      DO 8350 J=1,NSP
 8350 ALPB(J)=ALP(J,K)
      CALL HOCUS(T(K),P(K),Q(K),RHO(K),ALPB,DX,L)
      DO 8301 J=1,NSP
 8301 DACH(J,L)=DALCH(J)
      DTCH(L)=DTCHEM
```

```
      GO TO 8355
 8398 DTCH(L)=0.
      DO 8399 J=1,NSP
      WDOT(J,L)=0.
      WDOTN(J,L)=0.
 8399 DACH(J,L)=0.
 8355 CONTINUE
      GO TO 4000
 8351 DO 6100 L=1,NPTS
      DTCH(L)=0.
      DO 8302 J=1,NSP
      WDOT(J,L)=0.
      WDOTN(J,L)=0.
 8302 DACH(J,L)=0.
 6100 CONTINUE
 4000 CONTINUE
      RETURN
      END
      SUBROUTINE SHEAR(I,ASHEAR)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/CK/WTMOLE(7)
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/GK/DELX
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/SS/AL1,AL2,BQ1,BQ2,C1,C2,CH1,CH2,DB1,DB2,DD1,DD2,DT1,DT2,DV
     A1,DV2,PX1,PX2,TA1,TA2,TH1,TH2,V1,V2,Y1,Y2
      COMMON/ST/I13,IREGI,K ,KFIRST,KKKQ,PSTAR
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      COMMON/VT/DACH(7,55),DTCH(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      DIMENSION S3D(7)
      K=I
      V1=V2=VIS(K)
      DV1=DV2=DVIS(K)
      TA1=TA2=TAU(K)
      DT1=DT2=DTAU(K)
      Y1=Y2=Y(K)
      TH1=TH2=TH(K)
      S1D=S1(XJ,RE)
      CH2D=0.
      DO 10 J=1,NSP
   10 CH2D=CH2D+DALP(J,K)*CP(J,K)
      BQ1=BQ2=BQ(K)
      C1=C2=CPX(K)
      DB1=DB2=DBQ(K)
```

```
      PX1=PX2=DCPX(K)
      CH1=CH2=CH2D
      S2D=S2(XJ,RE)
      S3DT=0.
      DO 20 J=1,NSP
      AL1=AL2=DALP(J,K)
      DD1=DD2=DDALP(J,K)
      S3D(J)=S3(XJ,RE)
   20 S3DT=S3DT+S3D(J)/WTMOLE(J)
      PK=1./P(K)
      SH1=S1D/GAM(K)*PK/EM(K)**2
      QK=1./Q(K)
      SH2=-(GAM(K)-1.)*S2D/GAM(K)*PK*QK
      SH3=-W(K)*S3DT/RHO(K)*QK
      IF(XJ.EQ.0) SH4=0.
      IF(XJ.EQ.0) GO TO 40
      IF(K.NE.1.OR.Y(K).GT.1.E-6) GO TO 30
      SH4=TH(2)/Y(2)
      GO TO 40
   30 SH4=SIN(TH(K))/Y(K)
   40 CONTINUE
      OD=1./DELX
      SH5=-DTCH(K)/T(K)*OD*COS(TH(K))
      DUM=0.
      DO 50 J=1,NSP
   50 DUM=DUM+DACH(J,K)/WTMOLE(J)
      SH6=-W(K)*DUM/DELX*COS(TH(K))
      SH=SH1+SH2+SH3+SH4+SH5+SH6
      ASHEAR=-GAM(K)*P(K)*EM(K)**2*SH
      RETURN
      END
      SUBROUTINE PRESS(X,P,TH,THN)
      COMMON/AC/IBOD,PIN
      COMMON/WX/APRESS,APRESU
      COMMON/YX/ABODS,BPRESS,CPRESS
      P=APRESS+X*(BPRESS+CPRESS*X)
      P=P*PIN
      THN=TH
      RETURN
      END
      FUNCTION XVIS(A,IVV,IDUM)
      COMMON/DB/BETB(20),IS(20),IDI,IJENK,JENKI
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/GE/P3(3),VISINF
      COMMON/PQ/P33(2),T(55)
      COMMON/TW/TIN
      IDD=IVV
```

```
      U1=Q(IDUM)+.95*(Q(IDD)-Q(IDUM))
      U2=Q(IDUM)+.5*(Q(IDD)-Q(IDUM))
      IF(ABS(Q(IDD)-Q(IDUM))/Q(IDD).GT..15) GO TO 13
      TD=TIN*T(IDD)*1.8
      XXVIS=1./(VISINF*RE*RHO(IDD))
      XVIS=2.27E-8*(SQRT(TD**3)/(TD+198.6))*XXVIS
      RETURN
   13 DO 10 I=IDD,IDUM
      IF(U1.LT.Q(I))GO TO 10
      Y1=(Q(I-1)-U1)/(Q(I-1)-Q(I))*ABS(Y(I-1)-Y(I))+Y(I-1)
      GO TO 8
   10 CONTINUE
    8 DO 9I=IDD,IDUM
      IF(U2.LT.Q(I))GO TO 9
      Y2=(Q(I-1)-U2)/(Q(I-1)-Q(I))*ABS(Y(I-1)-Y(I))+Y(I-1)
      GO TO 7
    9 CONTINUE
    7 Z=Y2-Y1
      XVIS=ABS(.010*Z*Q(IDD))
      RETURN
      END
      SUBROUTINE COWL
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/DE/MM
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/HJ/KOUNT,LZ,NPT
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     ILS,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/HP/BETAN(20),IEMBED
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55),PTZERO,IDIVERG,TH1,XE,YE,RCR,PTOJ,TOJ
     1,EM1,XMU1,Q1
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/RC/R(55)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      ALPHA=1.
      BETA=0.
      NPTSSS=NPT
      NPT=NPT-3
      IF(P(NPT+MM)-P(NPT)) 2001,2002,2003
 2002 WRITE(6,9191)
 9191 FORMAT(1H1)
      WRITE(6,2004)
 2004 FORMAT(1H1,67H ERROR IN INPUT DATA - NO PRESSURE DIFFERENCE ACROSS
```

```
    1 SPLITTER PLATE/23H SET INPUT - INTACT = 0)
      STOP
2003  OPT=1.
      K=4
      IS(K)=NPTSSS-1
      L=IS(K)
      M=L+MM
      GO TO 2005
2001  OPT=-1.
      K=3
      IS(K)=NPT+MM
      M=NPT
      L=M+MM
2005  IFAN=MM-2
      KOPT=OPT*1.5
      N13=NPTSSS-2*KOPT
      IF((K/2)*2.EQ.K) N13=NPTSSS
      DO 300 N12=N13,NPTS
      K5=NPTS+N13-N12
      J5=K5+1
      CALL SWITCH(J5,K5)
  300 CONTINUE
      NPTS=NPTS+1
      DO 301 I11=1,IDD
      IF(I11.EQ.K) GO TO 301
      IF(IS(I11).GT.N13) IS(I11)=IS(I11)+1
  301 CONTINUE
      LL=L+KOPT
      TAU(LL)=0.
      PN(L)=P(L)
      THN(L)=TH(L)
      Q  N(L)=Q  (L)
      T  N(L)=T  (L)
      R  N(L)=R  (L)
      RHON(L)=RHO(L)
      GAMN(L)=GAM(L)
      BQ(LL)=0.
      DCPX(LL)=0.
      DTAU(LL)=0.
      DBQ(LL)=0.
      CPX(LL)=0.
      WN(L)=W(L)
      DO 2006 J=1,NSP
      HN(J,L)=H(J,L)
      DALP(J,LL)=0.
      DDALP(J,LL)=0.
2006  ALPN(J,L)=ALP(J,L)
      ITT=1
      BETB(K)=(TH(L)-OPT*XMU(L))*1.01
```

```
      BET=BETB(K)
 2007 IEMBED=1
      CALL HSHOCK(K)
      IEMBED=0
      KK=LL+KOPT
      P  (LL)=P  N(LL)
      Q  (LL)=Q  N(LL)
      T  (LL)=T  N(LL)
      W  (LL)=W  N(LL)
      R  (LL)=R  N(LL)
      TH (LL)=TH N(LL)
      EM (LL)=EM N(LL)
      XMU(LL)=XMUN(LL)
      GAM(LL)=GAMN(LL)
      RHO(LL)=RHON(LL)
      CPX(LL)=CPXN(LL)
      P  (KK)=P  N(LL)
      Q  (KK)=Q  N(LL)
      T  (KK)=T  N(LL)
      W  (KK)=W  N(LL)
      R  (KK)=R  N(LL)
      TH (KK)=TH N(LL)
      EM (KK)=EM N(LL)
      XMU(KK)=XMUN(LL)
      GAM(KK)=GAMN(LL)
      RHO(KK)=RHON(LL)
      CPX(KK)=CPXN(LL)
      DO 2008 J=1,NSP
      H  (J,LL)=H  N(J,LL)
      CP (J,LL)=CP N(J,LL)
      ALP(J,LL)=ALPN(J,LL)
      H  (J,KK)=H  N(J,LL)
      CP (J,KK)=CP N(J,LL)
 2008 ALP(J,KK)=ALPN(J,LL)
      X(LL)=X(L)
      X(KK)=X(L)
      THS=TH(KK)
      CALL PM(M,OPT)
      THPM=TH1
      ERR=THS-THPM
      IF(ABS(ERR).LT.1.E-04) GO TO 15
      ITT=ITT+1
      IF(ITT.GT.15) GO TO 102
      IF(ITT.GT.2) GO TO 14
      ER1=ERR
      BET1=BET
      BET=1.01*BET
      BETB(K)=BET
      GO TO 2007
```

```
102 WRITE(6,203)
203 FORMAT(* ERROR IN BETA SHOCK IN COWL*)
    STOP
 14 DUM1=BET1-ER1*(BET-BET1)/(ERR-ER1)
    ER1=ERR
    BET1=BET
    BET=DUM1
    BETB(K)=BET
    GO TO 2007
 15 CONTINUE
    EM(5)=EM1
    ANG=TH(5)
    TH(5)=TH1
    Q(5)=Q1
    XMU(5)=XMU1
    P(5)=P(7)
    Y(5)=1.-X(5)*TAN(XMU(5)-TH(5))
    Y(4)=1.-X(4)*TAN(XMU(2)-ANG)
    TH(4)=ATAN(Y(4)/(XE+X(4)))
    NPT=NPTSSS
    RETURN
    END
    SUBROUTINE DPOINT(K,L)
    COMMON/AL/GAR,GEW
    COMMON/BA/ALP(7,55),EMINF,WINF
    COMMON/CJ/CP(7,55),CP1(7),CPX(55)
    COMMON/CK/WTMOLE(7)
    COMMON/DP/YN(55)
    COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
    COMMON/EP/GAMINF,H1(7),RINF
    COMMON/GK/DELX
    COMMON/PD/W(55),X(55)
    COMMON/PQ/JCHEM,NSP,T(55)
    COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
    COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
    COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
   1TAU(55)
    COMMON/TV/ALPP(7,2),BET,BQP(2),DACHP(7,2),DALPP(7,2),DBQP(2),
   1DCPXP(2),DDALPP(7,2),DTAUP(2),DTCHP(2),GAMP(2),PP(2),QP(2),
   2TAUP(2),THP(2),TP(2),YP(2)
    COMMON/VT/DACH(7,55),DTCH(55)
    IT=1
    YD=(YP(1)+YP(2))/2.
 16 RAT=(YD-YP(1))/(YP(2)-YP(1))
    ALAMD=TAN(THP(1))+RAT*(TAN(THP(2))-TAN(THP(1)))
    YAT=YN(L)-ALAMD*DELX
    ERR=ABS((YAT-YD)/(YP(2)-YP(1)))
    IF(ERR.LT.1.E-05) GO TO 18
    YD=YAT
```

```
      IT=IT+1
      IF(IT.LE.10) GO TO 16
      WRITE(6,9191)
 9191 FORMAT(1H1)
      WRITE(6,202)
  202 FORMAT(* ERROR IN D POINT ITERATION*)
      STOP
   18 Y(K)=YD
      P    (K)=P    P(1)+RAT*(P    P(2)-P    P(1))
      Q    (K)=Q    P(1)+RAT*(Q    P(2)-Q    P(1))
      T    (K)=T    P(1)+RAT*(T    P(2)-T    P(1))
      TH   (K)=TH   P(1)+RAT*(TH   P(2)-TH   P(1))
      DVIS(K)=DVISP(1)+RAT*(DVISP(2)-DVISP(1))
      VIS(K)=VISP(1)+RAT*(VISP(2)-VISP(1))
      BQ   (K)=BQ   P(1)+RAT*(BQ   P(2)-BQ   P(1))
      TAU  (K)=TAU  P(1)+RAT*(TAU  P(2)-TAU  P(1))
      DBQ  (K)=DBQ  P(1)+RAT*(DBQ  P(2)-DBQ  P(1))
      DCPX(K)=DCPXP(1)+RAT*(DCPXP(2)-DCPXP(1))
      DTAU(K)=DTAUP(1)+RAT*(DTAUP(2)-DTAUP(1))
      DTCH(K)=DTCHP(1)+RAT*(DTCHP(2)-DTCHP(1))
      CPX(K)=0.
      W(K)=0.
      CALL THERMO(T(K),H1,CP1)
      DO 1 J=1,NSP
      H (J,K)=H 1(J)
      CP(J,K)=CP1(J)
      ALP  (J,K)=ALP  P(J,1)+RAT*(ALP  P(J,2)-ALP  P(J,1))
      DALP (J,K)=DALP P(J,1)+RAT*(DALP P(J,2)-DALP P(J,1))
      DACH(J,K)=DACHP(J,1)+RAT*(DACHP(J,2)-DACHP(J,1))
      DDALP(J,K)=DDALPP(J,1)+RAT*(DDALPP(J,2)-DDALPP(J,1))
      CPX(K)=CPX(K)+ALP(J,K)*CP(J,K)
    1 W(K)=W(K)+ALP(J,K)/WTMOLE(J)
      W(K)=1./W(K)
      RHO(K)=P(K)*W(K)*GEW/T(K)
      RETURN
      END
      SUBROUTINE STEP
      COMMON/AC/IBOD,PIN
      COMMON/AX/JSUBL,JSUBU
      COMMON/CA/WDOTN(7,55),XN(55)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/DP/YN(55)
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EG/EIN,PR,XLE
      COMMON/GE/RAD,ROO,UIN,VISINF
      COMMON/GK/DELX
      COMMON/HJ/KOUNT,LL,NPT
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     ILS,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
```

```
      COMMON/OR/THBP,YBP,YBPN
      COMMON/PQ/JCHEM,NSP,T(55),PTZERO,IDIVERG,TH1,XE,YE,RCR,PTOJ,TOJ
     1,EM1,XMU1,Q1
      COMMON/PD/W(55),X(55)
      COMMON/WAVE/XBOD(5),XWALL(5),AABOD(5),BBBOD(5),CCBOD(5),EEBOD(5),
     ZFFBOD(5),GGBOD(5),LWALL,LBOD
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/ST/I13,IREGI,KS,KFIRST,KKKQ,PSTAR
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/UV/I111,IERR,IPRESS,IPRESU,ISUB
      COMMON/VW/ICONT,IEND,KT,THBPN,XBPN
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/WX/APRESS,APRESU
      COMMON/YZ/BPRESU,CHEMFC,CPRESU,EMSUB,RTH,XSTEP
      DIMENSION DELLX(55),XW(2),YW(2),THW(2)
      DIMENSION DELV(55)
      DATA I13/0/
      DATA IREGI/0/
      ISPP=0
      ISPA=0
      NSAVE=2
      XW(1)=0.
      XW(2)=10000.
      YW(1)=10000.
      YW(2)=10000.
      THW(1)=0.
      THW(2)=0.
      ISUB=0
      JSUBL=NPTS+1
      JSUBU=NPTS+1
      DO 910 I=1,NPTS
      IF(EM(I).GT.EMSUB) GO TO 910
      JSUBL=1
      ISUB=1
      GO TO 800
  910 CONTINUE
      GO TO 801
  800 CONTINUE
      DO 802 I=1,NPTS
      II=NPTS-I+1
      IF(EM(II).GT.EMSUB) GO TO 802
      JSUBU=II+1
      GO TO 801
  802 CONTINUE
  801 CONTINUE
      IF(ISUB.EQ.0) GO TO 10
      I13=1
      KFIRST=KOUNT
   10 CONTINUE
```

```
      JDUM=JSUBU-1
      NP2=NPTS-1
      DO 499 K=1,NP2
      DEY=Y(K+1)-Y(K)
      IF(DEY.LT.1.E-08) GO TO 498
      IF(K.GE.JSUBL.AND.K.LE.JDUM) GO TO 498
      EM1=XM1(1.,0.,TH(K),XMU(K),0.,0.)
      EM2=XM2(1.,0.,TH(K+1),XMU(K+1),0.,0.)
      DELLX(K)=(Y(K+1)-Y(K))/(EM1-EM2)
      DO 776 J=1,IDD
      JJ= (J/2)*2
      IF(K.EQ.IS(J).AND.JJ.NE.J) DELLX(K)=DELLX(K-1)
      IF(K.EQ.IS(J).AND.JJ.EQ.J) DELLX(K-1)=DELLX(K-2)
  776 CONTINUE
      GO TO 499
  498 DELLX(K)=1.E+06
  499 CONTINUE
      DELXM=DELLX(1)
      DO 501 K=2,NP2
      IF(DELLX(K).LT.DELXM)DELXM=DELLX(K)
  501 CONTINUE
      DCHAR=DELXM
  775 DO 502 K=1,NPTS
      IF(XLE.EQ.0..OR.VIS(K).EQ.0.)GO TO 49
      RXLE=1./XLE
      DELV(K)=.50*PR*RE/VIS(K)*RXLE
      GO TO 50
   49 DELV(K)=1.E10
   50 DELV1=1.E10
      IF(K.NE.1) DELY=Y(K)-Y(K-1)
      IF(K.NE.NPTS) DELYY=Y(K+1)-Y(K)
      IF(K.EQ.1) DELY=DELYY
      IF(K.EQ.NPTS) DELYY=DELY
      IF(DELYY.LT.DELY) DELY=DELYY
      IF(DELY.LT.1.E-08) GO TO 502
      DELV1=DELV(K)*RHO(K)*Q(K)*DELY**2*COS(TH(K))
  502 DELLX(K)=DELV1
      DELXM=DELLX(1)
      DO 504 K=2,NPTS
  504 IF(DELLX(K).LT.DELXM)DELXM=DELLX(K)
      DSHEAR=DELXM
      DELX=1./(1./DCHAR+1./DSHEAR)
      DELX=DELX/XSTEP
      IF(ISPA.EQ.1) GO TO 4
      ISPA=1
      CALL SPACE(ISPP)
      IF(III1.EQ.1) RETURN
      IF(ISPP.EQ.1) GO TO 10
    4 CONTINUE
```

```
      IF(X(1)+DELX.GT.XWALL(LWALL)) DELX=XWALL(LWALL)-X(1)
      IF(X(1)+DELX.GT.XBOD(LBOD)) DELX=XBOD(LBOD)-X(1)
      IF(JCHEM.EQ.0) GO TO 4275
      DO 505 I=1,NPTS
      DTEST=Q(I)*UIN*4.E-7/RTH
      DTEST=CHEMFC*DTEST
  505 IF(DELX.GT.DTEST) DELX=DTEST
 4275 CONTINUE
      IF(I13.NE.1.OR.KOUNT.NE.KFIRST) GO TO 4545
      KKKQ=KOUNT+20
 4545 CONTINUE
      IF(EM(JSUBU).LT.1.05) KKKQ=KOUNT+1
      XWT=XBP+DELX
      RA=1./RAD
      IF(XWT.LT.XW(1)) GO TO 741
      IF(XWT.LE.XW(NSAVE)) GO TO 5209
      THBPN=0.
      XBPN=XW(NSAVE)
      YBPN=YW(NSAVE)
      II11=1
      GO TO 5210
 5209 CALL TBL(XWT,THBPN,XW,THW,NSAVE)
      GO TO 5204
  741 THBPN=THBP+DELX/COS(THBP)*RA
 5204 DELX=DELX/COS(THBP)*(COS(THBP)+COS(THBPN))/2.
      XBPN=XWT
      YBPN=YBP+(SIN(THBP)+SIN(THBPN))*.5*DELX/COS(THBP)
 5210 CONTINUE
      DO 5211 I=1,NPTS
      XN(I)=XBPN
      YN(I)=Y(I)+TAN(TH(I))*DELX
 5211 THN(I)=TH(I)
      IF(IBOD.EQ.1) CALL BODY(XN(1),YN(1),THN(1),0)
      IF(IPRESS.EQ.1) CALL PRESS(XN(1),PN(1),TH(1),THN(1))
      IF(IPRESU.EQ.1) PN(NPTS)=PIN*(APRESU+XN(NPTS)*(BPRESU+CPRESU*
     1XN(NPTS)))
      IF(IPRESU.EQ.1) RETURN
      IF(Y(NPTS).EQ.YBP) GO TO 6211
      CALL BODY(XWT,YN(NPTS),THN(NPTS),1)
      XN(NPTS)=XWT
      RETURN
 6211 XN(NPTS)=XBPN
      YN(NPTS)=YBPN
      THN(NPTS)=THBPN
      RETURN
      END
      SUBROUTINE SSONIC(IDG)
      COMMON/AC/IBOD,PIN
      COMMON/AX/JSUBL,JSUBU
```

```
      COMMON/BD/XMASS(55)
      COMMON/CG/AUP,BUP,CUP,DTSPRI(55),DUP,EUP,JCONV,THPRI(55),YPRI(55)
      COMMON/DP/YN(55)
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/GK/DELX
      COMMON/HJ/KOUNT,LL,NPT
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     IL,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/RO/APO,AP1,AP2
      COMMON/ST/I13,IREGI,K ,KFIRST,KKKQ,PSTAR
      COMMON/UV/II11,IERR,IPRESS,IPRESU,ISUB
      COMMON/VW/ICONT,IEND,KT,THBPN,XBPN
      COMMON/WV/NPTS,RE,XBP,XJ
      DIMENSION EZ(2),ERET(2),ERTHL(2)
      DATA LKIP/1/,LME/1/,LICQ/0/,LICK/0/,L1JUMP/0/
      DATA DTHQ/0./
      IF(I13.NE.1.OR.KOUNT.NE.KFIRST) GO TO 1777
      XKF=XBP
      CALL DPDTH(THSBOT,JSUBL)
      ATHB=Y(JSUBL)
      BTHB=TAN(TH(JSUBL))
      IF(IREGI.EQ.0)CTHB=THSBOT/COS(TH(JSUBL))**3
      IF(IREGI.NE.0)CTHB=(CTHB+DTHB*XDEL)
      DTHB=DTHQ
      XMKF=XMASS(JSUBU)
1777  CONTINUE
      K=JSUBU
      DQ=XBPN-XKF
      DS=1./6.
      DQ=1./24.
      YN(K)=AUP+BUP*DQ+CUP*DQ**2*.5+DUP*DQ**3*DS+EUP*DQ**4*DQ
      THN(K)=ATAN(BUP+CUP*DQ+DUP*DQ**2*.5+EUP*DQ**3*DS)
      DS=2.*DELX/(COS(TH(K))+COS(THN(K)))
      THGH=THN(K)
      YGH=YN(K)
      IBOD1=IBOD
      IBOD=1
      IPRES1=IPRESS
      IPRESS=0
      IPRE U1=IPRESU
      IPRESU=0
      ALSV=ALPHA
      BESV=BETA
      CALL LPOINT(JSUBU,0.)
      K=JSUBU
      THN(K)=THGH
      YN(K)=YGH
      ALPHA=.5
```

```
      BETA=.5
      CALL LPOINT(JSUBU,0.)
      ALPHA=ALSV
      BETA=BESV
      K=JSUBU
      THN(K)=THGH
      YN(K)=YGH
      IBOD=IBOD1
      IPRESS=IPRES1
      IPRESU=IPREU1
      DS=2.*DELX/(COS(TH(K))+COS(THN(K)))
      PSA=(PN(K)-P(K))/DS
      THSA=(CUP+DUP*DQ+EUP*DQ**2*.5)*COS(THN(K))**3
      PNA=-GAMN(K)*PN(K)*EMN(K)**2*THSA
      PYU=COS(THN(K))*PNA+SIN(THN(K))*PSA
      K=JSUBL
      DQ=XBPN-XKF
      YN(K)=ATHB+BTHB*DQ+CTHB*DQ**2*.5+DTHB*DQ**3*OS
      THN(K)=ATAN(BTHB+CTHB*DQ+DTHB*DQ**2*.5)
      THSB=(CTHB+DTHB*DQ)*COS(THN(K))**3
      DS=2.*DELX/(COS(TH(K))+COS(THN(K)))
      PYB=AP1
      ITE1=1
      IET=0
1790  AP2=(PYU-PYB)*.5/(YN(JSUBU)-YN(K))
      APO=PN(JSUBU)-.5*(PYB+PYU)*(YN(JSUBU)-YN(K))
      AP1=PYB
      PN(K)=APO
      ICONT=1
      IEND=0
      KP=K
      L=K
      KT=K
      PSTAR=PN(K)
      YGH=YN(K)
      THGH=THN(K)
      CALL CPOINT
      YN(K)=YGH
      THN(K)=THGH
      PNB=-GAMN(K)*PN(K)*EMN(K)**2*THSB
      PYB2=COS(THN(K))*PNB
      ET=PYB-PYB2
      IF(ABS(ET).LT.1.E-06) GO TO 1789
      IET=IET+1
      IF(IET.LT.20) GO TO 6532
      WRITE(6,6533)
6533  FORMAT(* ET LOOP IN SSONIC*)
      STOP
6532  CONTINUE
```

```
      ERET(ITE1)=ET
      IF(ITE1.GT.1) GO TO 358
      ITE1=2
      PYB1=PYB
      PYB=PYB2
      GO TO 1790
  358 PYBD=PYB1-ERET(1)*(PYB-PYB1)/(ERET(2)-ERET(1))
      PYB1=PYB
      ERET(1)=ERET(2)
      PYB=PYBD
      GO TO 1790
 1789 CONTINUE
      ICONT=1
      IEND=0
      JSUBL1=JSUBL+1
      JSUBU1=JSUBU-1
      DO 1734 KK=JSUBL1,JSUBU1
      K=JSUBU-KK+1
      THN(K)=TH(K)
      YN(K)=TAN(TH(K))*DELX+Y(K)
      PN(K)=AP0+AP1*(YN(K)-YN(JSUBL))+AP2    *(YN(K)-YN(JSUBL))**2
      KIP=1
      ME=1
      KP=K
      L=K
      KT=K
      PSTAR=PN(K)
      DS=2.*DELX/(COS(TH(K))+COS(THN(K)))
      YN(K)=Y(K)+.5*(TAN(TH(K))+TAN(THN(K)))*DELX
      YGH=YN(K)
      THGH=THN(K)
      CALL CPOINT
      YN(K)=YGH
      THN(K)=THGH
      YN(K)=Y(K)+.5*(TAN(TH(K))+TAN(THN(K)))*DELX
      KP=K+1
      TERM=(RHON(K)*QN(K)*COS(THN(K))+RHON(KP)*QN(KP)*COS(THN(KP)))/2.
      XMDUM=XMASS(KP)+TERM*(YN(K)**(1.+XJ)-YN(KP)**(1.+XJ))/(1.+XJ)
      Q1J=1.+XJ
      YN(K)=(YN(KP)**Q1J+Q1J*(XMASS(K)-XMASS(KP))/TERM)**(1./Q1J)
 1734 CONTINUE
      IF(KOUNT.NE.KKKQ-1) RETURN
      XMDIFF=XMKF-XMASS(JSUBU)
      JK=JSUBL+1
      DO 347 I=JK,JSUBU
  347 XMASS(I)=XMASS(I)+XMDIFF
      JSU1=JSUBU-1
      WRITE(6,1418)
 1418 FORMAT(10X,*CORRECTED INTERMEDIATE STREAMLINES*/2X,*STREAMLINE NO.
```

```
     1*,7X,*X*,12X,*Y*,11X,*TH*)
      DO 386 KK=1,JSU1
      K=JSUBU-KK
      KIP=1
      ME=1
      DTERM=0.
      DYDX=TAN(THPRI(K))
      D2YDX2=DTSPRI(K)/COS(THPRI(K))**3*.5
      IF(K.EQ.1)D2YDX2= CTHB*.5
      XDEL=XBPN-XKF
6030  YSTAR=YPRI(K)+DYDX*XDEL+D2YDX2*XDEL**2+DTERM*XDEL**3*OS
      THSTAR=ATAN(DYDX+2.*D2YDX2*XDEL+DTERM*XDEL**2*.5)
      KP=K+1
      TERM=(RHON(KP)*QN(KP)*COS(THN(KP))+RHON(K)*QN(K)*COS(THSTAR))/2.
      X1J=1.+XJ
      XMDUM=XMASS(KP)+TERM*(YSTAR**X1J-YN(KP)**X1J)/X1J
      EZ(ME)=XMDUM-XMASS(K)
      IF(ABS(EZ(ME)).LT.1.E-06                ) GO TO 6034
      KIP=KIP+1
      GO TO (6041,6042),ME
6041  ME=2
      DTERM1=DTERM
      DTERM=-.01/XDEL**2
      GO TO 6030
6042  DTERMD=DTERM1-EZ(1)*(DTERM-DTERM1)/(EZ(2)-EZ(1))
      DTERM1=DTERM
      DTERM=DTERMD
      EZ(1)=EZ(2)
      IF(KIP.LE.20) GO TO 6030
      WRITE(6,6081)
6081  FORMAT(* TOO MANY ITERATIONS FOR ONE POINT IN SSONIC*)
      STOP
6034  IF(K.EQ.1) GO TO 6036
      YN(K)=YSTAR
      THN(K)=THSTAR
      XDEL1=XDEL/4.
      DO 1417 I=1,4
      XDE=XDEL1*FLOAT(I)
      XPRNT=XKF+XDE
      YPRNT=YPRI(K)+DYDX*XDE+D2YDX2*XDE**2+DTERM*XDE**3*OS
      THPRNT=ATAN(DYDX+2.*D2YDX2*XDE+DTERM*XDE**2*.5)
      WRITE(6,1419) K,XPRNT,YPRNT,THPRNT
1419  FORMAT(5X,I5,5X,3E13.5)
1417  CONTINUE
      GO TO 386
6036  ERTH=THSTAR-THN(JSUBL)
      JCONV=0
      I13=2
      ERTHL(LME)=ERTH
```

```
      IF(LIJUMP.EQ.1) GO TO 2501
      IF(ABS(ERTHL(LME)).LT..001) GO TO 2501
      LKIP=LKIP+1
      GO TO (2502,2503),LME
 2502 LME=2
      DTHB2=DTHB
      DTHQ=DTHB-.05
      GO TO 2504
 2503 IF(LICQ.EQ.1) GO TO 2505
      IF(ERTHL(1)*ERTHL(2).LT.0.) GO TO 2505
      IF(LICK.EQ.1) GO TO 2506
      LICK=1
      RTHL=-.5
      IF(ABS(ERTHL(2)).GT.ABS(ERTHL(1))) RTHL=-RTHL
 2506 IF(ABS(ERTHL(2)).GT.ABS(ERTHL(1)).AND.LKIP.GE.4) GO TO 2507
      DTHB1=DTHB2
      DTHB2=DTHB
      DTHQ=DTHB+RTHL
 2509 ERTHX=ERTHL(1)
      ERTHL(1)=ERTHL(2)
      IF(LKIP.LE.10) GO TO 2504
      WRITE(6,2508)
 2508 FORMAT(* TOO MANY ITERATIONS IN LOWER WALL LOOP IN SSONIC*)
      STOP
 2507 PMB=ERTHL(1)*DTHB**2-ERTHL(2)*DTHB2**2+ERTHL(2)*DTHB1**2-ERTHX*
     1DTHB**2+ERTHX*DTHB2**2-ERTHL(1)*DTHB1**2
      PMC=ERTHL(2)*DTHB2-ERTHL(1)*DTHB+ERTHX*DTHB-ERTHL(2)*DTHB1
     1+ERTHL(1)*DTHB1-ERTHX*DTHB2
      DTHQ=-PMB/(2.*PMC)
      LIJUMP=1
      GO TO 2504
 2505 LICQ=1
      DTHD=DTHB2-ERTHL(1)*(DTHB-DTHB2)/(ERTHL(2)-ERTHL(1))
      DTHB1=DTHB2
      DTHB2=DTHB
      DTHQ=DTHD
      GO TO 2509
 2501 JCONV=1
      I13=0
      LKIP=1
      LME=1
      LICQ=0
      LICK=0
      LIJUMP=0
      IREGI=1
      DTHQ=0.
 2504 IF(JCONV.EQ.0)DTHB=DTHQ
  386 CONTINUE
      RETURN
```

```
      END
      SUBROUTINE BODY(X1,Y,TH,ID)
      COMMON/AC/IBOD,PIN
      COMMON/XO/XOO
      COMMON/ZY/ABOD,BBOD,CBOD,EBOD,FBOD,GBOD,IAVE,IPUNCH,JBOD,KKKKK
      COMMON/WAVE/XBOD(5),XWALL(5),AABOD(5),BBBOD(5),CCBOD(5),EEBOD(5),
     ZFFBOD(5),GGBOD(5),LWALL,LBOD
      XB=XBOD(LBOD-1)
      IF((LBOD-1).EQ.0) XB=0.0
      X=X1-XB
      IF(ID.EQ.1) GO TO 4
      IF(IBOD.EQ.0) GO TO 1
      X=X1-XB-XOO
      Y=ABOD+X*(BBOD+X*CBOD)
      TH=ATAN(BBOD+2.*CBOD*X)
      GO TO 2
    1 Y=0.
      TH=0.
      GO TO 2
    4 XB=XWALL(LWALL-1)
      IF((LWALL-1).EQ.0) XB=0.0
      X=X1-XB
      Y=EBOD + X*(FBOD + X*GBOD)
      TH=ATAN(FBOD+2.*GBOD*X)
    2 RETURN
      END
      SUBROUTINE DPDTH(DTDS,I)
      COMMON/AX/JSUBL,JSUBU
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/RO/APO,AP1,AP2
      CALL SHEAR(I,ASHEAR)
      ASH=ASHEAR
      PY=AP1+2.*AP2*(Y(I)-Y(JSUBL))
      D2=Y(I+1)-Y(I)
      D1=Y(I)-Y(I-1)
      SUM=D1+D2
      RAT1=D1/D2
      RAT2=D2/D1
      IF(I.GT.JSUBU) PY=(P(I+1)*RAT1-P(I)*(RAT1-RAT2)-P(I-1)*RAT2)/SUM
      THY=(TH(I+1)*RAT1-TH(I)*(RAT1-RAT2)-TH(I-1)*RAT2)/SUM
      DPDS    =(ASH*COS(TH(I))**2-GAM(I)*P(I)*EM(I)**2*COS(TH(I))*THY
     1-SIN(TH(I))*PY)/(EM(I)**2*COS(TH(I))**2-1.)
      DPDN=PY/COS(TH(I))-TAN(TH(I))*DPDS
      GS=1./GAM(I)
      SM=1./EM(I)**2
      DTDS=-DPDN*GS/P(I)*SM
      RETURN
      END
      SUBROUTINE CPOINT
```

```
      COMMON/AL/GAR,GEW
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/BO/GAMB,PB,QB,RHOB,THB,WB,XMUB,YB
      COMMON/CA/WDOTN(7,55),XN(55)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/CK/WTMOLE(7)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/DP/YN(55)
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EG/EIN,PR,XLE
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/GF/DELY,IFS,KOUNTO,MMM
      COMMON/GK/DELX
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     IL,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/HN/CHC(2),CPB(7),CPXP(2),DALDIF(7),DALPB(7),DDALPB(7),DELS,
     AEMP(2),HB(7),HC(7),RP(2),S3A(7),S3B(7),S3D(7),WDOTB(7),XP(2)
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/QS/RHOP(2),WDOT(7,55),WDOTC(7),WP(2),XMUP(2)
      COMMON/SQ/BQN(55),DALPN(7,55),DBQN(55),DCPXN(55),DDALPN(7,55),
     1DTAUN(55),TAUN(55)
      COMMON/SS/AL1,AL2,BQ1,BQ2,C1,C2,CH1,CH2,DB1,DB2,DD1,DD2,DT1,DT2,DV
     A1,DV2,PX1,PX2,TA1,TA2,TH1,TH2,V1,V2,Y1,Y2
      COMMON/ST/I13,IREGI,K ,KFIRST,KKKQ,PSTAR
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      COMMON/TV/ALPP(7,2),BET,BQP(2),DACHP(7,2),DALPP(7,2),DBQP(2),
     1DCPXP(2),DDALPP(7,2),DTAUP(2),DTCHP(2),GAMP(2),PP(2),QP(2),
     2TAUP(2),THP(2),TP(2),YP(2)
      COMMON/VT/DACH(7,55),DTCH(55)
      COMMON/VW/ICONT,IEND,KT,THBPN,XBPN
      COMMON/WV/NPTS,RE,XBP,XJ
      DIMENSION ALPSS(7),DALPSS(7),DDALPS(7),HSS(7),CPSS(7)
      DIMENSION DUMCHP(7),DACHSS(7)
      IF(IEND.EQ.1) GO TO 601
      EM3=XM3(ALPHA,BETA,TH(K),THN(L))
      XN(L)=XBPN
      IF(IFS.EQ.1.AND.L.EQ.IS(MMM)) EM3=TAN(BETB(MMM))
      IF(IFS.EQ.2.AND.L.EQ.IS(MMM)) EM3=.5*(TAN(BETB(MMM))+TAN(BET))
      YN(L)=Y(K)+DELX*EM3
      IF(ICONT.EQ.1) GO TO 601
      KP=1
      EM2P=XM1(ALPHA,BETA,TH(KT+1),XMU(KT+1),THN(L),XMUN(L))
      EM2L=XM1(ALPHA,BETA,TH(KT),XMU(KT),THN(L),XMUN(L))
```

```
 351 EM2K=0.5*(EM2L+EM2P)
     XP(KP)=XBP
     YP(KP)=YN(L)-DELX*EM2K
     IF(KP.EQ.1.AND.IS(MMM).EQ.K.AND.((MMM/2)*2.EQ.MMM))
    AYP(KP)=Y(KT)+2.E-4
     KIP2=0
     IF(YP(KP).LT.Y(KT+1)+1.E-05.AND.YP(KP).GT.Y(KT)-1.E-05) GO TO 201
4150 FORMAT(3I5,6E13.5)
     WRITE(6,9191)
     WRITE(6,4150) KP    ,L,KT,ALPHA,YP(KP),YN(L),THN(L),XMUN(L),PN(L)
     WRITE(6,111) Y(KT),Y(K),DELX,EM2K,XBPN,TH(K),XMU(KT),XMU(KT+1),
    1DELS,THBPN,DELY,Y(KT+1)
     WRITE(6,2000)
2000 FORMAT(97H Y LOCATION OF CHARACTERISTIC ON ORIGIONAL DATA LINE IS
    1OUTSIDE OF BOUNDING STREAMLINES IN CPOINT          )
     CALL PUNCH
     STOP
 201 RATB=(YP(KP)-Y(KT))/(Y(KT+1)-Y(KT))
     EM2=EM2L+RATB*(EM2P-EM2L)
     YBT=YP(KP)
     YP(KP)=YN(L)-DELX*EM2
     IF((ABS(YP(KP)-YBT)/ABS(Y(KT+1)-Y(KT))).LT.0.01)GO TO 202
     KIP2=KIP2+1
     IF(KIP2.LE.20) GO TO 201
     WRITE(6,9191)
9191 FORMAT(1H1)
     WRITE(6,2001)
2001 FORMAT(56H UNABLE TO LOCATE Y LOCATION OF CHARACTERISTIC IN CPOINT
    1)
     STOP
 202 RATB=(YP(KP) -Y(KT))/(Y(KT+1)-Y(KT))
     QP(KP)=Q(KT)+RATB*(Q(KT+1)-Q(KT))
     PP(KP)=P(KT)+RATB*(P(KT+1)-P(KT))
     TP(KP) =T(KT)+RATB*(T(KT+1)-T(KT))
     THP(KP)=TH(KT)+RATB*(TH(KT+1)-TH(KT))
     VISP(KP)=VIS(KT)+RATB*(VIS(KT+1)-VIS(KT))
     DVISP(KP)=DVIS(KT)+RATB*(DVIS(KT+1)-DVIS(KT))
     TAUP(KP)=TAU(KT)+RATB*(TAU(KT+1)-TAU(KT))
     BQP(KP)=BQ(KT)+RATB*(BQ(KT+1)-BQ(KT))
     DCPXP(KP)=DCPX(KT)+RATB*(DCPX(KT+1)-DCPX(KT))
     DTAUP(KP)=DTAU(KT)+RATB*(DTAU(KT+1)-DTAU(KT))
     DBQP(KP)=DBQ(KT)+RATB*(DBQ(KT+1)-DBQ(KT))
     DTCHP(KP)=DTCH(KT)+RATB*(DTCH(KT+1)-DTCH(KT))
     CPXP(KP)=0.0
     WP(KP)=0.0
     CHC(KP)=0.
     CALL THERMO(TP(KP),HB,CPB)
     DO 4020 J=1, NSP
     ALPP(J,KP)=ALP(J, KT)+RATB*(ALP(J, KT+1)-ALP(J, KT))
```

```
      DALPP(J,KP)=DALP(J, KT)+RATB*(DALP(J, KT+1)-DALP(J, KT))
      DDALPP(J,KP)=DDALP(J, KT)+RATB*(DDALP(J, KT+1)-DDALP(J, KT))
      CHC(KP)=CHC(KP)+DALPP(J,KP)*CPB(J)
      CPXP(KP)=CPXP(KP)+ALPP(J,KP)*CPB(J)
      WP(KP)=WP(KP)+ ALPP(J,KP)/WTMOLE(J)
      DACHP(J,KP)=DACH(J,KT)+RATB*(DACH(J,KT+1)-DACH(J,KT))
      IF(KP.NE.2)GO TO 4020
      WDOTB(J)=WDOT(J,KT)+RATB*(WDOT(J,KT+1)-WDOT(J,KT))
 4020 CONTINUE
      WP(KP)=1./WP(KP)
      RP(KP)=RO/WP(KP)
      GAMP(KP)=CPXP(KP)/(CPXP(KP)-RP(KP)/CPIN)
      RK=1./RP(KP)
      RHOP(KP)=PP(KP)*WP(KP)*GEW/TP(KP)
      EMP(KP)=QP(KP)*EMINF*SQRT(GAR/GAMP(KP)*RK/TP(KP))
      XMUP(KP)=ZMU(EMP(KP))
      IF(KP.EQ.2) GO TO 601
      KP=2
      IF(IFS.EQ.0) KT=L
      EM2P=XM2(ALPHA,BETA,TH(KT+1),XMU(KT+1),THN(L),XMUN(L))
      EM2L=XM2(ALPHA,BETA,TH(KT),XMU(KT),THN(L),XMUN(L))
      GO TO 351
C     GET ALL THE PROPERTIES AT THE C POINT
  601 CONTINUE
      IF(IFS.EQ.0) GO TO 8600
      Y    SS=Y    (K)
      P    SS=P    (K)
      Q    SS=Q    (K)
      T    SS=T    (K)
      TH   SS=TH   (K)
      BQ   SS=BQ   (K)
      W    SS=W    (K)
      TAU  SS=TAU  (K)
      RHO  SS=RHO  (K)
      CPX  SS=CPX  (K)
      DBQ  SS=DBQ  (K)
      DTAUSS=DTAU(K)
      DCPXSS=DCPX(K)
      DTCHSS=DTCH(K)
      DO 1555 J=1,NSP
      CPSS(J)=CP(J,K)
      HSS(J)=H(J,K)
      ALPSS(J)=ALP(J,K)
      DALPSS(J)=DALP(J,K)
      DACHSS(J)=DACH(J,K)
 1555 DDALPS(J)=DDALP(J,K)
      CALL DPOINT(K,L)
      KT=K
 8600 CONTINUE
```

```
      CH2D=0.0
      DO 4030 J=1, NSP
      CH2D=CH2D+DALP(J,K)*CP(J,K)
4030  CONTINUE
      IF(BETA.NE.0.0)GO TO 4036
      TAUN(L)=TAU(K)
      BQN(L)=BQ(K)
      VISN(L)=VIS(K)
      DVISN(L)=DVIS(K)
      DCPXN(L)=DCPX(K)
      DTAUN(L)=DTAU(K)
      DBQN(L)=DBQ(K)
      THN(L)=TH(K)
      CPXN(L)=CPX(K)
      TN(L)=T(K)+DTCH(K)
      WN(L)=W(K)
      CH2C=CH2D
      DO 4035 J=1, NSP
      DALPN(J,L)=DALP(J,K)
      DDALPN(J,L)=DDALP(J,K)
      HC(J)=H(J,K)
      WDOTC(J)=WDOTN(J,L)
4035  CONTINUE
4036  CONTINUE
      IF(BETA.EQ.0.0) GO TO 302
      CH2C=0.
      DO 301 J=1,NSP
      HC(J)=HN(J,K)
      WDOTC(J)=WDOTN(J,L)
 301  CH2C=CH2C+DALPN(J,L)*CPN(J,L)
 302  CONTINUE
      V1=VISP(1)
      V2=VISN(L)
      DV1=DVISP(1)
      DV2=DVISN(L)
      TA1=TAUP(1)
      TA2=TAUN(L)
      DT1=DTAUP(1)
      DT2=DTAUN(L)
      BQ1=BQP(1)
      BQ2=BQN(L)
      Y1=YP(1)
      Y2=YN(L)
      TH1=THP(1)
      TH2=THN(L)
      C1=CPXP(1)
      C2=CPXN(L)
      DB1=DBQP(1)
      DB2=DBQN(L)
```

```
      PX1=DCPXP(1)
      PX2=DCPXN(L)
      CH1=CHC(1)
      CH2=CH2C
      IF(ICONT.EQ.1) GO TO 4309
      S1A=S1(XJ,RE)
      S2A=S2(XJ,RE)
 4309 V1=VIS(K)
      DV1=DVIS(K)
      TA1=TAU(K)
      DT1=DTAU(K)
      BQ1=BQ(K)
      Y1=Y(K)
      TH1=TH(K)
      C1=CPX(K)
      DB1=DBQ(K)
      PX1=DCPX(K)
      CH1=CH2D
      S1D=S1(XJ,RE)
      S2D=S2(XJ,RE)
      IF(ICONT.EQ.1) GO TO 6427
      IF(L.EQ.NPTS) GO TO 6427
      V1=VISP(2)
      DV1=DVISP(2)
      TA1=TAUP(2)
      DT1=DTAUP(2)
      BQ1=BQP(2)
      Y1=YP(2)
      TH1=THP(2)
      C1=CPXP(2)
      DB1=DBQP(2)
      PX1=DCPXP(2)
      CH1=CHC(2)
      S1B=S1(XJ,RE)
      S2B=S2(XJ,RE)
 6427 CONTINUE
      S3AT=0.0
      S3BT=0.0
      S3DT=0.0
      DO 4040 J=1, NSP
      AL2=DALPN(J,L)
      DD2=DDALPN(J,L)
      IF(ICONT.EQ.1) GO TO 4311
      V1=VISP(1)
      DV1=DVISP(1)
      AL1=DALPP(J,1)
      DD1=DDALPP(J,1)
      BQ1=BQP(1)
      TH1=THP(1)
```

```
      Y1=YP(1)
      S3A(J)=S3(XJ,RE)
      S3AT=S3AT+S3A(J)/WTMOLE(J)
4311  AL1=DALP(J,KT)
      DD1=DDALP(J,KT)
      V1=VIS(K)
      DV1=DVIS(K)
      BQ1=BQ(KT)
      TH1=TH(KT)
      Y1=Y(KT)
      S3D(J)=S3(XJ,RE)
      S3DT=S3DT+S3D(J)/WTMOLE(J)
      IF(ICONT.EQ.1)GO TO 4040
      IF(L.EQ.NPTS)GO TO 4040
      V1=VISP(2)
      DV1=DVISP(2)
      AL1=DALPP(J,2)
      DD1=DDALPP(J,2)
      BQ1=BQP(2)
      TH1=THP(2)
      Y1=YP(2)
      S3B(J)=S3(XJ,RE)
      S3BT=S3BT+S3B(J)/WTMOLE(J)
4040  CONTINUE
      IF(ICONT.EQ.1) GO TO 6429
      GAMB=GAMP(1)
      PB=PP(1)
      QB=QP(1)
      RHOB=RHOP(1)
      THB=THP(1)
      WB=WP(1)
      XMUB=XMUP(1)
      YB=YP(1)
      A1=F1(L)
      A2=F2(L,S1A,S2A,S3AT)
      IF(JCHEM.EQ.1) GO TO 7252
      A3=0.
      GO TO 7255
7252  DO 1712 J=1,NSP
1712  DUMCHP(J)=(DACHP(J,1)+DACH(J,K))/2.
      DTCHP(1)=(DTCHP(1)+DTCH(K))/2.
      TP1=(T(L)+TP(1)+DTCH(L))/2.
      A3=F3(TP1,DTCHP(1),TP(1),TN(L),THP(1),THN(L),DUMCHP,WP(1),WN(L))
7255  A4=F4(BETA,1.,XMUP(1),THP(1),XMUN(L),THN(L))
      A2=(A2+A3)*A4
      IF(L.EQ.NPTS) GO TO 6429
      GAMB=GAMP(2)
      PB=PP(2)
      QB=QP(2)
```

```
      RHOB=RHOP(2)
      THB=THP(2)
      WB=WP(2)
      XMUB=XMUP(2)
      YB=YP(2)
      B1=F1(L)
      B2=F2(L,S1B,S2B,S3BT)
      IF(JCHEM.EQ.1) GO TO 7253
      B3=0.
      GO TO 7256
 7253 DO 1713 J=1,NSP
 1713 DUMCHP(J)=(DACHP(J,2)+DACH(J,K))/2.
      DTCHP(2)=(DTCHP(2)+DTCH(K))/2.
      TP2=(T(L)+TP(2)+DTCH(L))/2.
      B3=F3(TP2,DTCHP(2),TP(2),TN(L),THP(2),THN(L),DUMCHP,WP(2),WN(L))
 7256 B4=F4(BETA,-1.,XMUP(2),THP(2),XMUN(L),THN(L))
      B2=(B2+B3)*B4
 6429 CONTINUE
      IF(IEND.EQ.0) GO TO 630
      THN(L)=THBPN
      PN(L)=PP(1)+(THP(1)-THN(NPTS)-A2*(XN(NPTS)-XP(1)))/A1
      GO TO 631
  630 IF(ICONT.EQ.0)
     1PN(L)=(A1*PP(1)+B1*PP(2)+THP(1)-THP(2)-
     2(A2+B2)*XN(L)+A2*XP(1)+B2*XP(2))/(A1+B1)
      IF(ICONT.EQ.1)
     1PN(L)=PSTAR
      IF(ICONT.EQ.0)
     1THN(L)=THP(1)-A1*(PN(L)-PP(1))-A2*(XN(L)-XP(1))
  631 CONTINUE
      DELS=2.*(XN(L)-X(K))/(COS(TH(K))+COS(THN(L)))
      TERM2=RHO(K)*Q(K)
      IF(BETA.GT.0.)TERM2=(TERM2+RHON(L)*QN(L))*.5
      OT=1./TERM2
      QN(L)=(S1D*DELS-PN(L)+P(K))*OT+Q(K)
      IF(BETA.EQ.0.0)CPXN(L)=CPX(K)
      DTCHEM=DTCH(L)+(PN(L)-P(K))*(QN(L)+Q(K))/(CPX(K)+CPXN(L))*EIN*OT
      DTDIFF=S2D*DELS*EIN*2./(CPX(K)+CPXN(L))*OT
      TN(L)=T(K)+DTCHEM+DTDIFF
      CPXN(L)=0.0
      WN(L)=0.0
      CALL THERMO(TN(L),H1,CP1)
      DO 4050 J=1, NSP
      DALDIF(J)=S3D(J)*DELS*OT
      ALPN(J, L)=ALP(J,K)           +DALDIF(J)+DACH(J,L)
      HN(J,L)=H1(J)
      CPN(J,L)=CP1(J)
      WN(L)=WN(L)+ALPN(J, L)/WTMOLE(J)
      CPXN(L)=CPXN(L)+ALPN(J, L)*CPN(J, L)
```

```
4050 CONTINUE
     WN(L)=1./WN(L)
     RN(L)=RO/WN(L)
     GAMN(L)=CPXN(L)/(CPXN(L)-RN(L)/CPIN)
     ORN=1./RN(L)
     RHON(L)=PN(L)*WN(L)*GEW/TN(L)
     EMN(L)=QN(L)*EMINF*SQRT(GAR/GAMN(L)*ORN/TN(L))
     IF(EMN(L).LT.1.0001) GO TO 900
7360 XMUN(L)=ZMU(EMN(L))
 900 CONTINUE
     IF(IFS.EQ.0) GO TO 1361
     Y   (K)=Y   SS
     P   (K)=P   SS
     Q   (K)=Q   SS
     T   (K)=T   SS
     W   (K)=W   SS
     TH  (K)=TH  SS
     BQ  (K)=BQ  SS
     TAU (K)=TAU SS
     DBQ (K)=DBQ SS
     CPX (K)=CPX SS
     RHO (K)=RHO SS
     DCPX(K)=DCPXSS
     DTAU(K)=DTAUSS
     DTCH(K)=DTCHSS
     DO 1556 J=1,NSP
     ALP(J,K)=ALPSS(J)
     DALP(J,K)=DALPSS(J)
     DACH(J,K)=DACHSS(J)
     DDALP(J,K)=DDALPS(J)
     CP(J,K)=CPSS(J)
1556 H(J,K)=HSS(J)
1361 CONTINUE
 111 FORMAT(10X,9E13.5)
     RETURN
     END
     SUBROUTINE SPACE(ISPP)
     COMMON/AC/IBOD,PIN
     COMMON/AL/GAR,GEW
     COMMON/AX/JSUBL,JSUBU
     COMMON/BA/ALP(7,55),EMINF,WINF
     COMMON/BD/XMASS(55)
     COMMON/CA/WDOTN(7,55),XN(55)
     COMMON/CJ/CP(7,55),CP1(7),CPX(55)
     COMMON/CK/WTMOLE(7)
     COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
     COMMON/DP/YN(55)
     COMMON/ED/CPIN,RO
     COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
```

```
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/GK/DELX
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     IL,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/RC/R(55)
      COMMON/RO/APO,AP1,AP2
      COMMON/SQ/BQN(55),DALPN(7,55),DBQN(55),DCPXN(55),DDALPN(7,55),
     1DTAUN(55),TAUN(55)
      COMMON/ST/I13,IREGI,KS,KFIRST,KKKQ,PSTAR
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      COMMON/UV/II11,IERR,IPRESS,IPRESU,ISUB
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/WX/APRESS,APRESU
      COMMON/XY/APRS,APUS,DELTAY,EBODS,IBODS,INTACT,IPRS,IPUS,ITYP,
     1JBODS,MMAX,RHEAT,XK2,XK4,YBOT,YTP
      COMMON/YX/ABODS,BPRESS,CPRESS
      COMMON/ZY/ABOD,BBOD,CBOD,EBOD,FBOD,GBOD,IAVE,IPUNCH,JBOD,KKKKK
      DIMENSION ISN(4),XMASSN(55)
      XJ2=1.-XJ
      XJ1=1.+XJ
      DY=DELTAY
      DO 1 I=1,IDD
      IF(IS(I).EQ.0) GO TO 1
      N=-1
      IF((I/2)*2.EQ.I) N=1
      ISI=IS(I)
      DYS=ABS(Y(ISI+N)-Y(ISI+2*N))
      IF(DYS.LT.2.*DY) GO TO 2
C*********  ADD PT ON DOWNSTREAM SIDE OF SHOCK  *****
      ISM=IS(I)-1
      IF((I/2)*2.EQ.I) ISM=IS(I)+2
      DO 3 KK=ISM,NPTS
      K=NPTS+ISM-KK
      J=K+1
      CALL SWITCH(J,K)
    3 CONTINUE
      NPTS=NPTS+1
      ISPP=1
      IF(JSUBL.GT.IS(I)) JSUBL=JSUBL+1
      IF(JSUBU.GT.IS(I)) JSUBU=JSUBU+1
      DO 4 J=1,IDD
      IF(IS(J).GT.IS(I)) IS(J)=IS(J)+1
    4 CONTINUE
      IF((I/2)*2.NE.I) IS(I)=IS(I)+1
```

```
      L=ISM-1
      M=ISM+1
      K=ISM
      RAT=.5
      P     (K)=P     (L)+RAT*(P     (M)-P     (L))
      TH    (K)=TH    (L)+RAT*(TH    (M)-TH    (L))
      X     (K)=X     (L)+RAT*(X     (M)-X     (L))
      Y     (K)=Y     (L)+RAT*(Y     (M)-Y     (L))
      Q     (K)=Q     (L)+RAT*(Q     (M)-Q     (L))
      T     (K)=T     (L)+RAT*(T     (M)-T     (L))
      VIS(K)=VIS(L)+RAT*(VIS(M)-VIS(L))
      DVIS(K)=DVIS(L)+RAT*(DVIS(M)-DVIS(L))
      BQ    (K)=BQ    (L)+RAT*(BQ    (M)-BQ    (L))
      TAU   (K)=TAU   (L)+RAT*(TAU   (M)-TAU   (L))
      DBQ   (K)=DBQ   (L)+RAT*(DBQ   (M)-DBQ   (L))
      DCPX  (K)=DCPX  (L)+RAT*(DCPX  (M)-DCPX  (L))
      DTAU  (K)=DTAU  (L)+RAT*(DTAU  (M)-DTAU  (L))
      XMASS(K)=XMASS(L)+RAT*(XMASS(M)-XMASS(L))
      CPX(K)=0.
      W(K)=0.
      CALL THERMO(T(K),H1,CP1)
      DO 5 J=1,NSP
      ALP  (J,K)=ALP  (J,L)+RAT*(ALP  (J,M)-ALP  (J,L))
      DALP (J,K)=DALP (J,L)+RAT*(DALP (J,M)-DALP (J,L))
      DDALP(J,K)=DDALP(J,L)+RAT*(DDALP(J,M)-DDALP(J,L))
      H(J,K)=H1(J)
      CP(J,K)=CP1(J)
      W(K)=W(K)+ALP(J,K)/WTMOLE(J)
      CPX(K)=CPX(K)+ALP(J,K)*CP(J,K)
    5 CONTINUE
      W(K)=1./W(K)
      R(K)=RO/W(K)
      GAM(K)=CPX(K)/(CPX(K)-R(K)/CPIN)
      OR=1./R(K)
      RHO(K)=P(K)*W(K)*GEW/T(K)
      EM(K)=Q(K)*EMINF*SQRT(GAR/GAM(K)*OR/T(K))
      XMU(K)=ZMU(EM(K))
    2 CONTINUE
      IF((I/2)*2.EQ.I) GO TO 6
      J=IS(I)
      K=J+1
      GO TO 7
    6 J=IS(I)
      K=J-1
    7 IF(N*(Y(J)-Y(K)).GT..5*DY) GO TO 1
      ISIMN=IS(I)-N
      IF(ISIMN.EQ.NPTS.OR.ISIMN.EQ.1)GO TO 1
C*********  SUBTRACT PT FROM FREE STREAM SIDE OF SHOCK  ****
  775 L=K+1
```

```
      DO 8 K=L,NPTS
      J=K-1
      CALL SWITCH(J,K)
    8 CONTINUE
      NPTS=NPTS-1
      ISPP=1
      IF(JSUBL.GT.IS(I)) JSUBL=JSUBL-1
      IF(JSUBU.GT.IS(I)) JSUBU=JSUBU-1
      DO 9 J=1,IDD
      IF(IS(J).GT.IS(I)) IS(J)=IS(J)-1
    9 CONTINUE
      IF((I/2)*2.EQ.I) IS(I)=IS(I)-1
    1 CONTINUE
      IF(ITYP.NE.1) GO TO 850
      IF(NPTS.LT.MMAX) GO TO 2121
      II11=1
      IPUNCH=1
      WRITE(6,9191)
 9191 FORMAT(1H1)
      WRITE(6,851)
  851 FORMAT(74H REQUESTED MAXIMUM NUMBER OF FLOW FIELD PTS. EXCEEDED, P
     1UNCH FILE OBTAINED/97H RESUBMIT RUN WITH REDUCED NUMBER OF FLOW FI
     1ELD PTS. OR INCREASE INPUT FOR MAXIMUM NUMBER OF PTS.)
      RETURN
  850 CONTINUE
      IF(Y(1).EQ.YBOT.OR.ITYP.EQ.4) GO TO 2100
      IPRESS=1
      APRESS=P(1)/PIN
 2100 IF(Y(NPTS).EQ.YTP.OR.ITYP.EQ.3) GO TO 2101
      IPRESU=1
      APRESU=P(NPTS)/PIN
 2101 CONTINUE
      IF(NPTS.LT.MMAX) GO TO 1000
      ISC=0
      DO 700 I=1,IDD
  700 IF(IS(I).NE.0) ISC=ISC+1
      IF(ITYP.NE.2.OR.ISC.NE.0.OR.ISUB.NE.0.)GO TO 701
      YQ=YTP
      IF(Y(NPTS).LE.YTP-2.*DELTAY)YQ=Y(NPTS)+DELTAY
      IK=1
      IX=1
      NP=NPTS
      IF((NPTS/2)*2.NE.NPTS) GO TO 702
  800 J=NPTS+1
      K=NPTS
      CALL SWITCH(J,K)
      Y(J)=YQ
      NPTS=NPTS+1
      YFUN=(Y(J)*(XJ2+Y(J)*XJ)-Y(K)*(XJ2+Y(K)*XJ))/XJ1
```

```
      RQAV=RHO(K)*Q(K)*COS(TH(K))
      XMASS(J)=XMASS(K)+RQAV*YFUN
      TH(NPTS)=0.
      APRESU=P(NPTS)/PIN
      GO TO (702,903),IX
  702 J=1
      DO 703 K=3,NP,2
      J=J+1
      CALL SWITCH(J,K)
  703 CONTINUE
      DELTAY=DELTAY*2.
      IF(IK.EQ.2) GO TO 704
      NPTS=NPTS/2+1
      GO TO 1000
  701 IF(ITYP.NE.3.OR.IS(3).EQ.0.OR.ISUB.NE.0.OR.ISC.NE.1) GO TO 303
      IK=2
      NP=IS(3)-1
      IF((NP/2)*2.NE.NP) GO TO 702
      IQ=1
      IF(Y(1).GE.YBOT+2.*DELTAY+1.E-03) GO TO 706
      YT=YBOT
      GO TO 707
  706 YT=Y(1)-DELTAY
  707 DO 708 KK=1,NPTS
      K=NPTS+1-KK
      J=K+1
      CALL SWITCH(J,K)
  708 CONTINUE
      NPTS=NPTS+1
      DO 709 I=1,IDD
  709 IF(IS(I).NE.0) IS(I)=IS(I)+1
      IF(ISUB.EQ.0) GO TO 710
      JSUBL=JSUBL+1
      JSUBU=JSUBU+1
  710 Y(1)=YT
      YFUN=(Y(2)*(XJ2+Y(2)*XJ)-Y(1)*(XJ2+Y(1)*XJ))/XJ1
      RQAV=RHO(2)*Q(2)*COS(TH(2))
      XMASS(1)=XMASS(2)-RQAV*YFUN
      TH(1)=0.
      APRESS=P(1)/PIN
      GO TO (711,907),IQ
  711 NP=NP+1
      GO TO 702
  704 ISN(3)=NP/2+2
      ID=IS(3)-ISN(3)
      ISS=IS(3)
      IS(3)=ISN(3)
      DO 705 K=ISS,NPTS
      J=K-ID
```

```
      CALL SWITCH(J,K)
  705 CONTINUE
      NPTS=NPTS-ID
      GO TO 1000
  303 ICT=ISC
      ITOP=NPTS
      IF(IS(3).NE.0) ITOP=IS(3)-1
      IBOT=1
      IF(IS(4).NE.0) IBOT=IS(4)+1
      DTY=Y(ITOP)-Y(IBOT)
      DELTAY=DTY/FLOAT((MMAX-(NPTS-ITOP)-IS(4))/2-ICT)
      IB=IBOT
      ISN(1)=IS(1)
      ISN(2)=IS(2)
      ISN(3)=IS(3)
      ISN(4)=IS(4)
      JSUBLN=JSUBL
      JSUBUN=JSUBU
      IBB=IB
      IREG=1
      IF(IS(2).EQ.0) GO TO 501
      IT=IS(2)
      GO TO 502
  501 IREG=2
      IF(ISUB.EQ.0) GO TO 504
      IF(JSUBL.EQ.1) GO TO 503
      IT=JSUBL
      GO TO 502
  503 CONTINUE
      IB=JSUBU
      IBB=IB
  504 IREG=4
      IF(IS(1).EQ.0) GO TO 505
      IT=IS(1)-1
      GO TO 502
  505 IREG=5
      IF(IS(3).EQ.0) GO TO 506
      IT=IS(3)-1
      GO TO 502
  506 IT=NPTS
  502 MP=(Y(IT)-Y(IB))/DELTAY
      L=IB
      JZ=1
      DEL=(Y(IT)-Y(IB))/FLOAT(MP)
 5932 CONTINUE
      J=IBB
      K=IB
      X    N(J)=X     (K)
      Y    N(J)=Y     (K)
```

```
      Q    N(J)=Q     (K)
      P    N(J)=P     (K)
      T    N(J)=T     (K)
      W    N(J)=W     (K)
      R    N(J)=R     (K)
      EM   N(J)=EM    (K)
      TH   N(J)=TH    (K)
      BQ   N(J)=BQ    (K)
      DVISN(J)=DVIS(K)
      VISN(J)=VIS(K)
      TAU N(J)=TAU   (K)
      DBQ N(J)=DBQ   (K)
      GAM N(J)=GAM   (K)
      RHO N(J)=RHO   (K)
      XMU N(J)=XMU   (K)
      CPX N(J)=CPX   (K)
      DCPXN(J)=DCPX  (K)
      DTAUN(J)=DTAU  (K)
      XMASSN(J)=XMASS(K)
      DO3108 JJ=1,NSP
      H    N(JJ,J)=H     (JJ,K)
      CP   N(JJ,J)=CP    (JJ,K)
      ALP  N(JJ,J)=ALP   (JJ,K)
      DALPN(JJ,J)=DALP  (JJ,K)
      DDALPN(JJ,J)=DDALP(JJ,K)
3108  CONTINUE
      GO TO (2201,2904),JZ
2201  DO 600 KK=1,MP
      I=KK+I88-1
      YN(I+1)=YN(I)+DEL
 602  IF(YN(I+1).GE.Y(L).AND.YN(I+1).LT.Y(L+1)) GO TO 601
      L=L+1
      GO TO 602
 601  RAT=(YN(I+1)-Y(L))/(Y(L+1)-Y(L))
      IF(IT.EQ.JSUBU) GO TO 1200
      PN(I+1)=P(L)+RAT*(P(L+1)-P(L))
      THN(I+1)=TH(L)+RAT*(TH(L+1)-TH(L))
      GO TO 1201
1200  CONTINUE
      YY=YN(I+1)
      PN(I+1)=AP0+YY*(AP1+YY*AP2)
      THN(I+1)=0.
1201  CONTINUE
      M=L+1
      K=I+1
      X    N(K)=X     (L)+RAT*(X     (M)-X     (L))
      Y    N(K)=Y     (L)+RAT*(Y     (M)-Y     (L))
      Q    N(K)=Q     (L)+RAT*(Q     (M)-Q     (L))
      T    N(K)=T     (L)+RAT*(T     (M)-T     (L))
```

```
      BQ  N(K)=BQ   (L)+RAT*(BQ   (M)-BQ   (L))
      VISN(K)=VIS(L)+RAT*(VIS(M)-VIS(L))
      DVISN(K)=DVIS(L)+RAT*(DVIS(M)-DVIS(L))
      TAU N(K)=TAU  (L)+RAT*(TAU  (M)-TAU  (L))
      DBQ N(K)=DBQ  (L)+RAT*(DBQ  (M)-DBQ  (L))
      DCPXN(K)=DCPX (L)+RAT*(DCPX (M)-DCPX (L))
      DTAUN(K)=DTAU (L)+RAT*(DTAU (M)-DTAU (L))
      XMASSN(K)=XMASS(L)+RAT*(XMASS(M)-XMASS(L))
      CPXN(K)=0.
      WN(K)=0.
      CALL THERMO(TN(K),H1,CP1)
      DO55 J=1,NSP
      ALP N(J,K)=ALP  (J,L)+RAT*(ALP  (J,M)-ALP  (J,L))
      DALPN(J,K)=DALP (J,L)+RAT*(DALP (J,M)-DALP (J,L))
      DDALPN(J,K)=DDALP(J,L)+RAT*(DDALP(J,M)-DDALP(J,L))
      HN(J,K)=H1(J)
      CPN(J,K)=CP1(J)
      WN(K)=WN(K)+ALPN(J,K)/WTMOLE(J)
      CPXN(K)=CPXN(K)+ALPN(J,K)*CPN(J,K)
   55 CONTINUE
      WN(K)=1./WN(K)
      RN(K)=RO/WN(K)
      GAMN(K)=CPXN(K)/(CPXN(K)-RN(K)/CPIN)
      RK=1./RN(K)
      RHON(K)=PN(K)*WN(K)*GEW/TN(K)
      EMN(K)=QN(K)*EMINF*SQRT(GAR/GAMN(K)*RK/TN(K))
      IF(EMN(K).GT.1.)
     1XMUN(K)=ZMU(EMN(K))
  600 CONTINUE
      GO TO (2200,603,604,605,606),IREG
 2200 ISN(2)=I+1
      IB=IS(2)+1
      IBB=ISN(2)+1
      GO TO 501
  603 JSUBLN=I+1
      IB=JSUBU
      JSUBUN=JSUBLN+JSUBU-JSUBL
      IBB=JSUBUN
  604 CONTINUE
      GO TO 504
  605 ISN(1)=I+2
      IB=IS(1)
      IBB=ISN(1)
      GO TO 505
  606 IF(IS(3).NE.0) ISN(3)=I+2
      IF(IS(3).EQ.0) NPTS=I+1
      NP=NPTS
      IF(IS(3).EQ.0) GO TO 2203
      ID=IS(3)-ISN(3)
```

```
      ISS=IS(3)
      DO 2304 K=ISS,NPTS
      J=K-ID
      CALL SWITCH(J,K)
2304  CONTINUE
      NPTS=NPTS-ID
      NP=ISN(3)-1
       IF(ISUB.EQ.0) GO TO 2903
      JZ=2
      JZIO=JSUBL-1
      JZI=JSUBLN-1
2904  JZI=JZI+1
      JZIO=JZIO+1
      IF(JZI.EQ.JSUBUN) GO TO 2903
      IBB=JZI
      IB=JZIO
      GO TO 5932
2903  CONTINUE
2203  DO 2204 I=IBOT,NP
      J=I
      K=I
      X     (J)=XN    (K)
      Y     (J)=YN    (K)
      Q     (J)=QN    (K)
      P     (J)=P     N(K)
      T     (J)=T     N(K)
      W     (J)=W     N(K)
      R     (J)=R     N(K)
      EM    (J)=EM    N(K)
      TH    (J)=TH    N(K)
      DVIS(J)=DVISN(K)
      VIS(J)=VISN(K)
      BQ    (J)=BQ    N(K)
      TAU   (J)=TAU   N(K)
      DBQ   (J)=DBQ   N(K)
      GAM   (J)=GAM   N(K)
      RHO   (J)=RHO   N(K)
      XMU   (J)=XMU   N(K)
      CPX   (J)=CPX   N(K)
      DCPX  (J)=DCPXN(K)
      DTAU  (J)=DTAUN(K)
      XMASS(J)=XMASSN(K)
      DO4108 JJ=1,NSP
      H     (JJ,J)=H    N(JJ,K)
      CP    (JJ,J)=CP   N(JJ,K)
      ALP   (JJ,J)=ALP  N(JJ,K)
      DALP  (JJ,J)=DALPN(JJ,K)
      DDALP(JJ,J)=DDALPN(JJ,K)
4108  CONTINUE
```

```
2204 CONTINUE
     DO 607 I=1,4
 607 IS(I)=ISN(I)
     JSUBL=JSUBLN
     JSUBU=JSUBUN
1000 CONTINUE
     IF(ITYP.EQ.3) GO TO 903
     IF(Y(NPTS).EQ.YTP) GO TO 903
     YQ=YTP
     IF(Y(NPTS).LE.YTP-1.*DELTAY)YQ=Y(NPTS)+DELTAY
     IX=2
     L=NPTS-1
     M=L-1
     IF(ABS(P(M)-P(L))/P(L)-.001) 900,900,800
 900 IF(ABS(Q(M)-Q(L))/Q(L)-.001) 901,901,800
 901 IF(ABS(T(M)-T(L))/T(L)-.001) 902,902,800
 902 IF(ABS(ALP(5,M)-ALP(5,L))-.001*ALP(5,L)) 903,903,800
 903 IF(Y(1).EQ.YBOT) GO TO 907
     IF(ITYP.EQ.4) GO TO 907
     L=2
     M=3
     IQ=2
     IF(Y(1).GE.YBOT+DELTAY+1.E-03) GO TO 910
     YT=YBOT
     GO TO 912
 910 YT=Y(1)-DELTAY
 912 IF(ABS(P(M)-P(L))/P(L)-.001) 904,904,707
 904 IF(ABS(Q(M)-Q(L))/Q(L)-.001) 905,905,707
 905 IF(ABS(T(M)-T(L))/T(L)-.001) 906,906,707
 906 IF(ABS(ALP(4,M)-ALP(4,L))-.001*ALP(4,L)) 907,907,707
 907 CONTINUE
     IF(ITYP.EQ.4) GO TO 2102
     IF(Y(1).NE.YBOT) GO TO 2102
     IBOD=IBODS
     ABOD=ABODS
     IPRESS=IPRS
     APRESS=APRS
2102 IF(ITYP.EQ.3) GO TO 2103
     IF(Y(NPTS).NE.YTP) GO TO 2103
     JBOD=JBODS
     EBOD=EBODS
     IPRESU=IPUS
     APRESU=APUS
2103 CONTINUE
     IF(Y(1).EQ.YBOT.AND.ITYP.EQ.3) ITYP=1
     IF(Y(1).EQ.YBOT.AND.ITYP.EQ.2) ITYP=4
     IF(Y(NPTS).EQ.YTP.AND.ITYP.EQ.4) ITYP=1
     IF(Y(NPTS).EQ.YTP.AND.ITYP.EQ.2) ITYP=3
2121 CONTINUE
```

```
      IF(ISUB.EQ.1) RETURN
      JSUBL=NPTS+1
      JSUBU=NPTS+1
      RETURN
      END
      SUBROUTINE RSET
      COMMON/AL/GAR,GEW
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/BD/XMASS(55)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/DP/YN(55)
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     IL,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/OR/THBP,YBP,YBPN
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/RC/R(55)
      COMMON/SQ/BQN(55),DALPN(7,55),DBQN(55),DCPXN(55),DDALPN(7,55),
     1DTAUN(55),TAUN(55)
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      COMMON/VW/ICONT,IEND,KT,THBPN,XBPN
      COMMON/WV/NPTS,RE,XBP,XJ
      DO 5110 I=1,NPTS
      TH(I)=THN(I)
      X(I)=XBPN
      Y(I)=YN(I)
      Q(I)=QN(I)
      P(I)=PN(I)
      T(I)=TN(I)
      RHO(I)=RHON(I)
      EM(I)=EMN(I)
      XMU(I)=XMUN(I)
      VIS(I)=VISN(I)
      DVIS(I)=DVISN(I)
      TAU(I)=TAUN(I)
      BQ(I)=BQN(I)
      DCPX(I)=DCPXN(I)
      DTAU(I)=DTAUN(I)
      DBQ(I)=DBQN(I)
      DO4090J=1, NSP
      ALP(J, I)=ALPN(J, I)
      DALP(J, I)=DALPN(J, I)
      DDALP(J, I)=DDALPN(J, I)
```

```
      CP(J, I)=CPN(J, I)
      H(J, I)=HN(J, I)
 4090 CONTINUE
      W(I)=WN(I)
      R(I)=RN(I)
      GAM(I)=GAMN(I)
      CPX(I)=CPXN(I)
 5110 CONTINUE
      XJ1=1.+XJ
      IF(Y(1).EQ.0.) XMASS(1)=0.
      DO 10 I=2,NPTS
      YFUN=(Y(I)*(1.-XJ+Y(I)*XJ)- Y(I-1)*(1.-XJ+Y(I-1)*XJ))/XJ1
      RQAV=(RHO(I)*Q(I)*COS(TH(I))+ RHO(I-1)*Q(I-1)*COS(TH(I-1)))/2.
      XMASS(I)=XMASS(I-1)+RQAV*YFUN
   10 CONTINUE
      DO 8409 I=1,NPTS
      CPX(I)=0.
      CALL THERMO(T(I),H1,CP1)
      DO 8410 I4=1,NSP
      CP(I4,I)=CP1(I4)
      H(I4,I)=H1(I4)
 8410 CPX(I)=CPX(I)+ALP(I4,I)*CP1(I4)
      RHO(I)=GEW*W(I)*P(I)/T(I)
      GAM(I)=CPX(I)/(CPX(I)-R(I)/CPIN)
      RI=1./R(I)
      EM(I)=Q(I)*EMINF*SQRT(GAR/GAM(I)*RI/T(I))
      IF(EM(I).LT.1.0001) GO TO 8409
      XMU(I)=ZMU(EM(I))
 8409 CONTINUE
      XBP=XBPN
      YBP=Y(NPTS)
      THBP=TH(NPTS)
      IF(YBPN.EQ.YN(NPTS)) RETURN
      YBP=YBPN
      THBP=THBPN
      RETURN
      END
      SUBROUTINE SHEAR1(CFF,VISD)
      COMMON/AC/IBOD,PIN
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/SQ/BQN(55),DALPN(7,55),DBQN(55),DCPXN(55),DDALPN(7,55),
     1DTAUN(55),TAUN(55)
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
```

```
      COMMON/WV/NPTS,RE,XBP,XJ
      DIMENSION LOCS(8)
      KKI=0
      DO 100 K=1,8
  100 LOCS(K)=0
      LAST=NPTS
      LAST1=NPTS+1
      LAST2=NPTS-1
      Y (LAST1)=2.*Y (LAST)-Y (LAST2)
      Q (LAST1)=Q (LAST2)
      T (LAST1)=T (LAST2)
      VIS(LAST1)=VIS(LAST2)
      CPX (LAST1)=CPX (LAST2)
      P(LAST1)=P(LAST2)
      TH(LAST1)=TH(LAST2)
      TAU (LAST)=0.
      BQ (LAST)=0.
      DCPX (LAST)=0.
      DO 6290 J=1,NSP
      DALP (J,LAST)=0.
 6290 ALP (J,LAST1)=ALP (J,LAST2)
      DO 6292 K=2,LAST
      DELY2=Y (K+1)-Y (K)
      DELY1=Y (K)-Y (K-1)
      IF(DELY2.LT.1.E-06.OR.DELY1.LT.1.E-06) GO TO 1301
      SUM=DELY1+DELY2
      RATIO1=DELY1/DELY2
      RATIO2=DELY2/DELY1
      SU=1./SUM
      RMR=RATIO1-RATIO2
      TAU(K)=(Q(K+1)*RATIO1-Q(K)*RMR-Q(K-1)*RATIO2)*SU
      OD=1./DELY2
      DTAU(K)=2.*(Q(K+1)*DELY1*SU-Q(K)+Q(K-1)*DELY2*SU)/DELY1*OD
      BQ(K)=(T(K+1)*RATIO1-T(K)*RMR-T(K-1)*RATIO2)*SU
      DBQ(K)=2.*(T(K+1)*DELY1*SU-T(K)+T(K-1)*DELY2*SU)/DELY1*OD
      DCPX(K)=(CPX(K+1)*RATIO1-CPX(K)*RMR-CPX(K-1)*RATIO2)*SU
      DVIS(K)=(VIS(K+1)*RATIO1-VIS(K)*(RATIO1-RATIO2)-VIS(K-1)*RATIO2)/S
     1UM
      DO 6291 J=1,NSP
      DALP(J,K)=(ALP(J,K+1)*RATIO1-ALP(J,K)*RMR-ALP(J,K-1)*RATIO2)*SU
      DDALP(J,K)=2.*(ALP(J,K+1)*DELY1*SU-ALP(J,K)+ALP(J,K-1)*DELY2*SU)
     1/DELY1*OD
 6291 CONTINUE
      GO TO 6292
 1301 KKI=KKI+1
      LOCS(KKI)=K
 6292 CONTINUE
      DVIS(1)=0.
      TAU (1)=0.0
```

```
      DY=Y(2)-Y(1)
      IF(IBOD.EQ.1)TAU(1)=CFF*RE*RHO(1)*Q(1)**2*.5/VISD
      BQ (1)=0.0
      DCPX (1)=0.
      DTAU (1)=(Q (2)-Q (1))*2./(Y (2)-Y (1))**2
      IF(IBOD.EQ.1) DTAU(1)=4.*(Q(2)-Q(1))/DY**2-2.*(TAU(1)+TAU(2))/DY+
     1DTAU(2)
      DBQ (1)=(T (2)-T (1))*2./(Y (2)-Y (1))**2
      IF(IBOD.EQ.1) DBQ(1)=4.*(T(2)-T(1))/DY**2-2.*BQ(2)/DY+DBQ(2)
      DO6293J=1, NSP
      DALP (J, 1)=0.0
      DDALP (J, 1)=2.*(ALP (J, 2)-ALP (J, 1))/(Y (2)-
     1Y (1))**2
      IF(IBOD.EQ.1) DDALP(J,1)=4.*(ALP(J,2)-ALP(J,1))/DY**2-2.*DALP(J,2
     1)/DY+DDALP(J,2)
 6293 CONTINUE
      DO 101 M=1,8
      IF(LOCS(M).EQ.0) GO TO 102
      K=LOCS(M)
      L=1
      IF((M/2)*2.NE.M) L=-1
      YNK=Y (K)-Y (K+L)
      BQ (K)=2.*(T (K)-T (K+L))/YNK-BQ  (K+L)
      TAU (K)=2.*(Q (K)-Q (K+L))/YNK-TAU (K+L)
      DCPX (K)=2.*(CPX (K)-CPX (K+L))/YNK-DCPX (K+L)
      DTAU (K)=2.*(TAU (K)-TAU (K+L))/YNK-DTAU (K+L)
      DBQ (K)=2.*(BQ (K)-BQ (K+L))/YNK-DBQ (K+L)
      DO 103 J=1,NSP
      DALP (J,K)=2.*(ALP (J,K)-ALP (J,K+L))/YNK-DALP (J,K+L)
  103 DDALP (J,K)=2.*(DALP (J,K)-DALP (J,K+L))/YNK-DDALP (J,K+L)
  101 CONTINUE
  102 CONTINUE
      DO 7000 I=1,LAST
      TAUN(I)=TAU(I)
      BQN(I)=BQ(I)
      DCPXN(I)=DCPX(I)
      DTAUN(I)=DTAU(I)
      DBQN(I)=DBQ(I)
      DO 7001 J=1,NSP
      DALPN(J,I)=DALP(J,I)
 7001 DDALPN(J,I)=DDALP(J,I)
 7000 CONTINUE
      NPTS=LAST
      RETURN
      END
      SUBROUTINE SHEAR2(CFF,VISD)
      COMMON/AC/IBOD,PIN
      COMMON/DP/YN(55)
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
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```
     ILS,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/SQ/BQN(55),DALPN(7,55),DBQN(55),DCPXN(55),DDALPN(7,55),
     1DTAUN(55),TAUN(55)
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/WV/NPTS,RE,XBP,XJ
      DIMENSION LOCS(8)
      KKI=0
      DO 100 K=1,8
  100 LOCS(K)=0
      LAST=NPTS
      LAST1=NPTS+1
      LAST2=NPTS-1
      YN(LAST1)=2.*YN(LAST)-YN(LAST2)
      QN(LAST1)=QN(LAST2)
      TN(LAST1)=TN(LAST2)
      VISN(LAST1)=VISN(LAST2)
      CPXN(LAST1)=CPXN(LAST2)
      PN(LAST1)=PN(LAST2)
      THN(LAST1)=THN(LAST2)
      TAUN(LAST)=0.
      BQN(LAST)=0.
      DCPXN(LAST)=0.
      DO 3001 J=1,NSP
      DALPN(J,LAST)=0.
 3001 ALPN(J,LAST1)=ALPN(J,LAST2)
      DO 6002 K=2,LAST
      DELY2=YN(K+1)-YN(K)
      DELY1=YN(K)-YN(K-1)
      IF(DELY2.LT.1.E-06.OR.DELY1.LT.1.E-06) GO TO 1301
      SUM=DELY1+DELY2
      RATIO1=DELY1/DELY2
      RATIO2=DELY2/DELY1
      SU=1./SUM
      OD=1./DELY2
      RMR=RATIO1-RATIO2
      TAUN(K)=(QN(K+1)*RATIO1-QN(K)*RMR-QN(K-1)*RATIO2)*SU
      DTAUN(K)=2.*(QN(K+1)*DELY1*SU-QN(K)+QN(K-1)*DELY2*SU)/DELY1*OD
      BQN(K)=(TN(K+1)*RATIO1-TN(K)*RMR-TN(K-1)*RATIO2)*SU
      DBQN(K)=2.*(TN(K+1)*DELY1*SU-TN(K)+TN(K-1)*DELY2*SU)/DELY1*OD
      DCPXN(K)=(CPXN(K+1)*RATIO1-CPXN(K)*RMR-CPXN(K-1)*RATIO2)*SU
      DVISN(K)=(VISN(K+1)*RATIO1-VISN(K)*(RATIO1-RATIO2)-VISN(K-1)*RATIO
     12)/SUM
      DO 4081 J=1,NSP
      DALPN(J,K)=(ALPN(J,K+1)*RATIO1-ALPN(J,K)*RMR-ALPN(J,K-1)*RATIO2)
     1*SU
      DDALPN(J,K)=2.*(ALPN(J,K+1)*DELY1*SU-ALPN(J,K)+ALPN(J,K-1)*DELY2
     1*SU)/DELY1*OD
 4081 CONTINUE
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```
      GO TO 6002
 1301 KKI=KKI+1
      LOCS(KKI)=K
 6002 CONTINUE
      TAUN(1)=0.0
      DY=YN(2)-YN(1)
      IF(IBOD.EQ.1)TAUN(1)=CFF*RE*RHON(1)*QN(1)**2*.5/VISD
      BQN(1)=0.0
      DVISN(1)=0.0
      DCPXN(1)=0.
      DTAUN(1)=(QN(2)-QN(1))*2./(YN(2)-YN(1))**2
      IF(IBOD.EQ.1) DTAUN(1)=4.*(QN(2)-QN(1))/DY**2-2.*(TAUN(1)+TAUN(2)
     1)/DY+DTAUN(2)
      DBQN(1)=(TN(2)-TN(1))*2./(YN(2)-YN(1))**2
      IF(IBOD.EQ.1) DBQN(1)=4.*(TN(2)-TN(1))/DY**2-2.*BQN(2)/DY+DBQN(2)
      DO4082J=1, NSP
      DALPN(J, 1)=0.0
      DDALPN(J, 1)=2.*(ALPN(J, 2)-ALPN(J, 1))/(YN(2)-
     1YN(1))**2
      IF(IBOD.EQ.1) DDALPN(J,1)=4.*(ALPN(J,2)-ALPN(J,1))/DY**2-2.*DALPN
     1(J,2)/DY+DDALPN(J,2)
 4082 CONTINUE
      DO 101 M=1,8
      IF(LOCS(M).EQ.0) GO TO 102
      K=LOCS(M)
      L=1
      IF((M/2)*2.NE.M) L=-1
      YNK=YN(K)-YN(K+L)
      BQN(K)=2.*(TN(K)-TN(K+L))/YNK-BQ N(K+L)
      TAUN(K)=2.*(QN(K)-QN(K+L))/YNK-TAUN(K+L)
      DCPXN(K)=2.*(CPXN(K)-CPXN(K+L))/YNK-DCPXN(K+L)
      DTAUN(K)=2.*(TAUN(K)-TAUN(K+L))/YNK-DTAUN(K+L)
      DBQN(K)=2.*(BQN(K)-BQN(K+L))/YNK-DBQN(K+L)
      DO 103 J=1,NSP
      DALPN(J,K)=2.*(ALPN(J,K)-ALPN(J,K+L))/YNK-DALPN(J,K+L)
  103 DDALPN(J,K)=2.*(DALPN(J,K)-DALPN(J,K+L))/YNK-DDALPN(J,K+L)
  101 CONTINUE
  102 CONTINUE
      NPTS=LAST
      RETURN
      END
      SUBROUTINE LPOINT(I,OPTP)
      COMMON/AB/EPP,EPQ,EPT
      COMMON/AC/IBOD,PIN
      COMMON/AL/GAR,GEW
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/BB/S1B,S2B,S3BT
      COMMON/BO/GAMB,PB,QB,RHOB,THB,WB,XMUB,YB
      COMMON/CA/WDOTN(7,55),XN(55)
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      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/CK/WTMOLE(7)
      COMMON/DP/YN(55)
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EG/EIN,PR,XLE
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/FE/DEL
      COMMON/GF/DELY,IFS,KOUNTO,MMM
      COMMON/GK/DELX
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     ILS,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/HN/CHC(2),CPB(7),CPXP(2),DALDIF(7),DALPB(7),DDALPB(7),DELS,
     AEMP(2),HB(7),HC(7),RP(2),S3A(7),S3B(7),S3D(7),WDOTB(7),XP(2)
      COMMON/OP/ALPB(7),PHI(55)
      COMMON/PD/W(55),X(55)
      COMMON/PQ/JCHEM,NSP,T(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/QS/RHOP(2),WDOT(7,55),WDOTC(7),WP(2),XMUP(2)
      COMMON/SQ/BQN(55),DALPN(7,55),DBQN(55),DCPXN(55),DDALPN(7,55),
     1DTAUN(55),TAUN(55)
      COMMON/SS/AL1,AL2,BQ1,BQ2,C1,C2,CH1,CH2,DB1,DB2,DD1,DD2,DT1,DT2,DV
     A1,DV2,PX1,PX2,TA1,TA2,TH1,TH2,V1,V2,Y1,Y2
      COMMON/TS/DVIS(55),DVISN(55),DVISP(2),VIS(55),VISN(55),VISP(2)
      COMMON/TU/BQ(55),DALP(7,55),DBQ(55),DCPX(55),DDALP(7,55),DTAU(55),
     1TAU(55)
      COMMON/TV/ALPP(7,2),BET,BQP(2),DACHP(7,2),DALPP(7,2),DBQP(2),
     1DCPXP(2),DDALPP(7,2),DTAUP(2),DTCHP(2),GAMP(2),PP(2),QP(2),
     2TAUP(2),THP(2),TP(2),YP(2)
      COMMON/UV/II11,IERR,IPRESS,IPRESU,ISUB
      COMMON/VT/DACH(7,55),DTCH(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      DIMENSION DACHB(7)
      KPRESS=0
      L=I
      K=I+1
      IF(OPTP.EQ.0.) GO TO 2000
      K=I-1
      IF(IFS.NE.2) GO TO 8500
      IF((MMM/2)*2.NE.MMM) GO TO 8500
      K=I+1
      EM1R=XM2(ALPHA,BETA,TH(I    ),XMU(I    ),THN(I   ),XMUN(I   ))
      EM1L=XM2(ALPHA,BETA,TH(K    ),XMU(K    ),THN(I   ),XMUN(I   ))
      GO TO 8501
 8500 CONTINUE
      EM1R=XM1(ALPHA,BETA,TH(I),XMU(I),THN(I),XMUN(I))
      EM1L=XM1(ALPHA,BETA,TH(K),XMU(K),THN(I),XMUN(I))
 8501 CONTINUE
```

```
2000 CONTINUE
     YB=(Y(K)+Y(I))/2.
     KIP4=0
8372 CONTINUE
     RATG=(YB-Y(I))/(Y(K)-Y(I))
     THB=TH(I)+RATG*(TH(K)-TH(I))
     XMUB=XMU(I)+RATG*(XMU(K)-XMU(I))
     EM2=XM2(ALPHA,BETA,THB,XMUB,THN(I),XMUN(I))
     IF(OPTP.NE.0.) EM2=EM1L+RATG*(EM1R-EM1L)
     YBT=YB
     XB=XBP
     YB=YN(I)-EM2*DELX
     TESTY=(YB-YBT)/(Y(K)-Y(I))
     IF(ABS(TESTY).LT.0.01) GO TO 8371
     KIP4=KIP4+1
     IF(KIP4.LE.20) GO TO 8372
     WRITE(6,9191)
9191 FORMAT(1H1)
     WRITE(6,2020)
2020 FORMAT(56H UNABLE TO LOCATE Y LOCATION OF CHARACTERISTIC IN LPOINT
    1)
     STOP
8371 RATG=(YB-Y(I))/(Y(K)-Y(I))
  51 THB=TH(I)+RATG*(TH(K)-TH(I))
     QB=Q(I)+RATG*(Q(K)-Q(I))
     PB=P(I)+RATG*(P(K)-P(I))
     TT=T(I)+RATG*(T(K)-T(I))
     TAUB=TAU(I)+RATG*(TAU(K)-TAU(I))
     BQB=BQ(I)+RATG*(BQ(K)-BQ(I))
     VISB=VIS(I)+RATG*(VIS(K)-VIS(I))
     DVISB=DVIS(I)+RATG*(DVIS(K)-DVIS(I))
     DCPXB=DCPX(I)+RATG*(DCPX(K)-DCPX(I))
     DTAUB=DTAU(I)+RATG*(DTAU(K)-DTAU(I))
     DBQB=DBQ(I)+RATG*(DBQ(K)-DBQ(I))
     DTCHP(1)=DTCH(I)+RATG*(DTCH(K)-DTCH(I))
     DTCHB=(DTCHP(1)+DTCH(I))*.5
     CPXB=0.0
     WB=0.0
     CH2D=0.
     CH2B=0.0
     CALL THERMO(TT,HB,CPB)
     DO4060J=1, NSP
     ALPB(J)=ALP(J, I)+RATG*(ALP(J,K)-ALP(J, I))
     DALPB(J)=DALP(J,I)+RATG*(DALP(J,K)-DALP(J,I))
     DDALPB(J)=DDALP(J,I)+RATG*(DDALP(J,K)-DDALP(J,I))
     CH2D=CH2D+DALP(J, I)*CP(J, I)
     CH2B=CH2B+DALPB(J)*CPB(J)
     CPXB=CPXB+ALPB(J)*CPB(J)
     WB=WB+ALPB(J)/WTMOLE(J)
```

```
      WDOTB(J)=WDOT(J,I)+RATG*(WDOT (J,K)-WDOT(J,I))
      DACHH=DACH(J,I)+RATG*(DACH(J,K)-DACH(J,I))
      DACHB(J)=(DACHH+DACH(J,I))*.5
      DACHP(J,1)=DACHH
 4060 CONTINUE
      WB=1./WB
      RB=RO/WB
      GAMB=CPXB/(CPXB-RB/CPIN)
      OR=1./RB
      RHOB=PB*WB*GEW/TT
      EMB=QB*EMINF*SQRT(GAR/GAMB*OR/TT)
      XMUB=ZMU(EMB)
      IF(DEL.EQ.0.) GO TO 8392
      Y    P(1)=Y    B
      X    P(1)=X    B
      Q    P(1)=Q    B
      P    P(1)=P    B
      T    P(1)=TT
      W    P(1)=W    B
      R    P(1)=R    B
      TH   P(1)=TH   B
      EM   P(1)=EM   B
      BQ   P(1)=BQ   B
      VISP(1)=VISB
      DVISP(1)=DVISB
      RHO  P(1)=RHO  B
      XMU  P(1)=XMU  B
      CPX  P(1)=CPX  B
      GAM  P(1)=GAM  B
      TAU  P(1)=TAU  B
      DBQ  P(1)=DBQ  B
      DTAUP(1)=DTAUB
      DCPXP(1)=DCPXB
      DO 3939 J=1,NSP
      ALP   P(J,1)=ALP   B(J)
      DALP  P(J,1)=DALP  B(J)
 3939 DDALPP(J,1)=DDALPB(J)
 8392 CONTINUE
      IF(BETA.NE.0.0)GOTO4070
      TAUN(I)=TAU(I)
      BQN(I)=BQ(I)
      DCPXN(I)=DCPX(I)
      DTAUN(I)=DTAU(I)
      VISN(I)=VIS(I)
      DVISN(I)=DVIS(I)
      TN(I)=T(I)+DTCH(I)
      WN(I)=W(I)
      DBQN(I)=DBQ(I)
      CPXN(I)=CPX(I)
```

```
      CH2C=CH2D
      DO4071J=1, NSP
      DALPN(J, L)=DALP(J,I)
      DDALPN(J, L)=DDALP(J,I)
      HC(J)=H(J,I)
      WDOTC(J)=WDOTN(J,I)
4071  CONTINUE
4070  CONTINUE
      IF(BETA.EQ.0.0) GO TO 4072
      CH2C=0.0
      DO 4073 J=1,NSP
      HC(J)=HN(J,I)
      WDOTC(J)=WDOTN(J,I)
4073  CH2C=CH2C+DALPN(J,I)*CPN(J,I)
4072  CONTINUE
      V1=VISB
      V2=VISN(I)
      DV1=DVISB
      DV2=DVISN(I)
      TA1=TAUB
      TA2=TAUN(I)
      DT1=DTAUB
      DT2=DTAUN(I)
      BQ1=BQB
      BQ2=BQN(I)
      Y1=YB
      Y2=YN(I)
      TH1=THB
      TH2=THN(I)
      S1B=S1(XJ,RE)
      C1=CPXB
      C2=CPXN(I)
      DB1=DBQB
      DB2=DBQN(I)
      PX1=DCPXB
      PX2=DCPXN(I)
      CH1=CH2B
      CH2=CH2C
      IF(DEL.EQ.0.)1,2
    1 S2B=S2(XJ,RE)
      V1=VIS(I)
      DV1=DVIS(I)
      TA1=TAU(I)
      DT1=DTAU(I)
      BQ1=BQ(I)
      Y1=Y(I)
      TH1=TH(I)
      S1D=S1(XJ,RE)
      GO TO 56
```

```
    2 S2B=S2(XJ,RE)
   56 IF(DEL.EQ.0.)3,4
    3 V1=VIS(I)
      DV1=DVIS(I)
      C1=CPX(I)
      BQ1=BQ(I)
      DB1=DBQ(I)
      TA1=TAU(I)
      TH1=TH(I)
      Y1=Y(I)
      PX1=DCPX(I)
      CH1=CH2D
      S2D=S2(XJ,RE)
    4 S3BT=0.
      S3DT=0.0
      DO4075J=1, NSP
      AL1=DALPB(J)
      AL2=DALPN(J,L)
      DD1=DDALPB(J)
      DD2=DDALPN(J,L)
      V1=VISB
      DV1=DVISB
      BQ1=BQB
      TH1=THB
      Y1=YB
      S3B(J)=S3(XJ,RE)
      IF(DEL.EQ.0.)5,8
    5 V1=VIS(I)
      DV1=DVIS(I)
      AL1=DALP(J,I)
      DD1=DDALP(J,I)
      BQ1=BQ(I)
      TH1=TH(I)
      Y1=Y(I)
      S3D(J)=S3(XJ,RE)
      S3DT=S3DT+S3D(J)/WTMOLE(J)
    8 S3BT=S3BT+S3B(J)/WTMOLE(J)
 4075 CONTINUE
      IF(DEL.NE.0.) RETURN
      B1=F1(I)
      I15=0
      YAX=YB*YN(I)
      IF(YAX.LT.1.E-06.AND.XJ.NE.0.) I15=1
      XX=XJ
      IF(I15.EQ.1)60,61
   60 XJ=0.
   61 B2=F2(I,S1B,S2B,S3BT)
      XJ=XX
      IF(JCHEM.EQ.1) GO TO 7254
```

```
      B3=0.
      GO TO 7257
7254  TP1=(T(I)+DTCH(I)+TT)/2.
      B3=F3(TP1,DTCHB,TT,TN(I),THB,THN(I),DACHB,WB,WN(I))
7257  OPTT=1.
      IF(OPTP.NE.0.) OPTT=-1.
      B4=F4(BETA,-OPTT,XMUB,THB,XMUN(I),THN(I))
      B2=(B2+B3)*B4
      IF(OPTP.NE.0..AND.IPRES U.EQ.0) GO TO 7444
      IF(OPTP.NE.0..AND.IPRES U.EQ.1) GO TO 7482
      IF(IBOD.EQ.1) GO TO 7444
      IF(IPRESS.EQ.1) GO TO 7482
      AX=1.
      IF(I15.EQ.0) GO TO 100
      AX=XJ*SIN(XMUB)/SIN(THB-XMUB)
      IF(BETA.GT.0.0)AX=(AX+XJ*SIN(XMUN(I))
     1/SIN(THN(I)-XMUN(I)))*.5
      AX=1.-AX
 100  CONTINUE
      PN(I)=PB-(THB*AX+B2*(XN(I)-XB))/B1
      GO TO 7445
7482  CONTINUE
      KPRESS=KPRESS+1
      IF(KPRESS.LT.6) GO TO 3232
      IERR=7482
      WRITE(6,3131) IERR,I,THN(I),PN(I),YN(I),THB,PB,YB
3131  FORMAT(2I5,6E13.5)
      STOP
3232  THDUM=THN(I)
      KIP4=0
      THN(I)=THB+OPTT*B1*(PN(I)-PB)+OPTT*B2*(XN(I)-XB)
      IF(ABS(THN(I)-THDUM).GT.1.E-04) GO TO 8372
      YN(I)=Y(I)+.5*(TAN(TH(I))+TAN(THN(I)))*DELX
      GO TO 7445
7444  PN(I)=PB+OPTT*(THN(I)-THB)/B1-B2/B1*(XN(I)-XB)
7445  CONTINUE
      IF(ABS(PN(L)-P(L)).LE.EPP) PN(L)=P(L)
      DELS=2.*(XN(I)-X(I))/(COS(TH(I))+COS(THN(I)))
      TERM2=RHO(I)*Q(I)
      IF(BETA.GT.0.0)TERM2=(TERM2+RHON(I)
     1*QN(I))*.5
      OT=1./TERM2
      QN(I)=(S1D*DELS-PN(I)+P(I))*OT+Q(I)
      IF(ABS(QN(L)-Q(L)).LE.EPQ) QN(L)=Q(L)
      IF(BETA.EQ.0.0)CPXN(I)=CPX(I)
      DTCHEM=DTCH(I)+(PN(I)-P(I))*(QN(I)+Q(I))/(CPX(I)+CPXN(I))*EIN*OT
      DTDIFF=S2D*DELS*EIN*2./(CPX(I)+CPXN(I))*OT
      TN(I)=T(I)+DTCHEM+DTDIFF
      IF(ABS(TN(L)-T(L)).LE.EPT) TN(L)=T(L)
```

```
      CPXN(I)=0.0
      WN(I)=0.0
      CALL THERMO(TN(I),H1,CP1)
      DO4080J=1, NSP
      DALDIF(J)=S3D(J)*DELS/TERM2
      ALPN(J,I)=ALP(J,I)          +DALDIF(J)+DACH(J,I)
      HN(J,I)=H1(J)
      CPN(J,I)=CP1(J)
      WN(I)=WN(I)+ALPN(J, I)/WTMOLE(J)
      CPXN(I)=CPXN(I)+ALPN(J, I)*CPN(J, I)
4080  CONTINUE
      WN(I)=1./WN(I)
      RN(I)=RO/WN(I)
      GAMN(I)=CPXN(I)/(CPXN(I)-RN(I)/CPIN)
      OR=1./RN(I)
      RHON(I)=PN(I)*WN(I)*GEW/TN(I)
      EMN(I)=QN(I)*EMINF*SQRT(GAR/GAMN(I)*OR/TN(I))
      XMUN(I)=ZMU(EMN(I))
      RETURN
      END
      FUNCTION DERY(X1,X2,X3)
      COMMON/QR/DEL1,DEL2,RAT1,RAT2,SUM
      DERY=(X1*RAT1-X2*(RAT1-RAT2)-X3*RAT2)/SUM
      RETURN
      END
      SUBROUTINE THSSS(THSS)
      COMMON/AX/JSUBL,JSUBU
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/QR/DEL1,DEL2,RAT1,RAT2,SUM
      COMMON/RS/GPMS,PS,THS,THSL,THSU
      JSUBP=JSUBU+1
      JSUBM=JSUBU-1
      CALL SHEAR(JSUBP,ASH1)
      CALL SHEAR(JSUBU,ASH2)
      CALL SHEAR(JSUBM,ASH3)
      EMS=0.
      DEL2=Y(JSUBP)-Y(JSUBU)
      DEL1=Y(JSUBU)-Y(JSUBM)
      SUM=DEL2+DEL1
      RAT1=DEL1/DEL2
      RAT2=DEL2/DEL1
      AY=DERY(ASH1,ASH2,ASH3)
      COSTH=COS(TH(JSUBU))
      TERM1=-AY*COSTH
      EMY=DERY(EM(JSUBP),EM(JSUBU),EM(JSUBM))
      TANTH=TAN(TH(JSUBU))
      EMNN=EMY/COSTH-EMS*TANTH
      GPM=GAM(JSUBU)*P(JSUBU)*EM(JSUBU)**2
      TERM2=2.*COSTH*EM(JSUBU)*EMNN*PS
```

```
      GPMY=DERY(GAM(JSUBP)*P(JSUBP)*EM(JSUBP)**2,GPM,GAM(JSUBM)*P(JSUBM)
     1*EM(JSUBM)**2)
      GPMN=GPMY/COSTH-GPMS*TANTH
      THY=DERY(TH(JSUBP),TH(JSUBU),TH(JSUBM))
      THNN=THY/COSTH-THS*TANTH
      TERM3=GPMN*COSTH*THNN
      TERM4=-GPMS*COSTH*COSTH*(EM(JSUBU)**2-1.)*THS
      THSY=DERY(THSU,THS,THSL)
      TERM5=GPM*SIN(TH(JSUBU))*THSY
      THYP=DERY(TH(JSUBP+1),TH(JSUBP),TH(JSUBU))
      THYL=DERY(TH(JSUBU),TH(JSUBM),TH(JSUBM-1))
      THNNP=THYP/COSTH-THSU*TANTH
      THNNL=THYL/COSTH-THSL*TANTH
      THNY=DERY(THNNP,THNN,THNNL)
      TERM6=-GPM*COSTH*THNY
      D=GPM*(EM(JSUBU)**2*COSTH*COSTH-1.)
      XNUM=TERM1+TERM2+TERM3+TERM4+TERM5+TERM6
      THSS=XNUM/D
      RETURN
      END
      FUNCTION ZMU(EM)
      ZMU=ATAN(1.0/SQRT(EM*EM-1.0))
      RETURN
      END
      SUBROUTINE THERMO(TI,H,CB)
      COMMON/ED/CPIN,RO
      COMMON/HK/RCO2,RH2O,WFUEL
      COMMON/TW/TIN
      DIMENSION WTMOLE(9)
      DIMENSION H(7),CB(7)
      DIMENSION Q(9),AP(9)
      WTMOLE(1)=1.008
      WTMOLE(2)=16.0
      WTMOLE(3)=18.016
      WTMOLE(4)=2.016
      WTMOLE(5)=32.0
      WTMOLE(6)=17.008
      WTMOLE(7)=28.014
      WTMOLE(8)=44.011
      WTMOLE(9)=WFUEL
      T=TI*TIN
      C1=RO/CPIN
      C2=C1/TIN
      DO 10 J=1,9
      H1=C2/WTMOLE(J)
      H2=C1/WTMOLE(J)
      CALL COEFF(J,T,A,B,C,D,E,F,G)
      Q(J)=T*(A+T*(B*.5+T*(C/3.+T*(D*.25+E*.2*T))))+F
      Q(J)=Q(J)*H1
```

```
      AP(J)=A+T*(B+T*(C+T*(D+E*T)))
      AP(J)=AP(J)*H2
   10 CONTINUE
      H(1)=Q(1)
      H(2)=Q(2)
      H(3)=RH2O*Q(3)+RCO2*Q(8)
      H(4)=Q(4)
      H(5)=Q(5)
      H(6)=Q(6)
      H(7)=Q(7)
      CB(1)=AP(1)
      CB(2)=AP(2)
      CB(3)=RH2O*AP(3)+RCO2*AP(8)
      CB(4)=AP(4)
      CB(5)=AP(5)
      CB(6)=AP(6)
      CB(7)=AP(7)
      RETURN
      END
      SUBROUTINE TBL(TX,TEMPY,X,Y,N)
      DIMENSION X(1),Y(1)
      DO 10 J5=1,N
      IF(TX-X(J5)) 8,9,10
    8 J6=J5-1
      TEMPY=Y(J6)+(Y(J5)-Y(J6))*(TX-X(J6))/(X(J5)-X(J6))
      GO TO 11
    9 TEMPY=Y(J5)
      GO TO 11
   10 CONTINUE
   11 RETURN
      END
      FUNCTION XM1(ALPHA,BETA,TA,XA,TC,XC)
      XM1=ALPHA*TAN(TA+XA)
      IF(BETA.GT.0.)XM1=XM1+BETA*TAN(TC+XC)
      RETURN
      END
      FUNCTION XM2(AL,B,TA,XA,TC,XC)
      XM2=AL*TAN(TA-XA)
      IF(B.GT.0.)XM2=XM2+B*TAN(TC-XC)
      RETURN
      END
      FUNCTION XM3(A,B,TD,TC)
      XM3=A*TAN(TD)
      IF(B.GT.0.0)XM3=XM3+B*TAN(TC)
      RETURN
      END
      SUBROUTINE HOCUS(TI,P1,U1,RHO1,ALPHA,DX,L)
      COMMON/AC/IBOD,PIN
      COMMON/BC/IOCHEM
```

```
      COMMON/CA/WDOTN(7,55),XN(55)
      COMMON/GE/RAD,ROO,UIN,VISINF
       COMMON/HI/DALCH(7),DTCHEM
      COMMON/PO/ALPHN(7),IFUEL,PRES
      COMMON/QS/RHOP(2),WDOT(7,55),WDOTC(7),WP(2),XMUP(2)
      COMMON/TW/TIN
      DIMENSION ASAVE(7),WTMOLE(7),ALPHA(7)
      WTMOLE(1)=1.008
      WTMOLE(2)=16.
      WTMOLE(3)=18.016
      WTMOLE(4)=2.016
      WTMOLE(5)=32.0
      WTMOLE(6)=17.008
      WTMOLE(7)=28.014
      TXX=TI
      PXX=P1
      UXX=U1
      TERM=RHO1*U1
      TI=TI*TIN*.001
      P1=P1/PIN*PRES/2116.
      U1=U1*UIN
      DELTAT=4.E-7
      DELTAX=U1*DELTAT
      JER=INT(DX/DELTAX)
      IF (JER.EQ.0) JER=1
      DELX=DX/FLOAT(JER)
      TSAVE=TI
      DO 201 J=1,7
  201 ASAVE(J)=ALPHA(J)
      DT=DELX/U1
      P=P1
      OP=2116./89517.
      RH=P*OP/TI*.001
      DO 10 JERRY=1,JER
      P=P1
      DUM=0.0
      DO 96 J=1,7
   96 DUM=DUM+ASAVE(J)/WTMOLE(J)
      RHOI=RH/DUM
        IF(IOCHEM.EQ.0)
     1WRITE(6,250) TI,P,RHOI,ASAVE,DT,TN,ALPHN
  250 FORMAT(* POCUS FROM HOCUS*,10E11.3/17X,10E11.3/)
      CALL POCUS(TI,P,RHOI,ASAVE,DT,TN)
        IF(IOCHEM.EQ.0)
     1WRITE(6,250) TI,P,RHOI,ASAVE,DT,TN,ALPHN
        IF(IOCHEM.EQ.0)
     1WRITE(6,232)
  232 FORMAT(//)
      IF(JERRY.NE.1) GO TO 100
```

```
      DO 110 J=1,7
  110 WDOT(J,L)=TERM*(ALPHN(J)-ASAVE(J))/DELX
  100 CONTINUE
      IF(JERRY.EQ.JER)GO TO 10
      TI=TN
      DO 20 J=1,7
   20 ASAVE(J)=ALPHN(J)
   10 CONTINUE
      DTCHEM=(TN-TSAVE)*1000./TIN
      DO 40 J=1,7
      DALCH(J)=ALPHN(J)-ALPHA(J)
   40 WDOTN(J,L)=TERM*(ALPHN(J)-ASAVE(J))/DELX
      TI=TXX
      P1=PXX
      U1=UXX
      RETURN
      END
      SUBROUTINE COEFF(I,T,A    ,B    ,C    ,D    ,E    ,F    ,G    )
      IF(T-1000)10,10,20
   10 GO TO (15,16,13,11,12,17,14,18,19),I
   11 A    = 2.8460849E 00
      B    = 4.1932116E-03
      C    =-9.6119332E-06
      D    = 9.5122662E-09
      E    =-3.3093421E-12
      F    =-9.6725372E 02
      G    =-1.4117850E 00
      GO TO 40
   12 A    = 3.7189946E 00
      B    =-2.5167288E-03
      C    = 8.5837353E-06
      D    =-8.2998716E-09
      E    = 2.7082180E-12
      F    =-1.0576706E 03
      G    = 3.9080704E 00
      GO TO 40
   13 A    = 4.1565016E 00
      B    =-1.7244334E-03
      C    = 5.6982316E-06
      D    =-4.5930044E-09
      E    = 1.4233654E-12
      F    =-3.0288770E 04
      G    =-6.8616246E-01
      GO TO 40
   14 A    = 3.6916148E 00
      B    =-1.3332552E-03
      C    = 2.6503100E-06
      D    =-9.7688341E-10
      E    =-9.9772234E-14
```

```
      F    =-1.0628336E 03
      G    = 2.2874980E 00
      GO TO 40
   15 A    = 2.5000000E 00
      B    = 0.0
      C    = 0.0
      D    = 0.0
      E    = 0.0
      F    = 2.5470497E 04
      G    =-4.6001096E-01
      GO TO 40
   16 A    = 3.0218894E 00
      B    =-2.1737249E-03
      C    = 3.7542203E-06
      D    =-2.9947200E-09
      E    = 9.0777547E-13
      F    = 2.9137190E 04
      G    = 2.6460076E 00
      GO TO 40
   17 A    = 3.8234708E 00
      B    =-1.1187229E-03
      C    = 1.2466819E-06
      D    =-2.1035896E-10
      E    =-5.2546551E-14
      F    = 3.5852787E 03
      G    = 5.8253029E-01
      GO TO 40
   18 A=2.1701
      B=1.0378E-02
      C=-1.07339E-05
      D=6.34592E-09
      E=-1.62807E-12
      F=-4.83526E+04
      G=10.6644
      GO TO 40
   19 A=2.49125
      B=7.64362E-03
      C=7.97754E-06
      D=-1.29578E-08
      E=5.03078E-12
      F=-5421.86
      G=0.
      GO TO 40
   20 GO TO (25,26,23,21,22,27,24,28,29),I
   21 A    = 3.0436897E 00
      B    = 6.1187110E-04
      C    =-7.3993551E-09
      D    =-2.0331907E-11
      E    = 2.4593791E-15
```

```
      F    =-8.5491002E 02
      G    =-1.6481339E 00
      GO TO 40
   22 A    = 3.5976129E 00
      B    = 7.8145603E-04
      C    =- 2.2386670E-07
      D    = 4.2490159E-11
      E    =-3.3460204E-15
      F    =-1.1927918E 03
      G    = 3.7492659E 00
      GO TO 40
   23 A    = 2.6707532E 00
      B    = 3.0317115E-03
      C    =-8.5351570E-07
      D    = 1.1790853E-10
      E    =-6.1973568E-15
      F    =-2.9888994E 04
      G    = 6.8838391E 00
      GO TO 40
   24 A    = 2.8545761E 00
      B    = 1.5976316E-03
      C    =-6.2566254E-07
      D    = 1.1315849E-10
      E    =-7.6897070E-15
      F    =-8.9017445E+02
      G    = 6.3902879E 00
      GO TO 40
   25 A    = 2.5000000E 00
      B    = 0.0
      C    = 0.0
      D    = 0.0
      E    = 0.0
      F    = 2.5470497E 04
      G    =-4.6001096E-01
      GO TO 40
   26 A    = 2.5372567E 00
      B    =-1.8422190E-05
      C    =-8.8017921E-09
      D    = 5.9643621E-12
      E    =-5.5743608E-16
      F    = 2.9230007E 04
      G    = 4.9467942E 00
      GO TO 40
   27 A    = 2.8895544E 00
      B    = 9.9835061E-04
      C    =-2.1879904E-07
      D    = 1.9802785E-11
      E    =-3.8452940E-16
      F    = 3.8811792E 03
```

```
      G    = 5.5597016E 00
      GO TO 40
   28 A=4.41293
      B=3.19229E-03
      C=-1.2978E-06
      D=2.4147E-10
      E=-1.6743E-14
      F=-4.8944E+04
      G=-.72876
      GO TO 40
   29 A=3.16941
      B=1.02274E-02
      C=-3.85032E-06
      D=6.77198E-10
      E=-4.50135E-14
      F=-5845.93
      G=0.
   40 RETURN
      END
      FUNCTION S2(XJ,RE)
      COMMON/EG/EIN,PR,XLE
      COMMON/SS/AL1,AL2,BQ1,BQ2,C1,C2,CH1,CH2,DB1,DB2,DD1,DD2,DT1,DT2,DV
     A1,DV2,PX1,PX2,TA1,TA2,TH1,TH2,V1,V2,Y1,Y2
      RPR=1./PR
      TERM1=V1*C1*DB1*RPR+V2*C2*DB2*RPR
      TERM2=C1*DV1*BQ1*RPR+C2*DV2*BQ2*RPR
      TERM3=(V1*BQ1*CH1+V2*BQ2*CH2)*XLE*RPR
      TERM4=(V1*BQ1*PX1+V2*BQ2*PX2)*RPR
      TERM5=(V1*TA1**2+V2*TA2**2)*EIN
      IF(XJ.NE.0.) GO TO 10
      TERM6=0.
      GO TO 2
   10 YT=Y1*Y2
      IF(YT.LE.1.E-10) GO TO 20
      TERM6=V1*C1*BQ1*COS(TH1)/Y1*RPR+V2*C2*BQ2*COS(TH2)/Y2*RPR
      GO TO 2
   20 CONTINUE
      TERM6=V1*C1*DB1*RPR+V2*C2*DB2*RPR
    2 S2=(TERM1+TERM2+TERM3+TERM4+TERM5+TERM6)/RE*.5/EIN
      RETURN
      END
      FUNCTION S3(XJ,RE)
      COMMON/EG/EIN,PR,XLE
      COMMON/SS/AL1,AL2,BQ1,BQ2,C1,C2,CH1,CH2,DB1,DB2,DD1,DD2,DT1,DT2,DV
     A1,DV2,PX1,PX2,TA1,TA2,TH1,TH2,V1,V2,Y1,Y2
      RPR=1./PR
      TERM1=V1*DD1+V2*DD2
      TERM2=DV1*AL1+DV2*AL2
      IF(XJ.NE.0.) GO TO 10
```

```
      TERM3=0.
      GO TO 2
   10 YT=Y1*Y2
      IF(YT.LE.1.E-10) GO TO 20
      TERM3=COS(TH1)*V1*AL1/Y1+COS(TH2)*V2*AL2/Y2
      GO TO 2
   20 CONTINUE
      TERM3=TERM1
    2 S3=(TERM1+TERM2+TERM3)*XLE*RPR/RE*.5
      RETURN
      END
      FUNCTION F1(M)
      COMMON/BO/GAMB,PB,QB,RHOB,THB,WB,XMUB,YB
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     1L,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      RP=1./PB
      F1=SIN(XMUB)*COS(XMUB)/GAMB*RP
      RPN=1./PN(M)
      IF(BETA.GT.0.)F1=(F1+SIN(XMUN(M))*COS(XMUN(M))/GAMN(M)*RPN)*.5
      RETURN
      END
      FUNCTION F2(M,S11,S21,S31)
      COMMON/BO/GAMB,PB,QB,RHOB,THB,WB,XMUB,YB
      COMMON/DP/YN(55)
      COMMON/HL/ALPHA,BETA
      COMMON/HM/ALPN(7,55),CPN(7,55),CPXN(55),EMN(55),GAMN(55),HN(7,55),
     IL,PN(55),QN(55),RHON(55),RN(55),THN(55),TN(55),WN(55),XMUN(55)
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/WV/NPTS,RE,XBP,XJ
      IF(XJ.EQ.0.0)TERM1=0.0
      IF(XJ.NE.0.)TERM1=SIN(THB)/YB
      IF(XJ.NE.0..AND.BETA.GT.0.)TERM1=.5*(TERM1+SIN(THN(M))/YN(M))
      QS=1./QB**2
      TERM2=S11/RHOB*QS
      SQ=1./QN(M)**2
      IF(BETA.GT.0.)TERM2=.5*(TERM2+S11/RHON(M)*SQ)
      P1=1./PB
      TERM3=S21*(GAMB-1.)/GAMB*P1/QB
      P2=1./PN(M)
      IF(BETA.GT.0.)TERM3=.5*(TERM3+S21*(GAMN(M)-1.)/GAMN(M)*P2/QN(M))
      RQ=1./QB
      TERM4=S31*WB/RHOB*RQ
      QD=1./QN(M)
      IF(BETA.GT.0.)TERM4=.5*(TERM4+S31*WN(M)/RHON(M)*QD)
      F2=(TERM1+TERM2-TERM3-TERM4)
      RETURN
      END
      FUNCTION F4(B,OPT,XMU1,TH1,XMU2,TH2)
```

```
      F4=SIN(XMU1)/COS(TH1+OPT*XMU1)
      IF(B.GT.0.)F4=(F4+SIN(XMU2)/COS(TH2+OPT*XMU2))*.5
      RETURN
      END
      SUBROUTINE HERMAN(YN,DT,A,Y,CI,BB,CC,SCALE)
      DIMENSION P(10,10),SMALB(10),Q(10),A(10,10),Y(7),YN(7),CI(4),FINK(
     14)
      TIM1=DT/2.0
      TIM2=DT
      T0=TIM1**2
      T1=(DT**2-T0)*.5
      T2=(DT**3-TIM1*T0)/3.0
      T3=T0*.5
      T4=TIM1*T0/3.0
      K=1
      DO 19 I=1,4
      DO 10 J=1,4
      P(K,J)=-A(I,J)*T3
   10 P(K+1,J)=-A(I,J)*T1
   19 K=K+2
      K=1
      DO 20 I=1,4
      DO 11 J=1,4
      P(K,J+4)=-A(I,J)*(T4)
   11 P(K+1,J+4)=-A(I,J)*(T2)
   20 K=K+2
      J=1
      DO 12 I=1,8,2
      S=1./SCALE
      P(I,J)=P(I,J)+TIM1*S
      P(I,J+4)=P(I,J+4)+T0*S
      K=I+1
      P(K,J)=P(K,J)+(TIM2-TIM1)*S
      P(K,J+4)=P(K,J+4)+2.*T1*S
      J=J+1
   12 CONTINUE
      DO 13 I=1,8
   13 Q(I)=0.0
      FINK(1)=Y(1)
      FINK(2)=Y(2)
      FINK(3)=Y(6)
      FINK(4)=Y(3)
      K=1
      DO 15 I=1,4
      DO 14J=1,4
   14 Q(K)=Q(K)+A(I,J)*FINK(J)*(TIM2-TIM1)
      Q(K+1)=Q(K)
   15 K=K+2
      DO 16 I=1,4
```

```
      J=2*I
      Q(J-1)=Q(J-1)+CI(I)*(TIM2-TIM1)
   16 Q(J)=Q(J)+CI(I)*(TIM2-TIM1)
      DO 202 I=1,8
      Q(I)=Q(I)/1.0E-5
      DO 202 J=1,8
  202 P(I,J)=P(I,J)/1.0E-5
      CALL CLEM(8,SMALB,P,Q)
      CALL SOLT(SMALB,DT,CC,BB,Y,YN)
      RETURN
      END
      SUBROUTINE CLEM(M,X,B,D)
      DIMENSION AT(10,11),X(10)
      DIMENSION B(10,10),D(10)
      M1=M+1
      DO 12 I=1,M
   12 X(I)=0.0
      DO 200 I=1,M
  200 AT(I,M1)=D(I)
      DO 201 I=1,M
      DO 201 J=1,M
  201 AT(I,J)=B(I,J)
      DO 32 N=1,M
      D=AT(N,N)
      IT=0
      DO 9 I=N,M
      IF(ABS(AT(I,N))-ABS(D)) 9,9,8
    8 D=AT(I,N)
      IT=I
    9 CONTINUE
      IF(IT-N)7,7,70
   70 DO 71 J=N,M1
      TEMP=AT(N,J)
      AT(N,J)=AT(IT,J)
   71 AT(IT,J)=TEMP
    7 DO 10 I=1,M1
   10 AT(N,I)=AT(N,I)/D
      IF(M-N)50,50,18
   18 N1=N+1
      DO 30 I=N1,M
      D=AT(I,N)
      DO 30 J=N,M1
   30 AT(I,J)=AT(I,J)-AT(N,J)*D
   32 CONTINUE
   50 X(M)=AT(M,M+1)
      DO 65 N=2,M
      NR=M+1-N
      D=AT(NR,M+1)
      DO 60 I=NR,M
```

```
60 O=O-AT(NR,I)*X(I)
65 X(NR)=O/AT(NR,NR)
   RETURN
   END
   SUBROUTINE SOLT(SMALB,DT,CC,BB,Y,YN)
   DIMENSION SMALB(10),Y(7),YN(7)
   TIME=DT
   TNX=TIME**2
   YN(1)=Y(1)+SMALB(1)*TIME+SMALB(5)*TNX
   YN(2)=Y(2)+SMALB(2)*TIME+SMALB(6)*TNX
   YN(6)=Y(6)+SMALB(3)*TIME+SMALB(7)*TNX
   YN(3)=Y(3)+SMALB(4)*TIME+SMALB(8)*TNX
   YN(4)=CC-(YN(1)+YN(6))*.5-YN(3)
   YN(5)=BB-(YN(2)+YN(6)+YN(3))*.5
   RETURN
   END
   FUNCTION S1(XJ,RE)
   COMMON/SS/AL1,AL2,BQ1,BQ2,C1,C2,CH1,CH2,DB1,DB2,DD1,DD2,DT1,DT2,DV
  A1,DV2,PX1,PX2,TA1,TA2,TH1,TH2,V1,V2,Y1,Y2
   TERM1=V1*DT1+V2*DT2
   TERM2=DV1*TA1+DV2*TA2
   IF(XJ.NE.0.) GO TO 10
   TERM3=0.
   GO TO 2
10 YT=Y1*Y2
   IF(YT.LE.1.E-10) GO TO 20
   TERM3=COS(TH1)*V1*TA1/Y1+COS(TH2)*V2*TA2/Y2
   GO TO 2
20 CONTINUE
   TERM3=TERM1
 2 S1=(TERM1+TERM2+TERM3)/RE*.5
   RETURN
   END
   SUBROUTINE PUNCH
   COMMON/AC/IBOD,PIN
   COMMON/BA/ALP(7,55),EMINF,WINF
   COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
   COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
   COMMON/EG/EIN,PR,XLE
   COMMON/FH/XK1,XK3,XPOT
   COMMON/HJ/KOUNT,LL,NPT
   COMMON/PQ/ALPHN(7),IFUEL,PRES
   COMMON/PQ/JCHEM,NSP,T(55),PTZERO,IDIVERG,TH1,XE,YE,RCR,PTOJ,TOJ
  1,EM1,XMU1,Q1
   COMMON/WAVE/XBOD(5),XWALL(5),AABOD(5),BBBOD(5),CCBOD(5),EEBOD(5),
  ZFFBOD(5),GGBOD(5),LWALL,LBOD,III,JJJ
   COMMON/TW/TIN
   COMMON/WV/NPTS,RE,XBP,XJ
   COMMON/XY/APRS,APUS,DELTAY,EBODS,IBODS,INTACT,IPRS,IPUS,ITYP,
```

```
     1JBODS,MMAX,RHEAT,XK2,XK4,YBOT,YTP
      COMMON/YX/ABODS,BPRESS,CPRESS
      COMMON/YZ/BPRESU,CHEMFC,CPRESU,EMSUB,RTH,XSTEP
      COMMON/ZY/ABOD,BBOD,CBOD,EBOD,FBOD,GBOD,IAVE,IPUNCH,JBOD,KKKKK
      COMMON/1/MASFRAC
      REAL MASFRAC(7)
      REWIND 7
  100 FORMAT(16I5)
  101 FORMAT(8E10.3)
  200 FORMAT(I5,5X,7E10.3)
  102 FORMAT(7E10.3,F10.5)
  103 FORMAT(5F10.5)
  104 FORMAT(7E11.4)
      WRITE(7,100) KKKKK ,LL
      WRITE(7,200)IPUNCH,XSTEP,PTZERO,XE,YE,RCR,PTOJ,TOJ
      INTACT=0
      ISHOCK=0
      DO 1111 I=1,IDD
 1111 IF(IS(I).NE.0) ISHOCK=1
      WRITE(7,100)NPTS,NPT,ITYP,ISHOCK,MMAX,KOUNT
      WRITE(7,100)JCHEM,IAVE,INTACT,IDIVERG,IDD
      WRITE(7,102)XJ,       EMSUB,RTH,DELTAY,YBOT,YTP,CHEMFC,XBP
      RQ=RE/RTH
      WRITE(7,101)RQ,PR,XLE,EMINF,TIN,WINF,PRES
      WRITE(7,101)XPOT,XK1,XK2,XK3,XK4
      WRITE(7,200) IBODS,ABOD,BBOD,CBOD
      IF(IBODS.EQ.0) GO TO 3333
      WRITE(7,100)III
      IF(III.LE.0) GO TO 3333
      DO 2 I=1,III
    2 WRITE(7,101) XBOD(I),AABOD(I),BBBOD(I),CCBOD(I)
 3333 CONTINUE
      WRITE(7,200)JBODS,EBODS,FBOD,GBOD
      IF(JBODS.EQ.0) GO TO 333
      WRITE(7,100)JJJ
      IF(JJJ.LE.0) GO TO 333
      DO 6 I=1,JJJ
    6 WRITE(7,101)XWALL(I),EEBOD(I),FFBOD(I),GGBOD(I)
  333 CONTINUE
      WRITE(7,100) LWALL,LBOD
      WRITE(7,200)IPRS,APRS     ,BPRESS,CPRESS
      WRITE(7,200)IPUS,APUS     ,BPRESU,CPRESU
      IF(ISHOCK.EQ.0) GO TO 5
      WRITE(7,100)(IS(I),I=1,IDD)
      WRITE(7,101)(BETB(I),I=1,IDD)
    5 CONTINUE
      DO 10 I=1,NPTS
      A    =P(I)/PIN
      ALP7=ALP(7,I)-ALP(4,I)*(1.-RHEAT)
```

```
      ALP4=ALP(4,I)/RHEAT
      WRITE(7,103)Y(I),A    ,TH(I),EM(I),T(I)
      WRITE(7,104) ALP(1,I),ALP(2,I),ALP(3,I),ALP4,ALP(5,I),ALP(6,I),ALP
     17
   10 CONTINUE
      WRITE(7,101)(MASFRAC(I),I=1,7)
      REWIND 7
      END
      SUBROUTINE INDATA
      COMMON/AC/IBOD,PIN
      COMMON/AL/GAR,GEW
      COMMON/BA/ALP(7,55),EMINF,WINF
      COMMON/BD/XMASS(55)
      COMMON/CJ/CP(7,55),CP1(7),CPX(55)
      COMMON/CK/WTMOLE(7)
      COMMON/DB/BETB(20),IS(20),IDD,IJENK,JENKI
      COMMON/ED/CPIN,RO
      COMMON/EF/EM(55),GAM(55),P(55),TH(55),Y(55)
      COMMON/EG/EIN,PR,XLE
      COMMON/EP/GAMINF,H1(7),RINF
      COMMON/FH/XK1,XK3,XPOT
      COMMON/GE/RAD,ROO,UIN,VISINF
      COMMON/GF/DELY,IFS,KOUNTO,MMM
      COMMON/HJ/KOUNT,LL,NPT
      COMMON/HK/RCO2,RH2O,WFUEL
      COMMON/OR/THBP,YBP,YBPN
      COMMON/PD/W(55),X(55)
      COMMON/PO/ALPHN(7),IFUEL,PRES
      COMMON/PQ/JCHEM,NSP,T(55),PTZERO,IDIVERG,TH1,XE,YE,RCR,PTOJ,TOJ
     1,EM1,XMU1,Q1
      COMMON/QA/H(7,55),Q(55),RHO(55),XMU(55)
      COMMON/RC/R(55)
      COMMON/TW/TIN
      COMMON/UV/II11,IERR,IPRESS,IPRESU,ISUB
      COMMON/WV/NPTS,RE,XBP,XJ
      COMMON/WX/APRESS,APRESU
      COMMON/XY/APRS,APUS,DELTAY,EBODS,IBODS,INTACT,IPRS,IPUS,ITYP,
     1JBODS,MMAX,RHEAT,XK2,XK4,YBOT,YTP
      COMMON/YX/ABODS,BPRESS,CPRESS
      COMMON/YZ/BPRESU,CHEMFC,CPRESU,EMSUB,RTH,XSTEP
      COMMON/ZY/ABOD,BBOD,CBOD,EBOD,FBOD,GBOD,IAVE,IPUNCH,JBOD,KKKKK
      COMMON/WAVE/XBOD(5),XWALL(5),AABOD(5),BBBOD(5),CCBOD(5),EEBOD(5),
     ZFFBOD(5),GGBOD(5),LWALL,LBOD,III,JJJ
      COMMON/1/MASFRAC
      REAL MASFRAC(7)
      DIMENSION CPINJ(7)
      IIN=5
      ISUB=0
      XBP=0.
```

```
      YBP=10000.
      THBP=0.
      RAD=0.
      IFUEL=1
      WFUEL=2.016
  100 FORMAT(16I5)
  101 FORMAT(8E10.0)
  404 FORMAT(7E11.4)
  200 FORMAT(I5,5X,7E10.0)
      READ(IIN,100)        KKKKK,LL
      READ(IIN,200) IPUNCH,XSTEP,PTZERO,XE,YE,RCR,PTOJ,TOJ
      READ(IIN,100) NPTS,NPT,ITYP,ISHOCK,MMAX,KOUNT
      READ(IIN,100)JCHEM,IAVE,INTACT,IDIVERG,IDD
      IF(KOUNT.LT.1) KOUNT=0
      KOUNTO=KOUNT
      WRITE(6,111) KKKKK,LL
  111 FORMAT(8H1KKKKK =I5,5X,4HLL =I3/)
      WRITE(6,112)IPUNCH,XSTEP,PTZERO,IDIVERG,IDD
  112 FORMAT(9H IPUNCH =I2,5X,7HXSTEP =E10.3,5X,8HPTZERO =E10.3,5X,9HIDI
     6VERG =I2,5X,6HIDD = I2/)
      WRITE(6,1112)XE,YE,RCR,PTOJ,TOJ
 1112 FORMAT(1X,*XE,YE,RCR,PTOJ,TOJ*,8E10.3/)
      WRITE(6,113) NPTS,NPT,ITYP,ISHOCK,MMAX
  113 FORMAT(7H NPTS =I3,5X,5HNPT =I2,5X,6HITYP =I2,5X,8HISHOCK =I2,5X,6
     1HMMAX =I3/)
      WRITE(6,114) JCHEM,IAVE,            INTACT
  114 FORMAT(8H JCHEM =I2,5X,6HIAVE =I2,5X,
     18HINTACT =I2/)
      IF(ITYP.NE.2.AND.ITYP.NE.4) GO TO 12
      IF(INTACT.EQ.0.AND.ISHOCK.EQ.0) GO TO 12
      WRITE(6,9191)
 9191 FORMAT(1H1)
      WRITE(6,102)
  102 FORMAT(91H TYPE 2 OR TYPE 4 FLOWS MAY NOT START WITH SHOCKS OR HAV
     6E SHOCKS COMING OFF SPLITTER PLATES/43H RECHECK INPUTS AND SUBMIT
     1WITH PROPER TYPE)
      STOP
   12 CONTINUE
  104 READ(IIN,101) XJ,       EMSUB,RTH,DELTAY,YBOT,YTP,CHEMFC,XBP
      READ(IIN,101) RE,PR,XLE,EMINF,TIN,WINF,PRES
      READ(IIN,101) XPOT,XK1,XK2,XK3,XK4
      READ(IIN,200) IBOD,ABOD,BBOD,CBOD
      IF(IBOD.EQ.0) GO TO 1
      READ(5,100) III
      IF(III.LE.0) GO TO 1
      DO 2 I=1,III
    2 READ(5,101) XBOD(I),AABOD(I),BBBOD(I),CCBOD(I)
    1 CONTINUE
      READ(IIN,200) JBOD,EBOD,FBOD,GBOD
```

```
      IF(JBOD.EQ.0) GO TO 4
      READ(5,100) JJJ
      IF(JJJ.LE.0) GO TO 4
      DO 6 I=1,JJJ
    6 READ(5,101)XWALL(I),EEBOD(I),FFBOD(I),GGBOD(I)
    4 CONTINUE
      READ(IIN,100) LWALL,LBOD
      IF((LBOD-1).EQ.0)                          GO TO 97777
      ABOD=AABOD(LBOD-1)
      BBOD=BBBOD(LBOD-1)
      CBOD=CCBOD(LBOD-1)
97777 CONTINUE
      IF((LWALL-1).EQ.0)                           GO TO 93333
      EBOD=EEBOD(LWALL-1)
      FBOD=FFBOD(LWALL-1)
      GBOD=GGBOD(LWALL-1)
93333 CONTINUE
      READ(IIN,200) IPRESS,APRESS,BPRESS,CPRESS
      READ(IIN,200) IPRESU,APRESU,BPRESU,CPRESU
      IF(XBP.LT.0.) XBP=0.
      J=XJ+.5
      XJ=J
      WRITE(6,115) XJ,EMSUB,RTH,DELTAY,YBOT,YTP,CHEMFC
  115 FORMAT(5H XJ =E10.3,2X,7HEMSUB =E10.3,2X,5HRTH =E10.3,2X,8HDELTAY
     1=E10.3,2X,6HYBOT =E10.3,2X,5HYTP =E10.3,2X,8HCHEMFC =E10.3/)
      WRITE(6,116) RE,PR,XLE,EMINF,TIN,WINF,PRES
  116 FORMAT(5H RE =E10.3,2X,4HPR =E10.3,2X,5HXLE =E10.3,2X,7HEMINF =E10
     1.3,2X,5HTIN =E10.3,2X,6HWINF =E10.3,2X,6HPRES =E10.3/)
      WRITE(6,117) XPOT,XK1,XK2,XK3,XK4
  117 FORMAT(7H XPOT =E10.3,2X,5HXK1 =E10.3,2X,5HXK2 =E10.3,2X,5HXK3 =E1
     10.3,2X,5HXK4 =E10.3/)
      WRITE(6,118) IBOD,ABOD,BBOD,CBOD
  118 FORMAT(7H IBOD =I2,2X,6HABOD =E10.3,2X,6HBBOD =E10.3,2X,6HCBOD =E1
     10.3/)
      IF(III.LE.0) GO TO 222
      WRITE(6,500) III
  500 FORMAT(1X,*III=*,I5//,2X,*XBOD,AABOD,BBBOD,CCBOD*)
      DO 22 I=1,III
   22 WRITE(6,1010) XBOD(I),AABOD(I),BBBOD(I),CCBOD(I)
 1010 FORMAT(8E10.3)
  222 CONTINUE
      WRITE(6,119) JBOD,EBOD,FBOD,GBOD
  119 FORMAT(7H JBOD =I2,2X,6HEBOD =E10.3,2X,6HFBOD =E10.3,2X,6HGBOD =E1
     10.3/)
      IF(JJJ.LE.0) GO TO 666
      WRITE(6,501) JJJ
  501 FORMAT(1X,*JJJ=*,I5//,2X,*XWALL,EEBOD,FFBOD,GGBOD*)
      DO 66 I=1,JJJ
   66 WRITE(6,1010)XWALL(I),EEBOD(I),FFBOD(I),GGBOD(I)
```

```
 666 CONTINUE
     WRITE(6,502) LWALL,LBOD
 502 FORMAT(1X,*LWALL=*,I5,6X,*LBOD=*,I5)
     WRITE(6,120) IPRESS,APRESS,BPRESS,CPRESS
 120 FORMAT(9H IPRESS =I2,2X,8HAPRESS =E10.3,2X,8HBPRESS =E10.3,2X,8HCP
    1RESS =E10.3/)
     WRITE(6,121) IPRESU,APRESU,BPRESU,CPRESU
 121 FORMAT(9H IPRESU =I2,2X,8HAPRESU =E10.3,2X,8HBPRESU =E10.3,2X,8HCP
    1RESU =E10.3/)
 411 IBODS=IBOD
     ABODS=ABOD
     IPRS=IPRESS
     APRS=APRESS
     JBODS=JBOD
     EBODS=EBOD
     IPUS=IPRESU
     APUS=APRESU
     IF(ISHOCK.EQ.0) GO TO 5
     READ(IIN,100)(IS(I),I=1,IDD)
     READ(IIN,101)(BETB(I),I=1,IDD)
     WRITE(6,128)(I,IS(I),I=1,IDD)
 128 FORMAT(4(4H IS(,I2,2H)=I3,2X)/)
     WRITE(6,129)(I,BETB(I),I=1,IDD)
 129 FORMAT(4(6H BETB(,I2,2H)=E10.3,2X)/)
   5 CONTINUE
     DO 10 I=1,NPTS
     READ(IIN,101) Y(I),P(I),TH(I),EM(I),T(I)
     READ(IIN,404) (ALP(J,I),J=1,NSP)
  10 CONTINUE
     READ(5,101)(MASFRAC(I),I=1,7)
     WRITE(6,1101)(I,MASFRAC(I),I=1,7)
1101 FORMAT(9H MASFRAC(,I2,2H)=E15.7,2X)
     IF(ITYP.EQ.1)GO TO 4201
     IBOD=0
     JBOD=0
     IF(ITYP.EQ.3) JBOD=JBODS
     IF(ITYP.EQ.4) IBOD=IBODS
4201 RHEAT=1.
     RH2O=1.
     RCO2=0.
4204 WTMOLE(4)=WFUEL
     RE=RE*RTH
     IERR=0
     DO 13 I=1,7
     IF(MASFRAC(I).EQ.0.0) GO TO 13
     CALL COEFF(I,TIN,AZ,BZ,CZ,DZ,HZ,FZ,GZ)
     CPINJ(I)=(AZ+BZ*TIN+CZ*TIN**2+DZ*TIN**3+HZ*TIN**4)*RO/WTMOLE(I)
  13 CONTINUE
     CPIN=0.
```

```
      DO 1313 I=1,7
      CPIN=CPIN+MASFRAC(I)*CPINJ(I)
 1313 CONTINUE
      RINF=RO/WINF
      GAMINF=1./(1.-RINF/CPIN)
      RINFF=ROO/WINF
      UIN=EMINF*SQRT(GAMINF*RINFF*TIN)
      RF=1./RINFF
      RHOINF=PRES*RF/TIN
      VISINF=RHOINF*UIN*RTH/RE
      GAR=GAMINF*RINF
      GEW=GAMINF*EMINF**2/WINF
      EIN= (GAMINF-1.) * EMINF**2
      EMS=1./EMINF**2
      PIN=1./GAMINF*EMS
      WRITE(6,6898)
 6898 FORMAT(////48X,31HP R O G R A M   V I S - C H A R //60X,7HW I T H
     1//42X,43HE M B E D D E D   S U B S O N I C   F L O W//53X,21HS H O
     1 C K   W A V E S//33X,63HA N D   F I N I T E   R A T E   H2 - A I
     1 R   C H E M I S T R Y)
      IF(XJ.EQ.0.) WRITE(6,5610)
      IF(XJ.NE.0.) WRITE(6,5611)
      IF(JCHEM.EQ.0) WRITE(6,5612)
      IF(JCHEM.EQ.1) WRITE(6,5613)
 5610 FORMAT(///10X,31HTYPE OF FLOW IS TWO DIMENSIONAL)
 5611 FORMAT(///10X,28HTYPE OF FLOW IS AXISYMMETRIC)
 5612 FORMAT(10X,19HCHEMISTRY IS FROZEN)
 5613 FORMAT(10X,24HCHEMISTRY IS FINITE RATE)
      WRITE(6,5600) RTH
 5600 FORMAT(
     110X,28HJET OR NOZZLE RADIUS (RTH) = E13.5,4H FT.)
      WRITE(6,5601) EMINF,UIN,TIN,PRES,RHOINF,GAMINF,WINF,RE,PR,XLE
 5601 FORMAT(///20X,20HREFERENCE CONDITIONS/20X,20H--------------------/
     110X,18HMACH NO. (EMINF) = E13.5/10X,16HVELOCITY (UIN) = E13.5,
     1 7H FT/SEC/10X,19HTEMPERATURE (TIN) =E13.5,10H DEGREES K/10X,17HPR
     1ESSURE (PRES) =E13.5,9 H LB/FT**2/10X,18HDENSITY (RHOINF) =E13.5,
     112H SLUGS/FT**3/10X,37
     1HFROZEN SPECIFIC HEAT RATIO (GAMINF) =E13.5/10X,25HMOLECULAR WEIGH
     1T (WINF) =E13.5/10X,22HREYNOLDS NUMBER (RE) =E13.5/10X,21HPRANDTL
     1NUMBER (PR) =E13.5/10X,20HLEWIS NUMBER (XLE) =E13.5)
      WRITE(6,5602)
 5602 FORMAT(///20X,15HOUTPUT HEADINGS/20X,15H---------------/
     110X, 9HX - X/RTH/10X, 9HY - Y/RTH/10X,16HQ - VELOCITY/UIN/10X,
     119HT - TEMPERATURE/TIN/10X,17HP - PRESSURE/PRES/10X,30HTH - FLOW D
     1EFLECTION (RADIANS) /10X,16HEM - MACH NUMBER/10X,20HRHO - DENSITY/
     1RHOINF/10X,19HGAM - SPECIFIC HEAT
     1      /10X,33HXMASS - NON-DIMENSIONAL MASS FLOW
     1                           /10X,23HPHI - EQUIVALENCE RATIO/10X,
     120HW - MOLECULAR WEIGHT//10X14HMASS FRACTIONS/15X10HALP(1) - H/15X
```

```
    110HALP(2) - O/15X,12HALP(3) - H2O/15X,11HALP(4) - H2/15X,11HALP(5)
    1 - O2/15X,11HALP(6) - OH/15X,11HALP(7) - N2)
 413 DO 1774 I=1,NPTS
     X(I)=XBP
     P(I)=P(I)*PIN
     ALP(4,I)=RHEAT*ALP(4,I)
     ALP(7,I)=(1.-RHEAT)*ALP(4,I)+ALP(7,I)
     DO 788 J=1,NSP
 788 IF(ALP(J,I).LT.1.1E-10) ALP(J,I)=1.1E-10
     ALP(7,I)=1.-(ALP(1,I)+ALP(2,I)+ALP(3,I)+ALP(4,I)+ALP(5,I)+ALP(6,I)
    1)
1774 CONTINUE
     DO 8883 I=1,NPTS
     CALL THERMO(T(I),H1,CP1)
     CPX(I)=0.0
     W(I)=0.0
     DO1776 J=1, NSP
     CP(J,I)=CP1(J)
     H(J,I)=H1(J)
     CPX(I)=CPX(I)+ALP(J,I)*CP(J,I)
1776 W(I)=W(I)+ALP(J,I)/WTMOLE(J)
     W(I)=1./W(I)
     RHO(I)=GEW*W(I)*P(I)/T(I)
     R(I)=RO/W(I)
     GAM(I)=CPX(I)/(CPX(I)-R(I)/CPIN)
     OM=1./EMINF
     OR=1./R(I)
     Q(I)=EM(I)*OM/SQRT(GAR/GAM(I)*OR/T(I))
     IF(EM(I).GT.1.)
    1XMU(I)=ATAN(1./SQRT(EM(I)**2-1.))
8883 CONTINUE
     IF(INTACT.EQ.1) CALL COWL
     IF(INTACT.NE.1) GO TO 8401
     DO 3 K3=5,NPTS
     K3K=NPTS+5-K3
     J3=K3K+1
     CALL SWITCH(J3,K3K)
   3 CONTINUE
     NPTS=NPTS+1
     IS(3)=IS(3)+1
     IS(4)=5
     ZMANG=ASIN(1./EM(5))
     BETB(4)=-(ZMANG-TH(5))
8401 XJ1=1.+XJ
     XMASS(1)=0.
     DO 1785 I=1,NPTS
     IF(I.EQ.1) GO TO 1785
     XJ1=1.+XJ
     YFUN=(Y(I)*(1.-XJ+Y(I)*XJ)- Y(I-1)*(1.-XJ+Y(I-1)*XJ))/XJ1
```

```
      RQAV=(RHO(I)*Q(I)*COS(TH(I))+ RHO(I-1)*Q(I-1)*COS(TH(I-1)))/2.
      XMASS(I)=XMASS(I-1)+RQAV*YFUN
 1785 CONTINUE
      DELY=(YBP-Y(1))/FLOAT(NPTS-1)
      RETURN
      END
      FUNCTION F3(TP1,DTC,T1,TC,TH1,THC,DA,W1,WC)
      COMMON/CK/WTMOLE(7)
      COMMON/GK/DELX
      COMMON/HL/ALPHA,BETA
      DIMENSION DA(7)
      NSP=7
      A=ALPHA
      B=BETA
      TERM1=DTC/((A-B)*TP1+B*(T1+TC))
      TERM2=0.
      DO 10 J=1,NSP
      TERM2=TERM2+DA(J)/WTMOLE(J)
   10 CONTINUE
      TERM5=A*W1+B*WC
      TERM2=TERM2*TERM5
      TERM3=A*COS(TH1)+B*COS(THC)
      F3=-(TERM1+TERM2)*TERM3/DELX
      RETURN
      END
      SUBROUTINE POCUS(TI,PRESSI,RHOI,ALPHI,DT,TN)
      COMMON/PO/ALPHN(7),IFUEL,PRES
      DIMENSION ALPHI(7),AD(10,10),CI(10),Y(7),YN(7),ALPHA(7)
      DIMENSION TO(7),T1(7),B(7),C(7),D(7),E(7),G(7),Z(7)
      TO(1)=6.0
      TO(2)=6.0
      TO(3)=0.5
      TO(4)=0.5
      TO(5)=0.5
      TO(6)=0.5
      TO(7)=0.5
      T1(1)=6.0
      T1(2)=6.0
      T1(3)=3.0259
      T1(4)=4.0960
      T1(5)=2.9282
      T1(6)=3.6392
      T1(7)=2.4800
      B(1)=39.7055
      B(2)=2.5674
      B(3)=3.5961
      B(4)=27.4123
      B(5)=1.7771
      B(6)=3.3496
```

```
B(7)=2.0043
C(1)=0.0
C(2)=0.0
C(3)=.5486
C(4)=1.5999
C(5)=.1595
C(6)=.1619
C(7)=.1531
D(1)=0.0
D(2)=0.0
D(3)=-31.7850
D(4)=-34.5288
D(5)=-1.8504
D(6)=1.3139
D(7)=-1.4976
E(1)=0.0
E(2)=0.0
E(3)=6.3657
E(4)=38.9184
E(5)=2.5521
E(6)=4.3679
E(7)=2.6093
G(1)=404.5564
G(2)=29.1774
G(3)=-26.9024
G(4)=-8.088
G(5)=-.522
G(6)=3.4213
G(7)=-.5961
Z(1)=.063
Z(2)=1.0
Z(3)=1.13
Z(4)=.126
Z(5)=2.0
Z(6)=1.063
Z(7)=1.75
PSSSS=PRESSI
KASE=IFUEL
IF(KASE.EQ.2) PRESSI=PRESSI*.35
IF(KASE.EQ.3) PRESSI=.2*PRESSI
RHOI=RHOI*PRESSI/PSSSS
KTEST=0
EL0=1.0
DLTI=0.0
EPS=.001
TIME0=1.38725E-5*EL0
DT=DT/TIME0
P0=PRESSI*1.01325E6
RHO0=P0*1.924465E-10
```

```
      RHOI=RHOI*.5154/RHO0
      PRESSI=1.0
      T=TI
      HI=0.0
      DO 65 I=1,7
      IF(T-T1(I)) 62,61,61
   61 HI=(D(I)+E(I)*T)*ALPHI(I)+HI
      GO TO 65
   62 IF(T-T0(I)) 63,63,64
   63 HI=(G(I)+B(I)*T)*ALPHI(I)+HI
      GO TO 65
   64 HI=(G(I)+B(I)*T+C(I)*(T-T0(I))**2)*ALPHI(I)+HI
   65 CONTINUE
   92 CONTINUE
      JJJ = 25
      JJ=0
      T = TI
      TSAVE=T
      KOUNT=0
      RHO=RHOI
      DELTA=DLTI
      GAMMA=DT*DELTA+1.
      PRESS=PRESSI
      H=HI
      SUMY=0.
      DO 11 I=1,7
      ALPHA(I)=ALPHI(I)
      Y(I)=RHO*ALPHA(I)/Z(I)
      YN(I)=0.0
   11 SUMY=SUMY+Y(I)
      DUM1=8.67031E-7*RHO0*EL0
      DUM2=DUM1*RHO0/16.
      IF(ALPHA(3).GT.1.E-10)GO TO 6
      IF(ALPHA(6).GT.1.E-10) GO TO 6
      IF(ALPHA(5).GT.1.E-10) GO TO 30
      IF(ALPHA(2).GT.1.E-10) GO TO 30
      F5=(1.85E17*EXP (-25./T))*(DUM1*EXP (-29./T)/T)
      B5=1.E16*DUM1*RHO0/16.
      B11=-(F5*.5+2.*B5*Y(1))*SUMY
      CC1=B5*Y(1)**2*SUMY
      CC=GAMMA*(Y(2)+Y(1)*.5)
      C1=F5*CC*SUMY+CC1
      A11=DELTA+B11
      DUM=C1/A11
      YN(1)=-DUM+(Y(1)+DUM)*EXP (A11*DT)
      IF(YN(1).LT.0.0) YN(1)=0.0
      YN(4)=CC-YN(1)*.5
      GO TO 99
   30 IF(ALPHA(4).GT.1.E-10) GO TO 6
```

```
      IF(ALPHA(1).GT.1.E-10) GO TO 6
      F8=(5.8E16*EXP (-30.3/T))*(DUM1*EXP (-30.3/T)/T)
      B8=6.E14*DUM1*RHO0/16.
      B11=-(F8*.5+2.*B8*Y(1))*SUMY
      CC1=B8*Y(1)*Y(1)*SUMY
      BB=GAMMA*(Y(2)+Y(1)*.5)
      C1=F8*BB*SUMY+CC1
      A11=DELTA+B11
      DUM=C1/A11
      YN(1)=-DUM+(Y(1)+DUM)*EXP (A11*DT)
      YN(2)=BB-YN(1)*.5
      IF(YN(2).LT.0.0) YN(2)=0.0
      YN(5)=BB-YN(2)*.5
      GO TO 99
    6 CONTINUE
      KOUNT=1
      IF(KASE.EQ.2) T=1./(1.1087/T-.09497)
      IF(KASE.EQ.3) T=1./(.786/T+.2381)
      F1=3.E14*EXP (-8.81/T)*DUM1
      F2=3.E14*EXP (-4.03/T)*DUM1
      F3=3.E14*EXP (-3.02/T)*DUM1
      F4=F3
      B1=2.48E13*EXP (-.66/T)*DUM1
      B2=1.3E14*EXP (-2.49/T)*DUM1
      B3=1.33E15*EXP (-10.95/T)*DUM1
      B4=3.12E15*EXP (-12.51/T)*DUM1
       T=TSAVE
      TSAVE=T
      IF(KASE.EQ.2) T=1.241+.05524*T
      F6=9.66E18*EXP (-62.2/T)/T*DUM1
      F7=8.00E16*EXP (-52.5/T)/T*DUM1
      B6=1.E17*DUM2
      B7=1.E16*DUM2
      T=TSAVE
      F5=1.85E17*EXP (-54./T)/T*DUM1
      F8=5.80E16*EXP (-60.6/T)/T*DUM1
      B5=1.E16*DUM2
      B8=6.E14*DUM2
      DUM1=(Y(2)+Y(6)+Y(3))*.5
      DUM2=(Y(1)+Y(6))*.5+Y(3)
      DUM3=Y(1)*.5+Y(6)+Y(3)
      DUM4=F1*Y(1)*DUM1+B1*Y(2)*Y(6)
      DUM5=F2*Y(2)*DUM2+B2*Y(1)*Y(6)
      DUM6=F3*Y(6)*DUM2+B3*Y(1)*Y(3)
      DUM7=F4*Y(6)*Y(6)-B4*Y(2)*Y(3)
      DUM8=(F2*.5-B7*SUMY)*Y(2)+B2*Y(6)
      DUM9=(F1*.5-B7*SUMY)*Y(1)+B1*Y(6)
      DUM10=(F2*.5-B1)*Y(2)+(B2-F1*.5)*Y(1)
      DUM11=(F1*.5-B3)*Y(1)-F3*Y(6)
```

```
      DUM12=F1*DUM1-B3*Y(3)-F3*.5*Y(6)
      DUM13=(F8*SUMY+F1*Y(1))*.5
      DUM14=B6*Y(1)*SUMY-F3*DUM3
      DUM15=2.*F4*Y(6)
      DUM16=SUMY*Y(1)
      DUM17=B6*SUMY*Y(6)
      B12=DUM9-F2*DUM2
      B21=DUM8-F1*DUM1
      B19=(F6-F5)*SUMY-F2*Y(2)+DUM11
      B29=(F2-B4)*Y(2)-DUM13
      B91=DUM12+B21-DUM8+DUM17
      B27=SUMY*(F7-F8/2.)+DUM10+DUM15
      B79=F6*SUMY-DUM11+(2.*B4-F2)*Y(2)
      B77=-(DUM14+SUMY*F7+(F1*.5+B2)*Y(1)+(B1+F2*.5)*Y(2)+2.*DUM15)
      B92=-B4*Y(3)
      B22=-SUMY*(2.*B8*Y(2)+B7*Y(1))-B1*Y(6)+F2*DUM2-DUM13+B92
      B11=DUM12-F5*SUMY*.5-(F2*.5+B7*SUMY)*Y(2)-B2*Y(6)-DUM17-2.*B5*DUM1
     16
      B97=DUM14+DUM15
      B99=DUM11-(F1*.5*Y(1)+F6*SUMY+B4*Y(2))
      B71=-(DUM12+DUM8+DUM17)
      B72=2.*B4*Y(3)-DUM9-F2*DUM2
      B17=SUMY*(F7-F5/2.)-DUM10-DUM14-2.*F3*DUM3
      CC1=DUM5-DUM4+DUM6+(B6*Y(6)+B5*Y(1)+B7*Y(2))*DUM16
      CC2=DUM4-DUM5-DUM7+(B7*Y(1)+B8*Y(2))*SUMY*Y(2)
      CC7=DUM4+DUM5-DUM6+2.*DUM7+(B6*Y(6)-B7*Y(2))*DUM16
      CC9=DUM6-DUM7-B6*Y(6)*DUM16
   14 BB=GAMMA*(Y(5)+(Y(2)+Y(6)+Y(3))*.5)
      CC=GAMMA*(Y(4)+Y(3)+(Y(1)+Y(6))*.5)
      AD(1,1)=B11+DELTA-F1*BB
      AD(1,2)=B12+F2*CC
      AD(1,3)=B17+F3*CC
      AD(1,4)=B19
      AD(2,1)=B21+F1*BB
      AD(2,2)=B22+DELTA-F2*CC
      AD(2,3)=B27
      AD(2,4)=B29
      AD(3,1)=B71+F1*BB
      AD(3,2)=B72+F2*CC
      AD(3,3)=B77+DELTA-F3*CC
      AD(3,4)=B79
      AD(4,1)=B91
      AD(4,2)=B92
      AD(4,3)=B97+F3*CC
      AD(4,4)=B99+DELTA
      CI(1)=CC1+F5*SUMY*CC
      CI(2)=CC2+F8*SUMY*BB
      CI(3)=CC7
      CI(4)=CC9
```

```
      SCALE=0.0
      DO 50 I=1,4
      DO 50 J=1,4
   50 SCALE=AMAX1(SCALE,ABS(AD(I,J)))
      DO 51 I=1,4
      DO 52 J=1,4
   52 AD(I,J)=AD(I,J)/SCALE
   51 CI(I)=CI(I)/SCALE
      CALL HERMAN(YN,DT,AD,Y,CI,BB,CC,SCALE)
   99 DO 90 J=1,6
      IF(YN(J).GE.0.0) GO TO 90
      DT=DT/10.
      KTEST=KTEST+1
      IF(KTEST-3) 92,27,27
   90 CONTINUE
      DUM=0.0
      DO 1 J=1,6
    1 DUM=DUM+YN(J)*Z(J)
      RHON=DUM/(1.-ALPHA(7))
      YN(7)=RHON*ALPHA(7)/Z(7)
      SUMYN=0.0
      DO 2 J=1,7
    2 SUMYN=SUMYN+YN(J)
      TT=PRESS/SUMYN
      DO 4 J=1,6
    4 ALPHA(J)=YN(J)*Z(J)/RHON
      AH=0.0
      BH=0.0
      CH=0.0
      DO 505 I=1,7
      IF(TT-T1(I)) 502,501,501
  501 BH=BH-E(I)*ALPHA(I)*.5
      CH=CH+D(I)*ALPHA(I)
      GO TO 505
  502 IF(TT-T0(I)) 503,503,504
  503 BH=BH-B(I)*ALPHA(I)*.5
      CH=CH+G(I)*ALPHA(I)
      GO TO 505
  504 AH=AH+C(I)*ALPHA(I)
      BH=BH+ALPHA(I)*(C(I)*T0(I)-B(I)*.5)
      CH=CH+ALPHA(I)*(G(I)+C(I)*T0(I)**2)
  505 CONTINUE
      CH=CH-H
      IF(AH) 507,506,507
  506 T=CH/BH/2.
      GO TO 508
  507 T=(BH+SQRT (BH*BH-AH*CH))/AH
  508 CONTINUE
      IF(JJ)31,31,22
```

```
 31 ERR1=TT-T
    IF(ABS(TT/T-1.0).LE.EPS) GO TO 27
    GAM1=GAMMA
    GAMMA=.98*GAMMA
130 GAM2=GAMMA
    DELTA=(GAMMA-1.)/DT
    JJ=JJ+1
    IF (JJ-JJJ) 84,84,12
 84 IF (KOUNT.EQ.1) GO TO 14
    T=TSAVE
    GO TO 6
 22 ERR2=TT-T
    IF(ABS(TT/T-1.0).LE.EPS) GO TO 27
 25 GAMMA=GAM1-ERR1*(GAM2-GAM1)/(ERR2-ERR1)
    GAM1=GAM2
    ERR1=ERR2
    GO TO 130
 12 WRITE(6,13)
 13 FORMAT(1HO,23H JJ IS GREATER THAN JJJ)
 27 TN=T
    DO 28 J=1,7
 28 ALPHN(J)=ALPHA(J)
    DT=DT*TIMEO
    PRESSI=PSSSS
    RETURN
    END
```

APPENDIX B

SUBROUTINE OF PROGRAM

The name and the function of each subprogram unit are given in this appendix.

Name	Page	Description
EMVC	7	Main program manages the computation
WAVES[1]	17	Computes and inserts wave structure caused by geometric breaks
CROSS[1]	24	Computes interaction of shock waves of the same or opposite families
EMBED	28	Locates and computes properties on the free-stream and downstream side of embedded shocks
SOLVE	32	Calculates the determinant of a 3 by 3 matrix
HSHOCK	32	Computes shock-jump conditions and properties on downstream side of shock
SWITCH	38	Transfers properties to dummy storage during computations
PM	39	Used by COWL to compute properties in Prandtl-Meyer fans
CHEM	41	Calculates chemistry terms
SHEAR	42	Computes right-hand side of the modified continuity equation
PRESS	43	Calculates pressure as a function of x if a pressure boundary is specified
XVIS	43	Computes nondimensional viscosity (μ/μ_∞)
COWL	44	Used by INDATA to compute location and properties at shock points and Prandtl-Meyer points caused by pressure differences across a splitter wall

[1]New subroutines.

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Name	Page	Description
DPOINT	47	Computes streamline point on old data line from point on the free-stream side of a shock at the new data line
STEP	48	Locates subsonic regions and computes maximum allowable step and calls SPACE to readjust points
SSONIC	51	Computes properties at data points within the subsonic region
BODY	57	Computes the wall and center-body shape as a function of x
DPDTH	57	Computes θ_s along the upper bound of the subsonic region
CPOINT	57	Computes location and properties of streamline point on new data line using positive and negative characteristics
SPACE	65	Adds points on downstream side of shock, subtracts points from free-stream side of shock, and adds points to free stream when properties change at boundaries
RSET	75	Resets new data into old data line
SHEAR1	76	Computes shear terms for initial profile only
SHEAR2	78	Computes shear terms at new station before RSET is called
LPOINT	80	Computes location and properties of boundary streamline point on new data line using a positive or negative characteristic
DERY	87	Computes center differences for nonequally spaced grid in THSSS
THSSS	87	Computes θ_{ss} along the upper bound of the subsonic region
ZMU	88	Computes Mach angle as a function of Mach number

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Name	Page	Description
THERMO	88	Calculates specific heat C_{p_j}, derivatives of specific heat, and enthalpy H_j of each species from polynomial fits in temperature
TBL	89	Performs linear, single-table interpolation
XM1	89	Calculates $\tan(\theta + \mu)$ along positive characteristic
XM2	89	Calculates $\tan(\theta - \mu)$ along negative characteristic
XM3	89	Calculates $\tan \theta$ along streamline
HOCUS	89	Part of chemistry package
COEFF	91	Sets thermodynamic coefficients as functions of temperature
S2	94	Calculates diffusive terms in the energy equation
S3	94	Calculates diffusive terms in the species conservation equations
F1	95	Gives A_1 and B_1 coefficients[2] along positive or negative characteristic
F2	95	Gives A_2 and B_2 coefficients[2] along positive or negative characteristic
F4	95	Gives A_4 and B_4 coefficients[2] along positive or negative characteristic
HERMAN	96	Part of chemistry package
CLEM	97	Part of chemistry package
SOLT	98	Part of chemistry package
S1	98	Calculates diffusive terms in the s-momentum equation

[2]Coefficients in the P and θ relationship along the positive characteristic.

APPENDIX B

Name	Page	Description
PUNCH	98	Punches data deck for restarting program
INDATA	100	Accepts input of constants, reference conditions, and other initial flow properties
F3	106	A_3 and B_3 coefficients along positive or negative characteristic
POCUS	106	Part of chemistry package

APPENDIX C

DETAILS OF PROGRAM INPUT

The various input requirements are specified in this appendix. Note that pressure is required in U.S. Customary Units of pounds per square foot.

Initial Program Submittal

The initial program submittal is as follows:

Card	Format	Columns	Description
1	I5	1 to 5	KKKKK final run station
	I5	6 to 10	LL print interval
2	I5	1 to 5	IPUNCH controls punching of data deck to restart program. 0 no deck is punched 1 a deck is punched
	E10.0	11 to 20	XSTEP 1.0 unless it is desired to reduce the step size ΔX calculated by the program; that is, if XSTEP=10., then $\Delta X=\Delta X/10$.
	E10.0	21 to 30	PTZERO total pressure of the free stream, lb/ft^2
	E10.0	31 to 40	XE X location of the lip of a conical hydrogen injector (XE, YE, RCR, PTOJ, and TOJ are needed only if a conical injector is used)
	E10.0	41 to 50	YE Y location of the lip of a conical hydrogen injector
	E10.0	51 to 60	RCR critical radius for conical injector
	E10.0	61 to 70	PTOJ total pressure of injector flow, lb/ft^2
	E10.0	71 to 80	TOJ total temperature of injector flow, K
3	I5	1 to 5	NPTS number of data points in initial profile ≤ 54
	I5	6 to 10	NPT number of data points in the jet if jet is underexpanded and uniform NPT=5

Card	Format	Columns	Description
3	I5	11 to 15	ITYP Flow Type 1 nonuniform jet, external flow 2 uniform jet, external flow 3 uniform jet, nonuniform external flow 4 nonuniform jet, uniform external flow
	I5	16 to 20	ISHOCK 0 no shocks in initial profile 1 shocks in initial profile
	I5	21 to 25	MMAX maximum number of points to be allowed in the profile must be greater than NPTS but ≤ 54
	I5	26 to 30	KOUNT starting count for program, equals zero for initial profile
4	I5	1 to 5	JCHEM 0 frozen flow 1 finite-rate H_2-air chemistry
	I5	6 to 10	IAVE 0 shear terms not averaged 1 shear terms averaged across mixing step
	I5	11 to 15	INTACT 0 balanced pressure between jet and external flow 1 underexpanded jet
	I5	16 to 20	IDIVERG 0 parallel flow nozzle 1 divergent conical nozzle
	I5	21 to 25	IDD index of shock field to be scanned, initial profile should have IDD ≥ 4
5	E10.0	1 to 10	XJ 0.0 two-dimensional flow 1.0 axisymmetric flow
	E10.0	11 to 20	EMSUB=1.01
	E10.0	21 to 30	RTH jet radius in feet - reference for non-dimensionalized lengths

Card	Format	Columns	Description
5	E10.0	31 to 40	DELTAY[3] radial step size
	E10.0	41 to 50	YBOT[3] lower boundary at initial station
	E10.0	51 to 60	YTP[3] upper boundary at initial station
	E10.0	61 to 70	CHEMFC number of chemistry steps allowed in 1 mixing step
	E10.0	71 to 80	XBP[3] X starting location
6	E10.0	1 to 10	RE Reynolds number per foot; the program then sets RE=RE*RTH
	E10.0	10 to 20	PR Prandtl number
	E10.0	21 to 30	XLE Lewis number
	E10.0	31 to 40	EMINF reference Mach number[4]
	E10.0	41 to 50	TIN reference temperature,[4] K
	E10.0	51 to 60	WINF reference molecular weight,[4] lb/lb-mole
	E10.0	61 to 70	PRES reference pressure,[4] lb/ft^2
7	E10.0	1 to 10	XPOT=10.
	E10.0	11 to 20	XK1=.75E-03 } coefficients for
	E10.0	21 to 30	XK2=.285E-01 } Ferri-Kleinstein
	E10.0	31 to 40	XK3=100. } viscosity model
	E10.0	41 to 50	XK4=0.0
8	I5	1 to 5	IBOD lower boundary indicator 0 axis, plane of symmetry or pressure boundary 1 center body
	E10.0	11 to 20	ABOD } coefficients in the center-body
	E10.0	21 to 30	BBOD } shape equation $Y=A+BX+CX^2$, blank
	E10.0	31 to 40	CBOD } if IBOD=0
9	I5	1 to 5	III additional number of geometric sections required to specify center body ≦5, this card is not required if IBOD=0

[3]All lengths in program are nondimensionalized by RTH.
[4]Free-stream conditions normally used.

Card	Format	Columns	Description
10a to e	E10.0	1 to 10	XBOD(a) X starting location for the next center-body section
	E10.0	11 to 20	AABOD(a) coefficients for additional
	E10.0	21 to 30	BBBOD(a) sections; this card is repeated
	E10.0	31 to 40	CCBOD(a) for each of the III sections
11	I5	1 to 5	JBOD upper boundary indicator 0 no upper boundary or upper pressure boundary 1 upper physical wall
	E10.0	11 to 20	EBOD coefficients in the wall shape
	E10.0	21 to 30	FBOD equation $Y=A+BX+CX^2$, blank if
	E10.0	31 to 40	GBOD JBOD=0
12	I5	1 to 5	JJJ additional number of geometric sections required to specify the wall, ≤5; this card is not required if JBOD=0
13a to e	E10.0	1 to 10	XWALL(a) X starting location for the next wall section
	E10.0	11 to 20	EEBOD(a) coefficients for the additional
	E10.0	21 to 30	FFBOD(a) wall section; this card is
	E10.0	31 to 40	GGBOD(a) repeated for each of the JJJ sections
14	I5	1 to 5	LWALL indices of the next available wall
	I5	6 to 10	LBOD or center-body section - both equal one in initial profile
15	I5	1 to 5	IPRESS lower pressure boundary indicator 0 no lower pressure boundary 1 lower pressure boundary exists
	E10.0	11 to 20	APRESS coefficients in the center-line
	E10.0	21 to 30	BPRESS pressure distribution equation
	E10.0	31 to 40	CPRESS $P/PRES=A+BX+CX^2$, blank if IPRESS=0
16	I5	1 to 5	IPRESU upper pressure boundary indicator 0 no upper pressure boundary 1 upper pressure boundary exists
	E10.0	11 to 20	APRESU coefficients in the wall pres-
	E10.0	21 to 30	BPRESU sure distribution equation
	E10.0	31 to 40	CPRESU $P/PRES=A+BX+CX^2$, blank if IPRESU=0

If ISHOCK, the fourth input (columns 16 to 20) on card number three is zero skip cards 17a and b and 18a, b, and c.

Card	Format	Columns		Description
17a	I5	1 to 5	IS(1)	IS(I) is the upstream data point index for the Ith shock. Odd I's correspond to up-running shocks, and even I's correspond to down-running shocks. Only the first IDD values of the IS(I) fields are read; therefore, card 17b may not be needed. Fields IS(1) and IS(2) should be left blank since they are used by subroutine EMBED to insert combustion generated shocks.
	I5	6 to 10	IS(2)	
	I5	11 to 15	IS(3)	
	I5	16 to 20	IS(4)	
	.	.	.	
	.	.	.	
	.	.	.	
	I5	76 to 80	IS(16)	
17b	I5	1 to 5	IS(17)	
	I5	6 to 10	IS(18)	
	I5	11 to 15	IS(19)	
	I5	16 to 20	IS(20)	
18a	E10.0	1 to 10	BETB(1)	BETB(I) is the angle in radians between the X-axis and the Ith shock. If I is odd, BETB(I) is positive; if even, BETB(I) is negative. BETB(I) fields are blank for all IS(I)=0. Only the first IDD fields of BETP(I) are read; therefore, cards 18b and 18c may not be needed.
	E10.0	11 to 20	BETB(2)	
	E10.0	21 to 30	BETB(3)	
	E10.0	31 to 40	BETB(4)	
	E10.0	41 to 50	BETB(5)	
	E10.0	51 to 60	BETB(6)	
	E10.0	61 to 70	BETB(7)	
	E10.0	71 to 80	BETB(8)	
18b	E10.0	1 to 10	BETB(9)	
	E10.0	11 to 20	BETB(10)	
	E10.0	21 to 30	BETB(11)	
	E10.0	31 to 40	BETB(12)	
	E10.0	41 to 50	BETB(13)	
	E10.0	51 to 60	BETB(14)	
	E10.0	61 to 70	BETB(15)	
	E10.0	71 to 80	BETB(16)	
18c	E10.0	1 to 10	BETB(17)	
	E10.0	11 to 20	BETB(18)	
	E10.0	21 to 30	BETB(19)	
	E10.0	31 to 40	BETB(20)	

Each data point in the initial profile requires two cards of flow properties as described below, and each two-card set must be given in order of increasing radial distance Y.

Card	Format	Columns		Description
19	E10.0	1 to 10	Y(I)	radial location of data point/RTH
	E10.0	11 to 20	P(I)	pressure/PRES
	E10.0	21 to 30	TH(I)	flow angle, radians
	E10.0	31 to 40	EM(I)	Mach number
	E10.0	41 to 50	T(I)	temperature/TIN
20	E11.0	1 to 11	ALP(1)	mass fraction of H
	E11.0	12 to 22	ALP(2)	mass fraction of O
	E11.0	23 to 33	ALP(3)	mass fraction of H_2O
	E11.0	34 to 44	ALP(4)	mass fraction of H_2
	E11.0	45 to 55	ALP(5)	mass fraction of O_2
	E11.0	56 to 66	ALP(6)	mass fraction of OH
	E11.0	67 to 77	ALP(7)	mass fraction of N_2

Cards 19 and 20 are repeated NPTS times for the NPTS data points in the profile.

21	E10.0	1 to 10	MASFRAC(1) reference or free-stream mass fraction of H
	E10.0	11 to 20	MASFRAC(2) reference or free-stream mass fraction of O
	E10.0	21 to 30	MASFRAC(3) reference or free-stream mass fraction of H_2O
	E10.0	31 to 40	MASFRAC(4) reference or free-stream mass fraction of H_2
	E10.0	41 to 50	MASFRAC(5) reference or free-stream mass fraction of O_2
	E10.0	51 to 60	MASFRAC(6) reference or free-stream mass fraction of OH
	E10.0	61 to 70	MASFRAC(7) reference or free-stream mass fraction of N_2

APPENDIX C

Restart Capability

The program punches an input deck identical in format to that given in the section "Initial Program Submittal." This deck is produced at the final station KKKKK if specified by setting IPUNCH=1. Alternately, subroutine CPOINT produces a restart deck if the computed back characteristic is outside of the bounding streamlines. In the former case, the program can be restarted by changing the appropriate variables and resubmitting; that is, increasing the final station KKKKK on card one and/or changing the step size XSTEP on card two. In the latter case the deck can be used to diagnose the problem and restart as above if possible.

Data Initialization

Control card provisions must be made to set the core to zero, since a large number of variables are not initialized in the program.

Example A - First variation (fig. 2):

```
KKKKK = 3500     LL =***

IPUNCH = 1     XSTEP =  .100E+01     PTZERO =  .351E+05     IDIVERG = 0     IDD =  4

XE,YE,RCR,PTOJ,TOJ 0.         0.         0.         0.         0.
NPTS = 18     NPT = 5     ITYP = 2     ISHOCK = 0     MMAX = 54

JCHEM = 1     IAVE = 0     INTACT = 0

XJ = 0.          EMSUB =  .101E+01  RTH =  .250E-01  DELTAY =  .500E+00  YBOT = 0.          YTP =  .750E+01  CHEMFC =  .500E+01

RE =  .672E+06  PR =  .100E+01  XLE =  .100E+01  EMINF =  .190E+01  TIN =  .214E+04  WINF =  .232E+02  PRES =  .122E+04

XPOT =  .100E+02  XK1 =  .750E-03  XK2 =  .285E-01  XK3 =  .100E+03  XK4 = 0.

IBOD = 0  ABOD = 0.          BBOD = 0.          CBOD = 0.

JBOD = 1  EBOD =  .750E+01  FBOD = 0.          GBOD = 0.

JJJ=    5

 XWALL,EEBOD,FFBOD,GGBOD
 .920E+01   .750E+01   .213E+00 0.
 .142E+02   .856E+01   .699E-01 0.
 .192E+02   .891E+01   .213E+00 0.
 .472E+02   .149E+02 0.         0.
 .775E+03   .149E+02 0.         0.
LWALL=    1      LBOD=    1
IPRESS = 0  APRESS = 0.          BPRESS = 0.          CPRESS = 0.

IPRESU = 0  APRESU = 0.          BPRESU = 0.          CPRESU = 0.

MASFRAC( 1)=    .6864000E-05
MASFRAC( 2)=    .3529000E-03
MASFRAC( 3)=    .1694000E+00
MASFRAC( 4)=    .9177000E-02
MASFRAC( 5)=    .6758000E-01
MASFRAC( 6)=    .3343000E-02
MASFRAC( 7)=    .7501400E+00
```

PROGRAM VIS-CHAR

WITH

EMBEDDED SUBSONIC FLOW

SHOCK WAVES

AND FINITE RATE H2-AIR CHEMISTRY

TYPE OF FLOW IS TWO DIMENSIONAL
CHEMISTRY IS FINITE RATE
JET OR NOZZLE RADIUS (RTH) = .25000E-01 FT.

REFERENCE CONDITIONS

MACH NO. (EMINF) = .19030E+01
VELOCITY (UIN) = .61561E+04 FT/SEC
TEMPERATURE (TIN) = .21440E+04 DEGREES K
PRESSURE (PRES) = .12212E+04 LB/FT**2
DENSITY (RHOINF) = .14767E-03 SLUGS/FT**3
FROZEN SPECIFIC HEAT RATIO (GAMINF) = .12654E+01
MOLECULAR WEIGHT (WINF) = .23223E+02
REYNOLDS NUMBER (RE) = .16799E+05
PRANDTL NUMBER (PR) = .10000E+01
LEWIS NUMBER (XLE) = .10000E+01

OUTPUT HEADINGS

X - X/RTH
Y - Y/RTH
Q - VELOCITY/UIN
T - TEMPERATURE/TIN
P - PRESSURE/PRES
TH - FLOW DEFLECTION (RADIANS)
EM - MACH NUMBER
RHO - DENSITY/RHOINF
GAM - SPECIFIC HEAT
XMASS - NON-DIMENSIONAL MASS FLOW
PHI - EQUIVALENCE RATIO
W - MOLECULAR WEIGHT

```
MASS FRACTIONS
      ALP(1) - H
      ALP(2) - O
      ALP(3) - H2O
      ALP(4) - H2
      ALP(5) - O2
      ALP(6) - OH
      ALP(7) - N2
```

KOUNT= 0

X = .91820E+01

VISCOSITY(LB*SEC/FT**2)= .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05
.13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05
.13412E-05 .13412E-05 .13412E-05 .13412E-05

PT.	Y	Q	T	P	TH	EM	RHO	GAM	PITOT
1	0.	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
2	.50000E+00	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
3	.10000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
4	.15000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
5	.20000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
6	.25000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
7	.30000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
8	.35000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
9	.40000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
10	.45000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
11	.50000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
12	.55000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
13	.60000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
14	.65000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
15	.67500E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
16	.70000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
17	.72500E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
18	.75000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00

PT.	ALP(1)	ALP(2)	ALP(3)	ALP(4)	ALP(5)	ALP(6)	ALP(7)	PHI	W
1	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
2	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
3	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
4	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
5	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
6	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
7	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
8	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
9	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
10	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
11	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
12	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
13	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
14	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
15	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
16	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
17	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02

```
 18        .68640E-05    .35290E-03    .16940E+00    .91770E-02    .67580E-01    .33430E-02    .75014E+00    .10001E+01    .23218E+02
 *********

 DISCRET EXPANSION OF DNU=  .209E+00HAS BEEN INSERTED AT  .920E+01
 *********

A SHOCK WAVE BETB= -.371E+00HAS BEEN  INSERTED AT X=  .142E+02WITH A TURNING ANGLE=  .140E+00
 *********

 DISCRET EXPANSION OF DNU=  .140E+00HAS BEEN INSERTED AT  .192E+02
 *********

SHOCK WAVE BETB(  6)HAS REFLECTED FROM THE WALL AND HAS BECOME BETB(  7)
```

KOUNT= 3500

X = .47115E+02

SHOCK TYPE 7 BETA = .532E+00

VISCOSITY(LB*SEC/FT**2)= .13179E-05 .13262E-05 .13374E-05 .13511E-05 .13666E-05 .13835E-05 .14011E-05
.14188E-05 .14361E-05 .14522E-05 .14659E-05 .14752E-05 .14762E-05 .14618E-05
.14179E-05 .12729E-05 .12861E-05 .12930E-05 .12991E-05 .13020E-05 .13023E-05
.12998E-05 .12945E-05 .12944E-05 .12942E-05

PT.	Y	Q	T	P	TH	EM	RHO	GAM	PITOT
1	0.	.11654E+01	.96858E+00	.40707E+00	0.	.22867E+01	.43075E+00	.12595E+01	.95194E-01
2	.84500E+00	.11705E+01	.96489E+00	.40818E+00	.14091E-01	.23006E+01	.43347E+00	.12597E+01	.96527E-01
3	.16204E+01	.11724E+01	.96339E+00	.41107E+00	.27036E-01	.23058E+01	.43714E+00	.12599E+01	.97576E-01
4	.23409E+01	.11724E+01	.96334E+00	.41530E+00	.39121E-01	.23056E+01	.44159E+00	.12599E+01	.98494E-01
5	.30158E+01	.11712E+01	.96416E+00	.42051E+00	.50573E-01	.23021E+01	.44666E+00	.12599E+01	.99357E-01
6	.36526E+01	.11694E+01	.96546E+00	.42635E+00	.61588E-01	.22968E+01	.45219E+00	.12599E+01	.10019E+00
7	.42571E+01	.11671E+01	.96705E+00	.43256E+00	.72319E-01	.22903E+01	.45793E+00	.12599E+01	.10099E+00
8	.48365E+01	.11647E+01	.96883E+00	.43892E+00	.82912E-01	.22833E+01	.46372E+00	.12598E+01	.10173E+00
9	.53953E+01	.11622E+01	.97065E+00	.44516E+00	.93406E-01	.22761E+01	.46935E+00	.12598E+01	.10241E+00
10	.59352E+01	.11598E+01	.97221E+00	.45096E+00	.10371E+00	.22694E+01	.47461E+00	.12598E+01	.10298E+00
11	.64608E+01	.11578E+01	.97333E+00	.45585E+00	.11363E+00	.22639E+01	.47911E+00	.12598E+01	.10343E+00
12	.69747E+01	.11564E+01	.97377E+00	.45903E+00	.12269E+00	.22604E+01	.48213E+00	.12598E+01	.10365E+00
13	.74783E+01	.11562E+01	.97279E+00	.45902E+00	.12989E+00	.22608E+01	.48250E+00	.12599E+01	.10352E+00
14	.79736E+01	.11584E+01	.96924E+00	.45304E+00	.13336E+00	.22688E+01	.47786E+00	.12602E+01	.10276E+00
15	.84683E+01	.11651E+01	.96083E+00	.43584E+00	.12942E+00	.22912E+01	.46365E+00	.12607E+01	.10079E+00
16	.93494E+01	.11876E+01	.93389E+00	.38039E+00	.10403E+00	.23660E+01	.41593E+00	.12625E+01	.93956E-01
17	.93494E+01	.11939E+01	.92659E+00	.36631E+00	.92629E-01	.23885E+01	.40395E+00	.12627E+01	.92283E-01
18	.10056E+02	.11923E+01	.92842E+00	.36902E+00	.10725E+00	.23830E+01	.40612E+00	.12626E+01	.92310E-01
19	.10967E+02	.11909E+01	.92866E+00	.37093E+00	.12648E+00	.23795E+01	.40801E+00	.12626E+01	.92149E-01
20	.11885E+02	.11899E+01	.92818E+00	.37167E+00	.14600E+00	.23776E+01	.40892E+00	.12627E+01	.91751E-01
21	.12871E+02	.11892E+01	.92684E+00	.37136E+00	.16709E+00	.23773E+01	.40901E+00	.12629E+01	.91096E-01
22	.13844E+02	.11887E+01	.92507E+00	.37009E+00	.18795E+00	.23780E+01	.40824E+00	.12632E+01	.90219E-01
23	.14810E+02	.11882E+01	.92332E+00	.36801E+00	.20867E+00	.23786E+01	.40656E+00	.12634E+01	.89073E-01
24	.14824E+02	.11882E+01	.92331E+00	.36797E+00	.20896E+00	.23786E+01	.40653E+00	.12634E+01	.89055E-01
25	.14845E+02	.11882E+01	.92331E+00	.36792E+00	.20944E+00	.23786E+01	.40647E+00	.12634E+01	.89026E-01

PT.	ALP(1)	ALP(2)	ALP(3)	ALP(4)	ALP(5)	ALP(6)	ALP(7)	PHI	W
1	.53533E-03	.24526E-02	.21925E+00	.28180E-02	.17205E-01	.76026E-02	.75014E+00	.10001E+01	.23802E+02
2	.54401E-03	.24821E-02	.21908E+00	.28291E-02	.17343E-01	.75786E-02	.75014E+00	.10001E+01	.23796E+02
3	.55020E-03	.25068E-02	.21893E+00	.28395E-02	.17447E-01	.75864E-02	.75014E+00	.10001E+01	.23792E+02
4	.55486E-03	.25289E-02	.21878E+00	.28499E-02	.17530E-01	.76163E-02	.75014E+00	.10001E+01	.23788E+02
5	.55884E-03	.25509E-02	.21862E+00	.28608E-02	.17605E-01	.76615E-02	.75014E+00	.10001E+01	.23784E+02
6	.56281E-03	.25747E-02	.21845E+00	.28728E-02	.17682E-01	.77178E-02	.75014E+00	.10001E+01	.23779E+02
7	.56674E-03	.25993E-02	.21827E+00	.28854E-02	.17758E-01	.77808E-02	.75014E+00	.10001E+01	.23775E+02

8	.57048E-03	.26237E-02	.21809E+00	.28980E-02	.17833E-01	.78469E-02	.75014E+00	.10001E+01	.23771E+02
9	.57409E-03	.26477E-02	.21791E+00	.29104E-02	.17905E-01	.79134E-02	.75014E+00	.10001E+01	.23766E+02
10	.57846E-03	.26743E-02	.21771E+00	.29240E-02	.17990E-01	.79786E-02	.75014E+00	.10001E+01	.23762E+02
11	.58344E-03	.27021E-02	.21751E+00	.29380E-02	.18085E-01	.80370E-02	.75014E+00	.10001E+01	.23757E+02
12	.58866E-03	.27278E-02	.21733E+00	.29511E-02	.18185E-01	.80797E-02	.75014E+00	.10001E+01	.23752E+02
13	.59504E-03	.27529E-02	.21715E+00	.29638E-02	.18304E-01	.80943E-02	.75014E+00	.10001E+01	.23747E+02
14	.60325E-03	.27758E-02	.21700E+00	.29743E-02	.18448E-01	.80562E-02	.75014E+00	.10001E+01	.23742E+02
15	.61446E-03	.27947E-02	.21695E+00	.29776E-02	.18608E-01	.79200E-02	.75014E+00	.10001E+01	.23737E+02
16	.64446E-03	.28462E-02	.21703E+00	.29633E-02	.18882E-01	.74926E-02	.75014E+00	.10001E+01	.23714E+02
17	.64446E-03	.28462E-02	.21703E+00	.29633E-02	.18882E-01	.74926E-02	.75014E+00	.10001E+01	.23730E+02
18	.65029E-03	.28498E-02	.21707E+00	.29589E-02	.18940E-01	.73871E-02	.75014E+00	.10001E+01	.23728E+02
19	.65757E-03	.28846E-02	.21685E+00	.29738E-02	.19059E-01	.74330E-02	.75014E+00	.10001E+01	.23722E+02
20	.66655E-03	.29243E-02	.21661E+00	.29899E-02	.19201E-01	.74703E-02	.75014E+00	.10001E+01	.23715E+02
21	.67871E-03	.29749E-02	.21631E+00	.30095E-02	.19387E-01	.75035E-02	.75014E+00	.10001E+01	.23706E+02
22	.69140E-03	.30260E-02	.21601E+00	.30286E-02	.19577E-01	.75278E-02	.75014E+00	.10001E+01	.23697E+02
23	.70369E-03	.30750E-02	.21573E+00	.30466E-02	.19758E-01	.75493E-02	.75014E+00	.10001E+01	.23689E+02
24	.70372E-03	.30751E-02	.21573E+00	.30467E-02	.19759E-01	.75493E-02	.75014E+00	.10001E+01	.23689E+02
25	.70375E-03	.30752E-02	.21573E+00	.30467E-02	.19759E-01	.75493E-02	.75014E+00	.10001E+01	.23689E+02

Example B - Second variation (fig. 3):

```
KKKKK = 2161     LL =***

IPUNCH = 1     XSTEP =  .100E+01     PTZERO =  .351E+05     IDIVERG = 0     IDD =  4

XE,YE,RCR,PTOJ,TOJ 0.        0.        0.        0.        0.
NPTS = 18     NPT = 5     ITYP = 2     ISHOCK = 0     MMAX = 54

JCHEM = 1     IAVE = 0     INTACT = 0

XJ = 0.          EMSUB =  .101E+01  RTH =  .250E-01  DELTAY =  .500E+00  YBOT = 0.          YTP =  .750E+01  CHEMFC =  .500E+01

RE =  .672E+06  PR =  .100E+01  XLE =  .100E+01  EMINF =  .190E+01  TIN =  .214E+04  WINF =  .232E+02  PRES =  .122E+04

XPOT =  .100E+02  XK1 =  .750E-03  XK2 =  .285E-01  XK3 =  .100E+03  XK4 = 0.

IBOD = 0  ABOD = 0.          BBOD = 0.          CBOD = 0.

JBOD = 1  EBOD =  .750E+01  FBOD = 0.          GBOD = 0.

JJJ=    5

 XWALL,EEBOD,FFBOD,GGBOD
 .920E+01  .750E+01  .213E+00 0.
 .142E+02  .856E+01  .105E+00 0.
 .192E+02  .909E+01  .213E+00 0.
 .472E+02  .150E+02 0.        0.
 .775E+03  .150E+02 0.        0.
LWALL=    1      LBOD=    1
IPRESS = 0  APRESS = 0.          BPRESS = 0.          CPRESS = 0.

IPRESU = 0  APRESU = 0.          BPRESU = 0.          CPRESU = 0.

MASFRAC( 1)=    .6864000E-05
MASFRAC( 2)=    .3529000E-03
MASFRAC( 3)=    .1694000E+00
MASFRAC( 4)=    .9177000E-02
MASFRAC( 5)=    .6758000E-01
MASFRAC( 6)=    .3343000E-02
MASFRAC( 7)=    .7501400E+00
```

PROGRAM VIS-CHAR

WITH

EMBEDDED SUBSONIC FLOW

SHOCK WAVES

AND FINITE RATE H2-AIR CHEMISTRY

```
TYPE OF FLOW IS TWO DIMENSIONAL
CHEMISTRY IS FINITE RATE
JET OR NOZZLE RADIUS (RTH) =   .25000E-01 FT.


          REFERENCE CONDITIONS
          --------------------
MACH NO. (EMINF) =   .19030E+01
VELOCITY (UIN) =   .61561E+04 FT/SEC
TEMPERATURE (TIN) =   .21440E+04 DEGREES K
PRESSURE (PRES) =   .12212E+04 LB/FT**2
DENSITY (RHOINF) =   .14767E-03 SLUGS/FT**3
FROZEN SPECIFIC HEAT RATIO (GAMINF) =   .12654E+01
MOLECULAR WEIGHT (WINF) =   .23223E+02
REYNOLDS NUMBER (RE) =   .16799E+05
PRANDTL NUMBER (PR) =   .10000E+01
LEWIS NUMBER (XLE) =   .10000E+01


          OUTPUT HEADINGS
          ---------------
X - X/RTH
Y - Y/RTH
Q - VELOCITY/UIN
T - TEMPERATURE/TIN
P - PRESSURE/PRES
TH - FLOW DEFLECTION (RADIANS)
EM - MACH NUMBER
RHO - DENSITY/RHOINF
GAM - SPECIFIC HEAT
XMASS - NON-DIMENSIONAL MASS FLOW
PHI - EQUIVALENCE RATIO
W - MOLECULAR WEIGHT
```

MASS FRACTIONS

ALP(1) - H
ALP(2) - O
ALP(3) - H2O
ALP(4) - H2
ALP(5) - O2
ALP(6) - OH
ALP(7) - N2

APPENDIX D

KOUNT= 0

X = .91820E+01

VISCOSITY(LB*SEC/FT**2)= .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05
.13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05
.13412E-05 .13412E-05 .13412E-05 .13412E-05

PT.	Y	Q	T	P	TH	EM	RHO	GAM	PITOT
1	0.	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
2	.50000E+00	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
3	.10000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
4	.15000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
5	.20000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
6	.25000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
7	.30000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
8	.35000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
9	.40000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
10	.45000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
11	.50000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
12	.55000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
13	.60000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
14	.65000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
15	.67500E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
16	.70000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
17	.72500E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
18	.75000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00

PT.	ALP(1)	ALP(2)	ALP(3)	ALP(4)	ALP(5)	ALP(6)	ALP(7)	PHI	W
1	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
2	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
3	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
4	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
5	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
6	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
7	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
8	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
9	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
10	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
11	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
12	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
13	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
14	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
15	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
16	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
17	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02

```
 18        .68640E-05    .35290E-03    .16940E+00    .91770E-02    .67580E-01    .33430E-02    .75014E+00    .10001E+01    .23218E+02
 *********

 DISCRET EXPANSION OF DNU=  .209E+00HAS BEEN INSERTED AT  .920E+01
 *********

A SHOCK WAVE BETB= -.341E+00HAS BEEN  INSERTED AT X=  .142E+02WITH A TURNING ANGLE=  .105E+00
 *********

 DISCRET EXPANSION OF DNU=  .105E+00HAS BEEN INSERTED AT  .192E+02
```

KOUNT= 2161

X = .28565E+02

SHOCK TYPE 6 BETA = -.517E+00

VISCOSITY(LB*SEC/FT**2)= .13236E-05 .13232E-05 .13219E-05 .13189E-05 .14003E-05 .13186E-05 .12625E-05
.12306E-05 .12109E-05 .11971E-05 .11862E-05 .11773E-05 .11710E-05 .11686E-05
.11707E-05 .11766E-05 .11851E-05 .11927E-05 .11964E-05 .11964E-05 .11964E-05

PT.	Y	Q	T	P	TH	EM	RHO	GAM	PITOT
1	0.	.11427E+01	.97626E+00	.50450E+00	0.	.22279E+01	.52742E+00	.12603E+01	.11251E+00
2	.81231E+00	.11427E+01	.97607E+00	.50426E+00	.31468E-01	.22282E+01	.52725E+00	.12603E+01	.11238E+00
3	.16259E+01	.11429E+01	.97510E+00	.50335E+00	.62847E-01	.22294E+01	.52675E+00	.12604E+01	.11198E+00
4	.24985E+01	.11436E+01	.97136E+00	.50051E+00	.96100E-01	.22341E+01	.52554E+00	.12607E+01	.11126E+00
5	.24985E+01	.10377E+01	.10821E+01	.83117E+00	-.69246E-01	.19038E+01	.76996E+00	.12612E+01	.13898E+00
6	.32060E+01	.10605E+01	.10570E+01	.75123E+00	-.60953E-02	.19891E+01	.72475E+00	.12567E+01	.13609E+00
7	.37213E+01	.10723E+01	.10444E+01	.71087E+00	.31895E-01	.20227E+01	.69402E+00	.12573E+01	.13264E+00
8	.42658E+01	.10792E+01	.10361E+01	.68766E+00	.61957E-01	.20432E+01	.67654E+00	.12577E+01	.13036E+00
9	.48320E+01	.10835E+01	.10302E+01	.67296E+00	.87579E-01	.20568E+01	.66572E+00	.12581E+01	.12869E+00
10	.54140E+01	.10867E+01	.10252E+01	.66232E+00	.11048E+00	.20671E+01	.65815E+00	.12584E+01	.12730E+00
11	.60088E+01	.10891E+01	.10204E+01	.65350E+00	.13149E+00	.20760E+01	.65217E+00	.12588E+01	.12602E+00
12	.66111E+01	.10912E+01	.10158E+01	.64599E+00	.15051E+00	.20838E+01	.64729E+00	.12591E+01	.12483E+00
13	.72194E+01	.10925E+01	.10118E+01	.64031E+00	.16709E+00	.20898E+01	.64385E+00	.12595E+01	.12380E+00
14	.78304E+01	.10930E+01	.10086E+01	.63732E+00	.18060E+00	.20932E+01	.64256E+00	.12598E+01	.12308E+00
15	.84410E+01	.10924E+01	.10064E+01	.63743E+00	.19072E+00	.20936E+01	.64375E+00	.12600E+01	.12275E+00
16	.90508E+01	.10910E+01	.10050E+01	.64012E+00	.19774E+00	.20915E+01	.64699E+00	.12602E+01	.12275E+00
17	.97339E+01	.10888E+01	.10037E+01	.64432E+00	.20289E+00	.20880E+01	.65171E+00	.12605E+01	.12296E+00
18	.10400E+02	.10867E+01	.10025E+01	.64805E+00	.20632E+00	.20843E+01	.65589E+00	.12607E+01	.12314E+00
19	.11057E+02	.10848E+01	.10011E+01	.64952E+00	.20931E+00	.20814E+01	.65791E+00	.12609E+01	.12297E+00
20	.11064E+02	.10848E+01	.10011E+01	.64952E+00	.20935E+00	.20814E+01	.65790E+00	.12609E+01	.12297E+00
21	.11078E+02	.10848E+01	.10011E+01	.64951E+00	.20944E+00	.20814E+01	.65789E+00	.12609E+01	.12296E+00

PT.	ALP(1)	ALP(2)	ALP(3)	ALP(4)	ALP(5)	ALP(6)	ALP(7)	PHI	W
1	.64601E-03	.30271E-02	.21548E+00	.30741E-02	.19107E-01	.85252E-02	.75014E+00	.10001E+01	.23702E+02
2	.64688E-03	.30306E-02	.21546E+00	.30754E-02	.19120E-01	.85261E-02	.75014E+00	.10001E+01	.23701E+02
3	.65178E-03	.30508E-02	.21535E+00	.30829E-02	.19196E-01	.85328E-02	.75014E+00	.10001E+01	.23698E+02
4	.66110E-03	.31226E-02	.21482E+00	.31189E-02	.19380E-01	.87534E-02	.75014E+00	.10001E+01	.23686E+02
5	.66110E-03	.31226E-02	.21482E+00	.31189E-02	.19380E-01	.87534E-02	.75014E+00	.10001E+01	.23279E+02
6	.61031E-03	.31126E-02	.21370E+00	.32081E-02	.18997E-01	.10237E-01	.75014E+00	.10001E+01	.23682E+02
7	.62436E-03	.31667E-02	.21376E+00	.31964E-02	.19041E-01	.10068E-01	.75014E+00	.10001E+01	.23679E+02
8	.63634E-03	.32016E-02	.21366E+00	.32024E-02	.19204E-01	.99515E-02	.75014E+00	.10001E+01	.23673E+02
9	.64803E-03	.32401E-02	.21349E+00	.32138E-02	.19380E-01	.98839E-02	.75014E+00	.10001E+01	.23666E+02
10	.66054E-03	.32861E-02	.21327E+00	.32286E-02	.19569E-01	.98453E-02	.75014E+00	.10001E+01	.23659E+02
11	.67554E-03	.33448E-02	.21297E+00	.32484E-02	.19796E-01	.98250E-02	.75014E+00	.10001E+01	.23649E+02
12	.69185E-03	.34103E-02	.21263E+00	.32706E-02	.20041E-01	.98157E-02	.75014E+00	.10001E+01	.23638E+02

13	.70862E-03	.34791E-02	.21227E+00	.32945E-02	.20293E-01	.98192E-02	.75014E+00	.10001E+01	.23626E+02
14	.72543E-03	.35506E-02	.21188E+00	.33200E-02	.20547E-01	.98409E-02	.75014E+00	.10001E+01	.23614E+02
15	.74171E-03	.36229E-02	.21147E+00	.33466E-02	.20795E-01	.98825E-02	.75014E+00	.10001E+01	.23602E+02
16	.75736E-03	.36930E-02	.21105E+00	.33750E-02	.21049E-01	.99378E-02	.75014E+00	.10001E+01	.23590E+02
17	.77478E-03	.37776E-02	.21049E+00	.34158E-02	.21394E-01	.10007E-01	.75014E+00	.10001E+01	.23576E+02
18	.79295E-03	.38650E-02	.21002E+00	.34462E-02	.21656E-01	.10083E-01	.75014E+00	.10001E+01	.23562E+02
19	.81007E-03	.39465E-02	.20958E+00	.34737E-02	.21897E-01	.10148E-01	.75014E+00	.10001E+01	.23549E+02
20	.81008E-03	.39465E-02	.20958E+00	.34737E-02	.21898E-01	.10148E-01	.75014E+00	.10001E+01	.23549E+02
21	.81010E-03	.39466E-02	.20958E+00	.34737E-02	.21898E-01	.10149E-01	.75014E+00	.10001E+01	.23549E+02

```
KKKKK = 2565     LL =***

IPUNCH = 1     XSTEP =  .100E+02     PTZERO =  .351E+05     IDIVERG = 0     IDD =  6

XE,YE,RCR,PTOJ,TOJ 0.          0.          0.          0.          0.
NPTS = 19     NPT = 5     ITYP = 1     ISHOCK = 1     MMAX = 54

JCHEM = 1     IAVE = 0     INTACT = 0

XJ = 0.          EMSUB =  .101E+01  RTH =  .250E-01  DELTAY =  .500E+00  YBOT = 0.          YTP =  .750E+01  CHEMFC =  .500E+01

RE =  .672E+06  PR =  .100E+01  XLE =  .100E+01  EMINF =  .190E+01  TIN =  .214E+04  WINF =  .232E+02  PRES =  .122E+04

XPOT =  .100E+02  XK1 =  .750E-03  XK2 =  .285E-01  XK3 =  .100E+03  XK4 = 0.

IBOD = 0  ABOD = 0.          BBOD = 0.          CBOD = 0.

JBOD = 1  EBOD =  .909E+01  FBOD =  .213E+00  GBOD = 0.

JJJ=    5

 XWALL,EEBOD,FFBOD,GGBOD
 .920E+01   .750E+01   .213E+00 0.
 .142E+02   .856E+01   .105E+00 0.
 .192E+02   .909E+01   .213E+00 0.
 .472E+02   .150E+02 0.         0.
 .775E+03   .150E+02 0.         0.
LWALL=    4      LBOD=    1
IPRESS = 0  APRESS = 0.          BPRESS = 0.          CPRESS = 0.

IPRESU = 0  APRESU = 0.          BPRESU = 0.          CPRESU = 0.

IS( 1)=  0   IS( 2)=  0   IS( 3)=  0   IS( 4)=  0

IS( 5)=  0   IS( 6)=  4   IS(
BETB( 1)= 0.          BETB( 2)= 0.          BETB( 3)= 0.          BETB( 4)= 0.

BETB( 5)= 0.          BETB( 6)= -.517E+00   BETB(
MASFRAC( 1)=   .6860000E-05
MASFRAC( 2)=   .3530000E-03
MASFRAC( 3)=   .1690000E+00
MASFRAC( 4)=   .9180000E-02
MASFRAC( 5)=   .6760000E-01
MASFRAC( 6)=   .3340000E-02
MASFRAC( 7)=   .7500000E+00
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P R O G R A M V I S - C H A R

W I T H

E M B E D D E D S U B S O N I C F L O W

S H O C K W A V E S

A N D F I N I T E R A T E H 2 - A I R C H E M I S T R Y

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TYPE OF FLOW IS TWO DIMENSIONAL
CHEMISTRY IS FINITE RATE
JET OR NOZZLE RADIUS (RTH) =    .25000E-01 FT.


          REFERENCE CONDITIONS
          --------------------
MACH NO. (EMINF) =    .19000E+01
VELOCITY (UIN) =    .61453E+04 FT/SEC
TEMPERATURE (TIN) =    .21400E+04 DEGREES K
PRESSURE (PRES) =    .12200E+04 LB/FT**2
DENSITY (RHOINF) =    .14766E-03 SLUGS/FT**3
FROZEN SPECIFIC HEAT RATIO (GAMINF) =    .12661E+01
MOLECULAR WEIGHT (WINF) =    .23200E+02
REYNOLDS NUMBER (RE) =    .16800E+05
PRANDTL NUMBER (PR) =    .10000E+01
LEWIS NUMBER (XLE) =    .10000E+01


          OUTPUT HEADINGS
          ---------------
X - X/RTH
Y - Y/RTH
Q - VELOCITY/UIN
T - TEMPERATURE/TIN
P - PRESSURE/PRES
TH - FLOW DEFLECTION (RADIANS)
EM - MACH NUMBER
RHO - DENSITY/RHOINF
GAM - SPECIFIC HEAT
XMASS - NON-DIMENSIONAL MASS FLOW
PHI - EQUIVALENCE RATIO
W - MOLECULAR WEIGHT
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MASS FRACTIONS
     ALP(1) - H
     ALP(2) - O
     ALP(3) - H2O
     ALP(4) - H2
     ALP(5) - O2
     ALP(6) - OH
     ALP(7) - N2
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KOUNT= 2161

X = .28565E+02

SHOCK TYPE 6 BETA = -.517E+00

VISCOSITY(LB*SEC/FT**2)= .13222E-05 .13218E-05 .13206E-05 .13175E-05 .13989E-05 .12941E-05 .12392E-05
.12080E-05 .11887E-05 .11752E-05 .11645E-05 .11558E-05 .11496E-05 .11473E-05
.11494E-05 .11553E-05 .11637E-05 .11712E-05 .11747E-05

PT.	Y	Q	T	P	TH	EM	RHO	GAM	PITOT
1	0.	.11437E+01	.97626E+00	.50450E+00	0.	.22279E+01	.52794E+00	.12604E+01	.11226E+00
2	.81231E+00	.11437E+01	.97607E+00	.50426E+00	.31470E-01	.22282E+01	.52777E+00	.12604E+01	.11213E+00
3	.16259E+01	.11439E+01	.97510E+00	.50335E+00	.62850E-01	.22294E+01	.52729E+00	.12605E+01	.11174E+00
4	.24985E+01	.11445E+01	.97136E+00	.50051E+00	.96100E-01	.22341E+01	.52606E+00	.12608E+01	.11102E+00
5	.24985E+01	.10273E+01	.10821E+01	.83117E+00	-.69250E-01	.19038E+01	.78421E+00	.12556E+01	.13827E+00
6	.32060E+01	.10614E+01	.10570E+01	.75123E+00	-.61000E-02	.19891E+01	.72547E+00	.12568E+01	.13579E+00
7	.37213E+01	.10732E+01	.10444E+01	.71087E+00	.31900E-01	.20227E+01	.69470E+00	.12574E+01	.13234E+00
8	.42658E+01	.10801E+01	.10361E+01	.68766E+00	.61960E-01	.20432E+01	.67721E+00	.12578E+01	.13007E+00
9	.48320E+01	.10845E+01	.10302E+01	.67296E+00	.87580E-01	.20569E+01	.66638E+00	.12582E+01	.12841E+00
10	.54140E+01	.10876E+01	.10252E+01	.66232E+00	.11048E+00	.20671E+01	.65878E+00	.12585E+01	.12702E+00
11	.60088E+01	.10901E+01	.10204E+01	.65350E+00	.13149E+00	.20760E+01	.65281E+00	.12589E+01	.12574E+00
12	.66111E+01	.10921E+01	.10158E+01	.64599E+00	.15051E+00	.20838E+01	.64793E+00	.12592E+01	.12455E+00
13	.72194E+01	.10935E+01	.10118E+01	.64031E+00	.16709E+00	.20898E+01	.64447E+00	.12595E+01	.12353E+00
14	.78304E+01	.10939E+01	.10086E+01	.63732E+00	.18060E+00	.20932E+01	.64318E+00	.12598E+01	.12281E+00
15	.84410E+01	.10934E+01	.10064E+01	.63743E+00	.19072E+00	.20937E+01	.64437E+00	.12601E+01	.12247E+00
16	.90508E+01	.10919E+01	.10050E+01	.64012E+00	.19774E+00	.20915E+01	.64765E+00	.12603E+01	.12247E+00
17	.97339E+01	.10898E+01	.10037E+01	.64432E+00	.20289E+00	.20880E+01	.65235E+00	.12606E+01	.12268E+00
18	.10400E+02	.10876E+01	.10025E+01	.64805E+00	.20632E+00	.20843E+01	.65654E+00	.12608E+01	.12286E+00
19	.11078E+02	.10857E+01	.10011E+01	.64951E+00	.20944E+00	.20814E+01	.65854E+00	.12610E+01	.12269E+00

PT.	ALP(1)	ALP(2)	ALP(3)	ALP(4)	ALP(5)	ALP(6)	ALP(7)	PHI	W
1	.64600E-03	.30270E-02	.21550E+00	.30740E-02	.19110E-01	.85250E-02	.75012E+00	.10002E+01	.23702E+02
2	.64690E-03	.30310E-02	.21550E+00	.30750E-02	.19120E-01	.85260E-02	.75010E+00	.10003E+01	.23701E+02
3	.65180E-03	.30510E-02	.21530E+00	.30830E-02	.19200E-01	.85330E-02	.75018E+00	.99993E+00	.23698E+02
4	.66110E-03	.31230E-02	.21480E+00	.31190E-02	.19380E-01	.87530E-02	.75016E+00	.10000E+01	.23686E+02
5	.66110E-03	.31230E-02	.21480E+00	.31190E-02	.19380E-01	.87530E-02	.75016E+00	.10000E+01	.23686E+02
6	.61030E-03	.31130E-02	.21370E+00	.32080E-02	.19000E-01	.10240E-01	.75013E+00	.10001E+01	.23682E+02
7	.62440E-03	.31670E-02	.21380E+00	.31960E-02	.19040E-01	.10070E-01	.75010E+00	.10002E+01	.23678E+02
8	.63630E-03	.32020E-02	.21370E+00	.32020E-02	.19200E-01	.99520E-02	.75011E+00	.10002E+01	.23673E+02
9	.64800E-03	.32400E-02	.21350E+00	.32140E-02	.19380E-01	.98840E-02	.75013E+00	.10001E+01	.23666E+02
10	.66050E-03	.32860E-02	.21330E+00	.32290E-02	.19570E-01	.98450E-02	.75011E+00	.10002E+01	.23658E+02
11	.67550E-03	.33450E-02	.21300E+00	.32480E-02	.19800E-01	.98250E-02	.75011E+00	.10002E+01	.23649E+02
12	.69180E-03	.34100E-02	.21260E+00	.32710E-02	.20040E-01	.98160E-02	.75017E+00	.10000E+01	.23638E+02
13	.70860E-03	.34790E-02	.21230E+00	.32950E-02	.20290E-01	.98190E-02	.75011E+00	.10003E+01	.23626E+02
14	.72540E-03	.35510E-02	.21190E+00	.33200E-02	.20550E-01	.98410E-02	.75011E+00	.10002E+01	.23614E+02

15	.74170E-03	.36230E-02	.21150E+00	.33470E-02	.20800E-01	.98820E-02	.75011E+00	.10002E+01	.23602E+02
16	.75740E-03	.36930E-02	.21100E+00	.33750E-02	.21050E-01	.99380E-02	.75019E+00	.99992E+00	.23591E+02
17	.77480E-03	.37780E-02	.21050E+00	.34160E-02	.21390E-01	.10010E-01	.75013E+00	.10002E+01	.23575E+02
18	.79300E-03	.38650E-02	.21000E+00	.34460E-02	.21660E-01	.10080E-01	.75016E+00	.10000E+01	.23562E+02
19	.81010E-03	.39470E-02	.20960E+00	.34740E-02	.21900E-01	.10150E-01	.75012E+00	.10002E+01	.23549E+02

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SHOCK WAVE BETB(6)HAS REFLECTED FROM THE WALL AND HAS BECOME BETB(7)

KOUNT= 2560

X = .47112E+02

SHOCK TYPE 7 BETA = .602E+00

VISCOSITY(LB*SEC/FT**2)= .13085E-05 .13121E-05 .13229E-05 .13362E-05 .13522E-05 .13700E-05 .13886E-05
.14073E-05 .14256E-05 .14430E-05 .14592E-05 .14735E-05 .14862E-05 .14964E-05
.15039E-05 .15088E-05 .15116E-05 .15136E-05 .12752E-05 .12954E-05 .13076E-05
.13122E-05 .13102E-05

PT.	Y	Q	T	P	TH	EM	RHO	GAM	PITOT
1	0.	.11795E+01	.95771E+00	.40391E+00	0.	.23248E+01	.43264E+00	.12602E+01	.97206E-01
2	.94952E+00	.11789E+01	.95850E+00	.40540E+00	.15385E-01	.23226E+01	.43383E+00	.12601E+01	.97363E-01
3	.17596E+01	.11781E+01	.95888E+00	.40897E+00	.28382E-01	.23204E+01	.43740E+00	.12602E+01	.98002E-01
4	.25213E+01	.11756E+01	.96103E+00	.41408E+00	.40610E-01	.23127E+01	.44179E+00	.12601E+01	.98541E-01
5	.32360E+01	.11727E+01	.96351E+00	.42019E+00	.52167E-01	.23038E+01	.44707E+00	.12600E+01	.99180E-01
6	.39178E+01	.11696E+01	.96607E+00	.42693E+00	.63378E-01	.22944E+01	.45294E+00	.12600E+01	.99895E-01
7	.45638E+01	.11666E+01	.96844E+00	.43386E+00	.74269E-01	.22856E+01	.45907E+00	.12599E+01	.10065E+00
8	.51824E+01	.11637E+01	.97056E+00	.44073E+00	.85025E-01	.22774E+01	.46523E+00	.12598E+01	.10141E+00
9	.57812E+01	.11611E+01	.97239E+00	.44738E+00	.95798E-01	.22698E+01	.47126E+00	.12598E+01	.10212E+00
10	.63670E+01	.11586E+01	.97398E+00	.45367E+00	.10670E+00	.22628E+01	.47700E+00	.12598E+01	.10276E+00
11	.69450E+01	.11562E+01	.97532E+00	.45948E+00	.11780E+00	.22564E+01	.48233E+00	.12598E+01	.10330E+00
12	.75051E+01	.11541E+01	.97636E+00	.46457E+00	.12884E+00	.22509E+01	.48704E+00	.12598E+01	.10371E+00
13	.80614E+01	.11523E+01	.97695E+00	.46895E+00	.14001E+00	.22463E+01	.49121E+00	.12599E+01	.10401E+00
14	.86042E+01	.11508E+01	.97712E+00	.47239E+00	.15100E+00	.22428E+01	.49459E+00	.12599E+01	.10417E+00
15	.91375E+01	.11496E+01	.97700E+00	.47482E+00	.16180E+00	.22402E+01	.49706E+00	.12600E+01	.10416E+00
16	.96639E+01	.11488E+01	.97652E+00	.47626E+00	.17244E+00	.22388E+01	.49868E+00	.12601E+01	.10402E+00
17	.10173E+02	.11482E+01	.97567E+00	.47687E+00	.18271E+00	.22383E+01	.49962E+00	.12602E+01	.10376E+00
18	.11087E+02	.11475E+01	.97490E+00	.47715E+00	.20150E+00	.22376E+01	.50022E+00	.12603E+01	.10307E+00
19	.11087E+02	.12011E+01	.91395E+00	.35083E+00	.10680E+00	.24150E+01	.39221E+00	.12638E+01	.89830E-01
20	.12097E+02	.11972E+01	.91731E+00	.35756E+00	.13353E+00	.24028E+01	.39822E+00	.12637E+01	.90154E-01
21	.13079E+02	.11946E+01	.91821E+00	.36146E+00	.15917E+00	.23959E+01	.40198E+00	.12637E+01	.90012E-01
22	.14039E+02	.11931E+01	.91775E+00	.36268E+00	.18394E+00	.23928E+01	.40340E+00	.12639E+01	.89392E-01
23	.15035E+02	.11922E+01	.91615E+00	.36165E+00	.20986E+00	.23923E+01	.40276E+00	.12641E+01	.88263E-01

PT.	ALP(1)	ALP(2)	ALP(3)	ALP(4)	ALP(5)	ALP(6)	ALP(7)	PHI	W
1	.54596E-03	.24613E-02	.21932E+00	.28140E-02	.17351E-01	.73929E-02	.75012E+00	.10002E+01	.23799E+02
2	.54783E-03	.24730E-02	.21923E+00	.28201E-02	.17388E-01	.74232E-02	.75012E+00	.10002E+01	.23797E+02
3	.55296E-03	.24987E-02	.21904E+00	.28325E-02	.17482E-01	.74653E-02	.75013E+00	.10001E+01	.23793E+02
4	.55715E-03	.25262E-02	.21882E+00	.28470E-02	.17567E-01	.75414E-02	.75014E+00	.10001E+01	.23788E+02
5	.56098E-03	.25533E-02	.21861E+00	.28616E-02	.17648E-01	.76233E-02	.75014E+00	.10001E+01	.23783E+02
6	.56458E-03	.25797E-02	.21842E+00	.28759E-02	.17725E-01	.77062E-02	.75013E+00	.10001E+01	.23778E+02
7	.56827E-03	.26059E-02	.21823E+00	.28899E-02	.17801E-01	.77856E-02	.75012E+00	.10002E+01	.23773E+02
8	.57220E-03	.26324E-02	.21804E+00	.29039E-02	.17880E-01	.78611E-02	.75012E+00	.10002E+01	.23769E+02
9	.57673E-03	.26609E-02	.21782E+00	.29184E-02	.17967E-01	.79340E-02	.75012E+00	.10002E+01	.23764E+02

10	.58170E-03	.26906E-02	.21761E+00	.29334E-02	.18062E-01	.80039E-02	.75012E+00	.10002E+01	.23758E+02
11	.58702E-03	.27209E-02	.21734E+00	.29488E-02	.18165E-01	.80702E-02	.75012E+00	.10002E+01	.23753E+02
12	.59256E-03	.27497E-02	.21717E+00	.29647E-02	.18282E-01	.81283E-02	.75011E+00	.10002E+01	.23747E+02
13	.59924E-03	.27813E-02	.21691E+00	.29825E-02	.18419E-01	.81810E-02	.75013E+00	.10001E+01	.23741E+02
14	.60533E-03	.28157E-02	.21663E+00	.30040E-02	.18579E-01	.82277E-02	.75013E+00	.10001E+01	.23735E+02
15	.61277E-03	.28509E-02	.21641E+00	.30201E-02	.18708E-01	.82722E-02	.75013E+00	.10002E+01	.23728E+02
16	.62032E-03	.28840E-02	.21619E+00	.30361E-02	.18847E-01	.83061E-02	.75012E+00	.10002E+01	.23722E+02
17	.62948E-03	.29158E-02	.21598E+00	.30487E-02	.18977E-01	.83329E-02	.75012E+00	.10002E+01	.23715E+02
18	.68636E-03	.29762E-02	.21636E+00	.30066E-02	.19490E-01	.73656E-02	.75012E+00	.10002E+01	.23712E+02
19	.68636E-03	.29762E-02	.21636E+00	.30066E-02	.19490E-01	.73656E-02	.75012E+00	.10002E+01	.23704E+02
20	.69590E-03	.30022E-02	.21616E+00	.30144E-02	.19621E-01	.73228E-02	.75019E+00	.99992E+00	.23700E+02
21	.70600E-03	.30476E-02	.21587E+00	.30388E-02	.19813E-01	.73902E-02	.75013E+00	.10002E+01	.23690E+02
22	.71617E-03	.31004E-02	.21551E+00	.30626E-02	.20015E-01	.74377E-02	.75016E+00	.10000E+01	.23682E+02
23	.73069E-03	.31592E-02	.21521E+00	.30845E-02	.20227E-01	.74709E-02	.75012E+00	.10002E+01	.23671E+02

****

A SHOCK WAVE BETB= -.390E+00HAS BEEN INSERTED AT X= .472E+02WITH A TURNING ANGLE= .210E+00

Example C - Third variation (fig. 4):

```
KKKKK = 2635     LL =***

IPUNCH = 1     XSTEP =  .100E+01     PTZERO =  .351E+05     IDIVERG = 0     IDD =  4

XE,YE,RCR,PTOJ,TOJ 0.        0.        0.        0.        0.
NPTS = 18     NPT = 5     ITYP = 2     ISHOCK = 0     MMAX = 54

JCHEM = 1     IAVE = 0     INTACT = 0

XJ = 0.         EMSUB =  .101E+01  RTH =  .250E-01  DELTAY =  .500E+00  YBOT = 0.         YTP =  .750E+01  CHEMFC =  .500E+01

RE =  .672E+06  PR =  .100E+01  XLE =  .100E+01  EMINF =  .190E+01  TIN =  .214E+04  WINF =  .232E+02  PRES =  .122E+04

XPOT =  .100E+02  XK1 =  .750E-03  XK2 =  .285E-01  XK3 =  .100E+03  XK4 = 0.

IBOD = 0  ABOD = 0.         BBOD = 0.         CBOD = 0.

JBOD = 1  EBOD =  .750E+01  FBOD = 0.         GBOD = 0.

JJJ=    3

 XWALL,EEBOD,FFBOD,GGBOD
 .920E+01  .750E+01  .213E+00 0.
 .433E+02  .147E+02 0.        0.
 .775E+03  .147E+02 0.        0.
LWALL=    1      LBOD=    1
IPRESS = 0  APRESS = 0.         BPRESS = 0.         CPRESS = 0.

IPRESU = 0  APRESU = 0.         BPRESU = 0.         CPRESU = 0.

MASFRAC( 1)=   .6864000E-05
MASFRAC( 2)=   .3529000E-03
MASFRAC( 3)=   .1694000E+00
MASFRAC( 4)=   .9177000E-02
MASFRAC( 5)=   .6758000E-01
MASFRAC( 6)=   .3343000E-02
MASFRAC( 7)=   .7501400E+00
```

PROGRAM VIS-CHAR
WITH
EMBEDDED SUBSONIC FLOW
SHOCK WAVES
AND FINITE RATE H2-AIR CHEMISTRY

```
TYPE OF FLOW IS TWO DIMENSIONAL
CHEMISTRY IS FINITE RATE
JET OR NOZZLE RADIUS (RTH) =    .25000E-01 FT.


          REFERENCE CONDITIONS
          --------------------
MACH NO. (EMINF) =    .19030E+01
VELOCITY (UIN) =    .61561E+04 FT/SEC
TEMPERATURE (TIN) =    .21440E+04 DEGREES K
PRESSURE (PRES) =    .12212E+04 LB/FT**2
DENSITY (RHOINF) =    .14767E-03 SLUGS/FT**3
FROZEN SPECIFIC HEAT RATIO (GAMINF) =    .12654E+01
MOLECULAR WEIGHT (WINF) =    .23223E+02
REYNOLDS NUMBER (RE) =    .16799E+05
PRANDTL NUMBER (PR) =    .10000E+01
LEWIS NUMBER (XLE) =    .10000E+01


          OUTPUT HEADINGS
          ---------------
X - X/RTH
Y - Y/RTH
Q - VELOCITY/UIN
T - TEMPERATURE/TIN
P - PRESSURE/PRES
TH - FLOW DEFLECTION (RADIANS)
EM - MACH NUMBER
RHO - DENSITY/RHOINF
GAM - SPECIFIC HEAT
XMASS - NON-DIMENSIONAL MASS FLOW
PHI - EQUIVALENCE RATIO
W - MOLECULAR WEIGHT
```

MASS FRACTIONS
ALP(1) - H
ALP(2) - O
ALP(3) - H2O
ALP(4) - H2
ALP(5) - O2
ALP(6) - OH
ALP(7) - N2

KOUNT= 0

X = .51820E+01
VISCOSITY(LB*SEC/FT**2)= .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05
.13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05 .13412E-05
.13412E-05 .13412E-05 .13412E-05 .13412E-05

PT.	Y	Q	T	P	TH	EM	RHO	GAM	PITOT
1	0.	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
2	.50000E+00	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
3	.10000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
4	.15000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
5	.20000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
6	.25000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
7	.30000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
8	.35000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
9	.40000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
10	.45000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
11	.50000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
12	.55000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
13	.60000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
14	.65000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
15	.67500E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
16	.70000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
17	.72500E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00
18	.75000E+01	.10001E+01	.10000E+01	.10000E+01	0.	.19030E+01	.99980E+00	.12655E+01	.16817E+00

PT.	ALP(1)	ALP(2)	ALP(3)	ALP(4)	ALP(5)	ALP(6)	ALP(7)	PHI	W
1	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
2	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
3	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
4	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
5	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
6	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
7	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
8	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
9	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
10	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
11	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
12	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
13	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
14	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
15	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
16	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
17	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02
18	.68640E-05	.35290E-03	.16940E+00	.91770E-02	.67580E-01	.33430E-02	.75014E+00	.10001E+01	.23218E+02

****

DISCRET EXPANSION OF DNU= .209E+00HAS BEEN INSERTED AT .920E+01

KOUNT= 2635

X = .43186E+02

VISCOSITY(LB*SEC/FT**2)= .12911E-05 .12955E-05 .13081E-05 .13273E-05 .13510E-05 .13769E-05 .14029E-05
.14274E-05 .14491E-05 .14673E-05 .14815E-05 .14917E-05 .14978E-05 .15002E-05
.14999E-05 .14989E-05 .14970E-05 .14940E-05 .14938E-05 .14936E-05

PT.	Y	Q	T	P	TH	EM	RHO	GAM	PITOT
1	0.	.12042E+01	.93325E+00	.35908E+00	0.	.24059E+01	.39450E+00	.12613E+01	.92357E-01
2	.10489E+01	.12035E+01	.93403E+00	.36061E+00	.58192E-02	.24035E+01	.39583E+00	.12612E+01	.92569E-01
3	.20921E+01	.12014E+01	.93622E+00	.36497E+00	.12132E-01	.23965E+01	.39967E+00	.12611E+01	.93173E-01
4	.31247E+01	.11982E+01	.93950E+00	.37165E+00	.19377E-01	.23861E+01	.40553E+00	.12610E+01	.94081E-01
5	.41435E+01	.11943E+01	.94343E+00	.37989E+00	.27891E-01	.23734E+01	.41276E+00	.12608E+01	.95176E-01
6	.51469E+01	.11901E+01	.94756E+00	.38891E+00	.37883E-01	.23598E+01	.42065E+00	.12606E+01	.96333E-01
7	.61349E+01	.11858E+01	.95151E+00	.39795E+00	.49446E-01	.23464E+01	.42858E+00	.12604E+01	.97441E-01
8	.71086E+01	.11818E+01	.95499E+00	.40644E+00	.62571E-01	.23341E+01	.43603E+00	.12603E+01	.98411E-01
9	.80700E+01	.11782E+01	.95779E+00	.41391E+00	.77180E-01	.23234E+01	.44265E+00	.12602E+01	.99179E-01
10	.90216E+01	.11751E+01	.95979E+00	.42008E+00	.93146E-01	.23146E+01	.44818E+00	.12602E+01	.99703E-01
11	.99662E+01	.11726E+01	.96094E+00	.42477E+00	.11032E+00	.23080E+01	.45251E+00	.12602E+01	.99960E-01
12	.10907E+02	.11707E+01	.96121E+00	.42795E+00	.12852E+00	.23034E+01	.45560E+00	.12603E+01	.99942E-01
13	.11847E+02	.11694E+01	.96062E+00	.42961E+00	.14759E+00	.23010E+01	.45748E+00	.12604E+01	.99651E-01
14	.12791E+02	.11686E+01	.95922E+00	.42984E+00	.16739E+00	.23004E+01	.45820E+00	.12606E+01	.99096E-01
15	.13266E+02	.11684E+01	.95817E+00	.42939E+00	.17765E+00	.23009E+01	.45811E+00	.12608E+01	.98709E-01
16	.13744E+02	.11683E+01	.95693E+00	.42863E+00	.18803E+00	.23018E+01	.45778E+00	.12609E+01	.98264E-01
17	.14226E+02	.11683E+01	.95555E+00	.42759E+00	.19855E+00	.23030E+01	.45721E+00	.12611E+01	.97761E-01
18	.14684E+02	.11683E+01	.95450E+00	.42635E+00	.20856E+00	.23039E+01	.45629E+00	.12612E+01	.97181E-01
19	.14705E+02	.11683E+01	.95449E+00	.42628E+00	.20903E+00	.23039E+01	.45622E+00	.12612E+01	.97151E-01
20	.14723E+02	.11683E+01	.95449E+00	.42623E+00	.20944E+00	.23039E+01	.45617E+00	.12612E+01	.97123E-01

PT.	ALP(1)	ALP(2)	ALP(3)	ALP(4)	ALP(5)	ALP(6)	ALP(7)	PHI	W
1	.54914E-03	.23921E-02	.21996E+00	.27658E-02	.17293E-01	.68954E-02	.75014E+00	.10001E+01	.23810E+02
2	.54892E-03	.23939E-02	.21994E+00	.27672E-02	.17294E-01	.69116E-02	.75014E+00	.10001E+01	.23810E+02
3	.54860E-03	.24004E-02	.21988E+00	.27718E-02	.17299E-01	.69586E-02	.75014E+00	.10001E+01	.23809E+02
4	.54837E-03	.24113E-02	.21978E+00	.27793E-02	.17312E-01	.70308E-02	.75014E+00	.10001E+01	.23807E+02
5	.54857E-03	.24266E-02	.21964E+00	.27892E-02	.17334E-01	.71206E-02	.75014E+00	.10001E+01	.23805E+02
6	.54953E-03	.24462E-02	.21947E+00	.28012E-02	.17371E-01	.72203E-02	.75014E+00	.10001E+01	.23801E+02
7	.55153E-03	.24701E-02	.21928E+00	.28150E-02	.17424E-01	.73233E-02	.75014E+00	.10001E+01	.23797E+02
8	.55476E-03	.24982E-02	.21906E+00	.28304E-02	.17496E-01	.74240E-02	.75014E+00	.10001E+01	.23793E+02
9	.55936E-03	.25306E-02	.21881E+00	.28472E-02	.17589E-01	.75189E-02	.75014E+00	.10001E+01	.23787E+02
10	.56544E-03	.25673E-02	.21855E+00	.28653E-02	.17703E-01	.76055E-02	.75014E+00	.10001E+01	.23780E+02
11	.57309E-03	.26087E-02	.21827E+00	.28847E-02	.17840E-01	.76828E-02	.75014E+00	.10001E+01	.23773E+02
12	.58244E-03	.26550E-02	.21797E+00	.29055E-02	.18001E-01	.77505E-02	.75014E+00	.10001E+01	.23765E+02
13	.59353E-03	.27066E-02	.21764E+00	.29277E-02	.18187E-01	.78085E-02	.75014E+00	.10001E+01	.23756E+02
14	.60633E-03	.27632E-02	.21729E+00	.29512E-02	.18395E-01	.78569E-02	.75014E+00	.10001E+01	.23746E+02
15	.61373E-03	.27949E-02	.21709E+00	.29640E-02	.18514E-01	.78783E-02	.75014E+00	.10001E+01	.23740E+02

16	.62159E-03	.28280E-02	.21690E+00	.29771E-02	.18638E-01	.78976E-02	.75014E+00	.10001E+01	.23734E+02
17	.62976E-03	.28619E-02	.21670E+00	.29904E-02	.18766E-01	.79144E-02	.75014E+00	.10001E+01	.23728E+02
18	.63673E-03	.28912E-02	.21652E+00	.30018E-02	.18875E-01	.79315E-02	.75014E+00	.10001E+01	.23723E+02
19	.63677E-03	.28914E-02	.21652E+00	.30019E-02	.18876E-01	.79315E-02	.75014E+00	.10001E+01	.23723E+02
20	.63679E-03	.28914E-02	.21652E+00	.30019E-02	.18876E-01	.79315E-02	.75014E+00	.10001E+01	.23723E+02

REFERENCES

1. Ferri, A.: Review of SCRAMJET Propulsion Technology. J. Aircr., vol. 5, no. 1, Jan.-Feb. 1968, pp. 3-10.

2. Becker, John V.: New Approaches to Hypersonic Aircraft. Paper Presented at the Seventh Congress of the International Council of the Aeronautical Sciences (Rome, Italy), Sept. 1970.

3. Henry, John R.; and Beach, H. Lee.: Hypersonic Air-Breathing Propulsion Systems. Vehicle Technology for Civil Aviation - The Seventies and Beyond, NASA SP-292, 1971, pp. 157-177.

4. Henry, John R.; and Anderson, Griffin Y.: Design Considerations for the Airframe-Integrated Scramjet. NASA TM X-2895, 1973.

5. Dash, S.; and Del Guidice, P.: Analysis of Supersonic Combustion Flow Fields With Embedded Subsonic Regions. NASA CR-112223, 1972.

6. Kalben, Paul: A Fortran Program for the Analysis of Supersonic Combustion Flow Fields With Embedded Subsonic Regions. NASA CR-112223-1, 1972.

7. Davis, R. T.; and Flügge-Lotz, I.: Second-Order Boundary-Layer Effects in Hypersonic Flow Past Axisymmetric Blunt Bodies. J. Fluid Mech., vol. 20, pt. 4, Dec. 1964, pp. 593-623.

8. Ferri, Antonio; and Dash, Sanford: Viscous Flow at High Mach Numbers With Pressure Gradients. Viscous Interaction Phenomena in Supersonic and Hypersonic Flow, Univ. of Dayton Press, 1970, pp. 271-317.

9. Dash, S.: An Analysis of Internal Supersonic Flows With Diffusion, Dissipation and Hydrogen-Air Combustion. NASA CR-111783, 1970.

10. Ferri, Antonio; Libby, Paul A.; and Zakkay, Victor: Theoretical and Experimental Investigation of Supersonic Combustion. ARL 62-467, U.S. Air Force, Sept. 1962.

11. Kleinstein, Gdalia: On the Mixing of Laminar and Turbulent Axially Symmetric Compressible Flows. PIBAL Rept. No. 756 (Contract No AF 33(616)-7661), Polytech. Inst. Brooklyn, Feb. 1963.

12. Eggers, James M.: Turbulent Mixing of Coaxial Compressible Hydrogen-Air Jets. NASA TN D-6487, 1971.

13. Jenkins, Renaldo V.: Mixing and Combustion of an Underexpanded H_2 Jet in Supersonic Flow. AIAA Paper No. 76-610, July 1976.

14. Casaccio, Anthony; and Rupp, Richard L.: A Supersonic Combustion Test Program Utilizing Gas Sampling, Optical and Photographic Measuring Techniques. NASA CR-66393, [1976].

15. Rogers, R. C.; and Eggers, J. M.: Supersonic Combustion of Hydrogen Injected Perpendicular to a Ducted Vitiated Airstream. AIAA Paper No. 73-1322, Nov. 1973.

16. Jones, Robert A.; and Huber, Paul W.: Toward Scramjet Aircraft. Astronaut. & Aeronaut., vol. 16, no. 2, Feb. 1978, pp. 38-48.

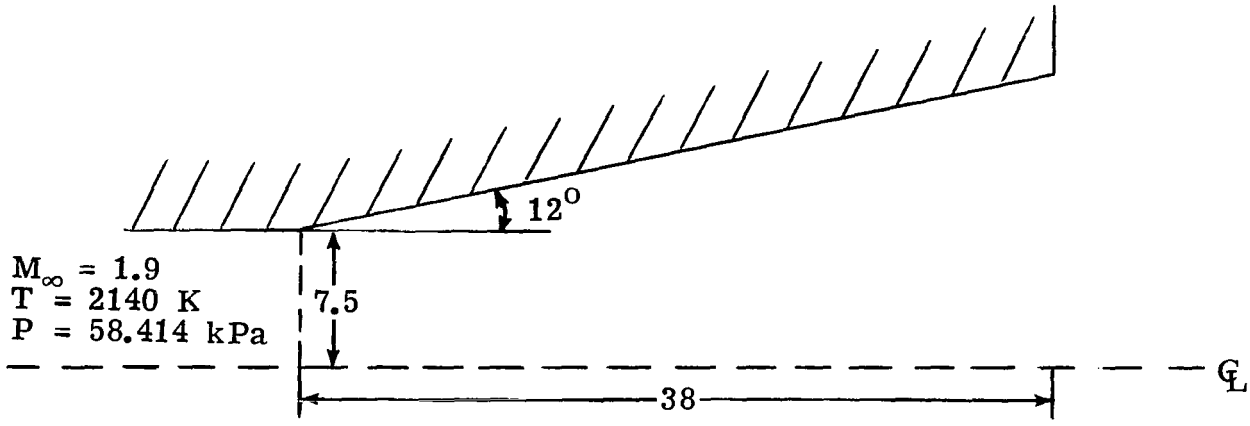

Figure 1.- Half-section of the 12° divergent combustor.
Linear distances are nondimensional.

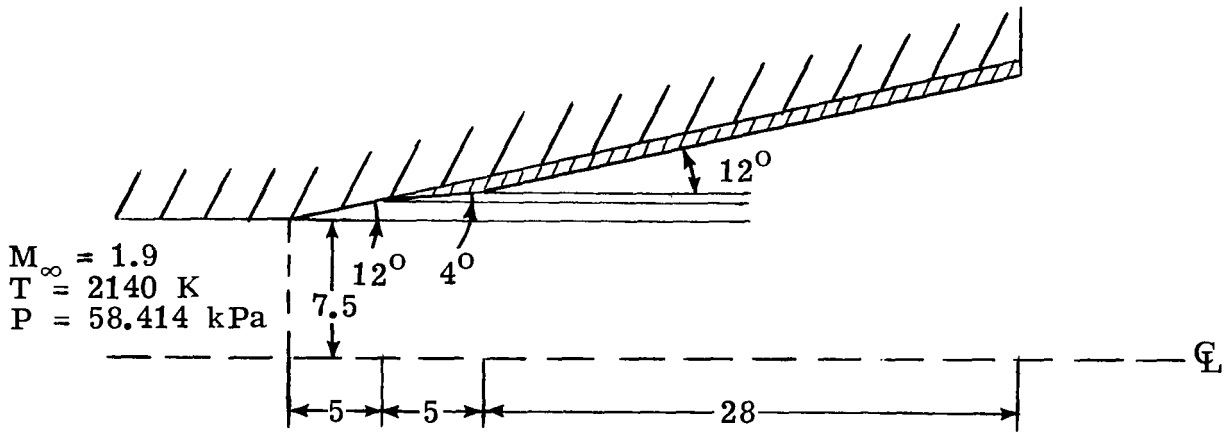

Figure 2.- Half-section of combustor with a shock-generating filler plate which produces 8° turning. Linear distances are nondimensional.

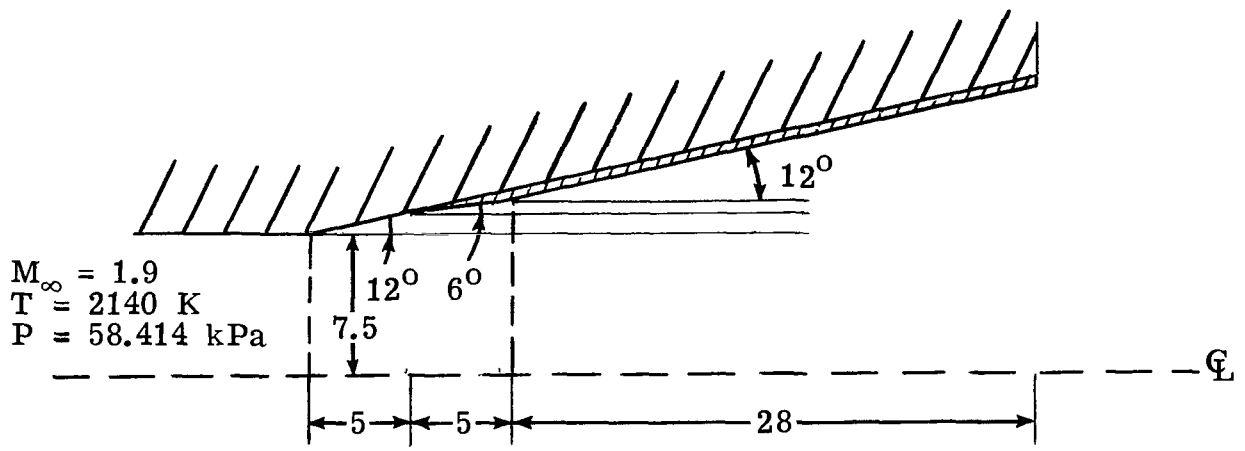

Figure 3.- Half-section of combustor with a shock-generating filler plate which produces 6° turning. Linear distances are nondimensional.

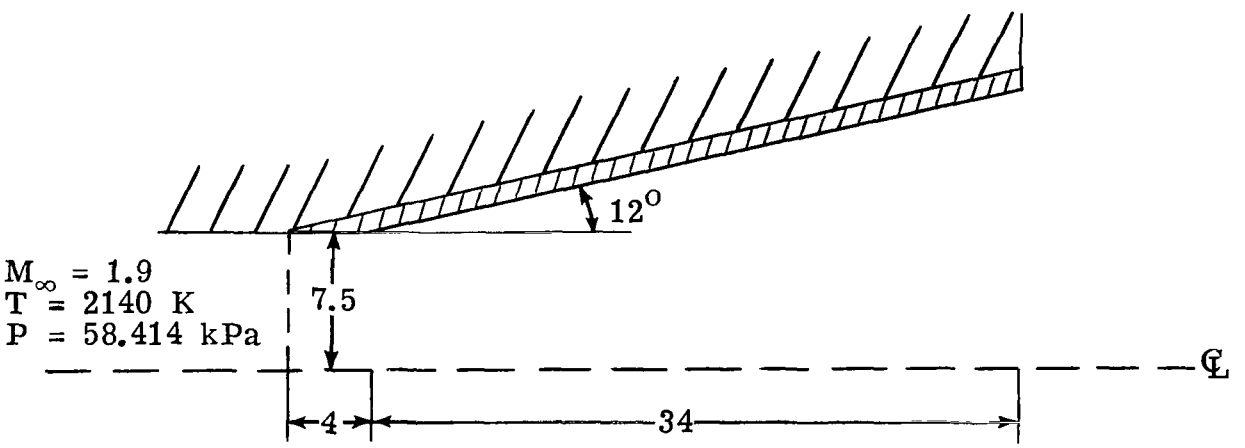

Figure 4.- Half-section of combustor with a shock-generating filler plate which produces four-unit-length constant area. Linear distances are nondimensional.

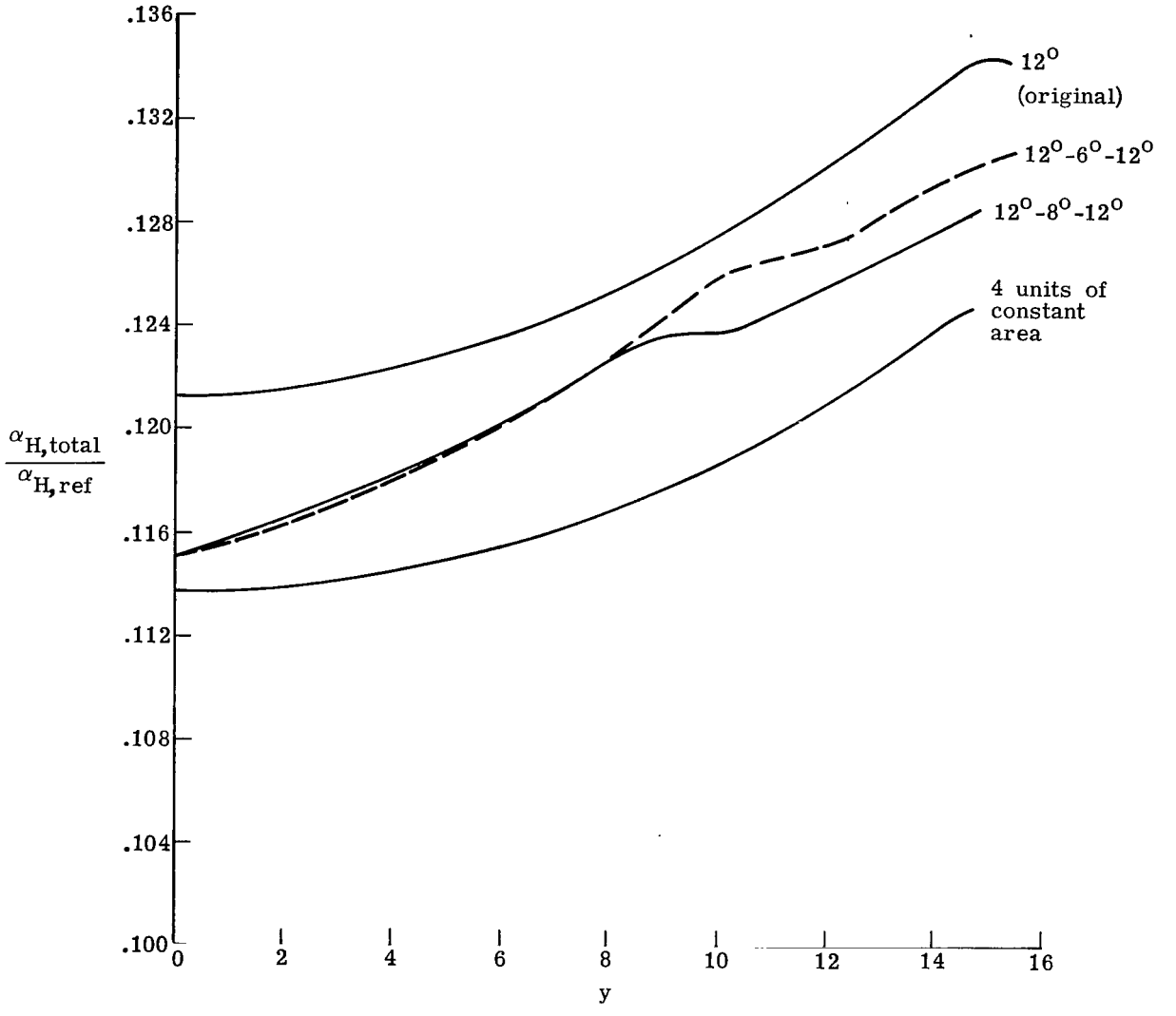

Figure 5.- Comparison of unreacted hydrogen exit profiles for several combustor shapes.

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16. Abstract

An improved two-dimensional/viscous characteristics analysis program is presented in this report. The program is built upon the foundation of a FORTRAN program in NASA CR-112223 entitled "Analysis of Supersonic Combustion Flow Fields With Embedded Subsonic Regions." The major improvements are described and a listing of the new program is provided. The subroutines and their functions are given as well as the input required for the program. Additionally, several applications of the new program to real problems are qualitatively described. Similarly, three runs obtained in the investigation of a real problem are presented to provide insight for the input and output of the program. This new program has greatly extended the viscous characteristics analysis of NASA CR-112223 and has transformed it into a useful combustor design tool. None of the problems described in this paper could be solved with the program capability of NASA CR-112223.

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