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Description of a Computer Program to Calculate Reacting Supersonic Internal Flow Fields with Shock Waves Using Viscous Characteristics - Program Manual And Sample Calculations*

by

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ABSTRACT

A computer program for calculating internal supersonic flow fields with chemical reactions and shock waves typical of supersonic combustion chambers with either wall or mid-stream injectors is described. The usefulness and limitations of the program are indicated. The program manual and listing are presented along with a sample calculation.

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INTRODUCTION

The structure of the flow field within a supersonic combustion chamber designed to operate over a range of flight Mach numbers is complex due to many interacting phenomena. This flow field is permeated both by nonuniformities and discontinuities. The nonuniformities inherent in the incoming stream are produced by the inlet flow, fuel injectors, and combustor walls. The nonuniformities exhibit themselves in a variety of ways among which are:

1) Nonuniform initial conditions such as flow direction, Mach number, and total pressure distributions.
2) The boundary layer on the inlet walls introduce shear layers with very large gradients normal to the streamlines and possible reverse flow if separation occurs.
3) Oblique shock intersections produce slipstreams as well as rotational flow and vortical layers.
4) The fuel injector and combustion phenomena produce nonuniformities in the gas composition and phase.
5) Other nonuniformities are due to three-dimensional fields.

In view of the above complexities, a truly realistic theoretical description of a supersonic combustion flow field presents a formidable task. A first attack at this task is attempted here for a more simiplified flow field. The assumptions inherent in the present analysis are a steady, viscous, two-dimensional (or axisymmetric), completely supersonic flow field. In view of the last assumption, the boundary layer formed near solid walls is disregarded here. Also, changes in the local sound speed produced by either variation of species, or temperature rise as produced in exothermic reactions, or excessive flow deceleration produced by pressure rises so as to drive the flow subsonic are not allowed. The steadiness of the flow is imposed on the fluid mechanical time scale as well as on the chemical time scale. Therefore, combustion unsteadiness, "sputtering", as produced by conditions in near flamability limits thermodynamic conditions of the fluid is not considered here. The chemistry is assumed to occur at a finite rate or frozen and the reactions are assumed to occur between air and gaseous hydrogen. The viscous transport phenomena can either be laminar or turbulent.

The immediate problem at hand is to predict the flow downstream of a given initial station and bounded by an upper and lower wall with two either converging or diverging shocks and with chemical reactions as shown on Figs. 1a and 1b. Region one can be either uniform or nonuniform. The flow properties across the shocks are calculated assuming no gas composition change across them, i.e. as in an ideal gas using the local value of the ratio of specific heats.

ANALYSIS

Since the flow field is assumed to be completely supersonic (both air stream and fuel stream) the field can be considered to be "quasi-hyperbolic" if viscous stress terms due to gradients along the streamlines are neglected and the viscous stress terms due to gradients normal to streamlines are approximated by constants in a small neighborhood. Under these assumptions the governing equations can be cast in characteristic form with driving-functions on the right hand side. The driving functions depend solely on the viscous transport and chemical phenomena. A derivation of the compatibility equations along the characteristic lines may be found in Refs. 1, 2, and 3 along with the chemical reactions, reaction rates, and calculation procedure. The imposition of the proper boundary condition is observed in the present computer program.

The turbulent viscosity model used in the present program is

$$\mu_t = K\, r_{\frac{1}{2}}\, \rho_o\, u_o$$

where $r_{\frac{1}{2}}$ is a measure of the size of the eddies and is determined as the height where $\rho u = \frac{1}{2}(\rho_e u_e + \rho_o u_o)$ where e denotes external conditions and o denotes centerline or wall conditions.

COMPUTER PROGRAM

The computer program proceeds from a given initial data line at a constant axial station to the next station by taking a calculated step size satisfying both parabolic and characteristic as well as chemical stability criteria. A listing of the program is given in Table 1.

In the main part of the program the initial profile is set up and the type of flow (i.e., converging or diverging shocks) is selected. The main loop for each step begins at statement number 6789 and ends at the statement prior to 1572. The following is a list and description of the sub-routines in the program:

MESH	traces a characteristic line
SHKINT	determines the intersection point of converging shocks
HERMAN	solves for chemical time
CLEM	
SOLT	
ETHANE(T)	fudges the chemistry for ethane-air reaction
PROP(T)	fudges the chemistry for propane-air reaction
ETH 2(T)	

SURFAC(IND,L,X,R,DR)	reads in wall slopes and computes wall position
CUBIC (C,Z)	solves for shock wave angle
COEF (I,T)	gives thermodynamic coefficients, constant, fits
THERM(IND,L)	calculates enthalpy
UPSC (THS)	calculates upstream flow if nonuniform
STEP(DELX,N1,NP2)	calculates step size
INTER(RAT,KL,N1,N2)	interpolation subroutine
FIND	locates intersection point of streamline with given data line
ERROR(IIII)	writes out error message number
SHOCK	calculates shock point
FLIP(IMB,N1,NPTS,XMSR)	stores new station into old - updates data
FLOW	calculates an intergral point
POINT(ID,NPO,IU,IFM)	adds internal point near shock
BODY (JXT)	calculates wall point
POCUS(TI,PRESSI,RHOI.)	calculates finite rate chemistry
CHEMP(IWD,DX,L)	calculates chemical production term
COMPS (IND)	calculates viscous dissipation terms (viscosity)

PROGRAM MANUAL

The program can be used to calculate the two flow fields described in Figs. 2a and 2b. The control cards and input cards necessary are given in Table 2. A sample input data is shown in Table 3. The present program is not equipped to handle a slip stream discontinuity as would occur immediately at the lip of the injector. The initial profile data must be continuous. The slip-stream can therefore be approximated by a strong gradient in the y direction.

Sample Calculation - Wall Injector

A sample calculation using this program was made for the wall injector shown in Fig. 3. The H_2 jet was chosen 0.02 ft. high. The jet initial Mach number is 2.0 and the air external stream is 2.7. Other initial conditions (temperature, velocity, pressure, Mach number, flow direction, and H_2 mass fraction) are shown in Fig. 4. The fuel injector shock was located away from the combustion zone in this calculation.

The lower wall geometry has a 10° slope discontinuity (expansion) at the mouth of the injector. The expansion wave from this point propagates into the combustion zone. The wall angle distribution for this injector is shown in Fig. 3b. The wall is assumed inviscid (i.e. no boundary layer) in this calculation. The pressure, Mach number, velocity, and temperature distributions along the wall of the combustor are shown in Figs. 5a through 5d. The corresponding distributions calculated assuming Prandtl-Meyer expansion of the flow along this wall are shown for comparison. The differences are due to down running waves from the combustion zone and the external stream. Flow profiles at downstream stations are shown in Fig. 6a through 6i. The temperature profiles show a characteristic peek typical of a flame. While the pressure profiles show the propagation of combustion induced waves. The species profile show the diffusion of the fuel into the flame water from the flame.

A plot of the characteristic and streamlines through the combustion zone is shown in Fig. 7. The flame zone, edge of mixing, and other flow characteristics are shown for comparison.

RESULTS

A useful tool for analyzing a simplified supersonic flow with chemical reactions is presented. In spite of its limitations, the computer program can

can be used 1) in assisting in the design of fuel injectors and supersonic combustors, 2) in segregating the highly coupled fluid-mechanical effects of combustion and mixing in supersonic streams, and 3) in evaluating turbulent eddy viscosity models by comparing experiment with theory.

REFERENCES

1. Ferri, A., Moretti, G., Slutsky, S., "Mixing Processes in Supersonic Combustion," Journal of Society of Industrial and Applied Mathematics, Vol. 13, No. 1, March 1965, p. 229.

2. Dash, S., "An Analysis of Internal Supersonic Flows with Diffusion, Dissipation and Hydrogen - Air Combustion," Advanced Technology Laboratory, Jericho, New York, ATL TR-152, May 1970.

3. Cavalleri, R.J., "Reacting and Non-Reacting Analysis of Supersonic Viscous Flow," Ph.D. Thesis, New York University, School of Engineering and Science, April 1972.

Table 1 Program Listing

COMBUSTOR

```
      PROGRAM CHAR(INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,
     1TAPE7=PUNCH)
      COMMON /IO/ IOCHEM
      COMMON /ZOUT/         JOUT(3),IOUT(3)
      COMMON/EDVI/ FACTOR (3) ,VISCX(3)
      COMMON/YSH/ Y1(150,2),COALT,ICN(2)
      COMMON/POYNT/ YASL
      COMMON /SHNT/ DXM,DIN,DXIN,XSHINT
      COMMON/FRSTR/  TIN,UIN,EMINF,GAMINF,CPIN,RO,WTMOLE(7)
      COMMON/PROPT/H1(7),CP1(7),DCP1(7)
      COMMON/FUDGE/ AFAC
      COMMON/COF/ AZ,BZ,CZ,DZ,EZ,FZ,GZ
      COMMON/BLK1/CPXN(150),CPX(150)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S3I(7,150),S3IN(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK16/PHI(150),XS(  7),  DACH(7,150)
      COMMON/BLK19/ N2D,IFAM
      COMMON/BLK20/ NLO(3),NOP(3),DELXF(3),ANG(3),ANGN(3)
      COMMON/BLK21/ IR,IRD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/FIN,XJ,RE,PR,XLE,EPTH,EPP,EPQ,EPT,RINF,WINF,NSP,JCHEM
      COMMON/UP1/ GAMAUP(3),XMWUP(3),DUP(3),RHOUP(3),HUP(3),ALPUP(7,3)
      COMMON/UP2/XMUUP(3),PUP(3),QUP(3),TUP(3), XUP(3),EMUP(3),WPUP(3)
      COMMON/DISS/ FDISP(3),D2P(3),XMUP(3),PP(3),QP(3),RHOP(3),THP(3)
      COMMON/MSCK/ XMASS(150)
      COMMON/KASE/ CAS1,CAS2
      DIMENSION XPRO(14)
      DIMENSION NMAX(3)
      DATA III1/0/
      XM3(QZ1,QZ2,QZ3,QZ4 )= QZ1*TAN(QZ3)+QZ2*TAN(QZ4)
      XM1(QX3,QX4,QX7)   =     TAN(QX3+QX7*QX4)
  999 CONTINUE
      WRITE(6,400)
      CAS1=0.
      CAS2=1.0
      CAS1=1.0
      AFAC=.1
      CAS2=.0
C CAS1=0 . CAS2=1  USE WDOT
C CAS1=1 , CAS2=0  USE DACH
C     JCHEM=0    FROZEN
C     JCHEM=1    REACTING
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
```

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```
      WRITE(6,124) DXN,DIN,DXIN
      X(1)=XRP
      DUP(2)=DUP(2)*.01745329
      DUP(3)=DUP(3)*.01745329
      READ(5,102) (ALPUP(J,2),J=1,NSP)
      READ(5,102) (ALPUP(J,3),J=1,NSP)
      WRITE(6,125) (ALPUP(J,2),J=1,NSP)
      WRITE(6,126) (ALPUP(J,3),J=1,NSP)
      READ(5,101) ITYPE
      READ(5,101) NLO(1),NOP(1),NLO(2),NOP(2),NLO(3),NOP(3)
      WRITE(6,123) NLO(1),NOP(1),NLO(2),NOP(2),NLO(3),NOP(3),ITYPE
      WRITE(6,400)
      DO 2003 IR=1,3
      DO 2004 J=1,NSP
      IF(ALPUP(J,IR).LT.1.1E-10) ALPUP(J,IR)=1.1E-10
      ALPUP(J,1)=.0
 2004 CONTINUE
      N1=NLO(IR)
      N2=NOP(IR)
      GO TO (43,44),ISTART
   43 CONTINUE
      READ(5,102) (Y(I),I=N1,N2)
   44 CONTINUE
      WRITE(6,128)
      DO 788 I=N1,N2
      D2N(I )= 1.
      EDISN(I )= 1.
      X(I)=XRP
      GO TO (40,41) ,ISTART
   40 CONTINUE
      READ(5,102)P(I), T(I), Q(I), TH(I)
      GO TO 42
   41 CONTINUE
      READ(5,102)P(I), T(I), Q(I), TH(I),Y(I) ,DUM
      Y(I)=DUM
   42 CONTINUE
      WRITE(6,127)  I,P(I), T(I), Q(I), TH(I) ,Y(I)
      Y1(I,1)=Y(I)
      Y1(I,2)=Y(I)
      YN(I)=Y(I)
      TH(I)=TH(I)*.01745329
      THN(I)=TH(I)
      PN(I)= P(I)
      QN(I)=Q(I)
      TN(I)=T(I)
  788 CONTINUE
      WRITE(6,131)
      XMASS(N1)=.0
      DO 789 I=N1,N2
      READ(5,102)ALP(1,I),ALP(2,I),ALP(3,I),ALP(4,I),ALP(5,I),ALP(6,I),
     1ALP(7,I)
      DUM=0.
      DO   8181 J=1,6
      DUM= DUM+ ALP(J,I)
 8181 CONTINUE
      ALP(7,I)=1.-DUM
      CALL THERM (1,I)
      W(I)=0.0
```

```
      HX(I)=0.0
      CPX (I)=.0
      DO 18 J=1,7
      IF(ALP(J,I).LT.1.1E-10) ALP(J,I)=1.1E-10
      ALPN(J,I)=ALP(J,I)
      HX(I)=HX(I)+ALP(J,I)*H1(J)
      W(I)=W(I)+ALP(J,I)/WTMOLE(J)
      CPX (I)=CP1 (J)*ALP (J,I) +CPX(I)
   18 CONTINUE
      CPXN(I)=CPX(I)
      HT(I)=HX(I)+Q(I)**2 *.5
      W(I)=1./W(I)
      WN(I)=W(I)
      R(I)=RO/W(I)*45092.8
      RN(I)=R(I)
      GAM(I)=CPX(I)/(CPX(I)-R(I))
      GAMN(I)=GAM(I)
      FM(I)=Q(I) / SQRT(GAM(I)*R(I)*T(I) )
      FMN(I)=FM(I)
      WRITE(6,129)I,ALP(1,I),ALP(2,I),ALP(3,I),ALP(4,I),ALP(5,I),ALP(6,I
     1),ALP(7,I),FM(I),GAM(I)
      RHO(I)= P (I)/(R (I)*T (I) )
      RHON(I)= RHO(I)
      XMU(I)=ASIN(1./EM(I) )
      XMUN(I)=XMU(I)
      IF(I.EQ.N1) GO TO 789
      ROAV=(RHO(I)*Q(I)*COS(TH(I))+ RHO(I-1)*Q(I-1)*COS(TH(I-1)))/2.
      DUM2=1.+Y(I-1)*XJ -XJ
      DUM1=1.+XJ*Y(I)  -XJ
      XMASS(I)=XMASS(I-1)+ROAV*(Y(I)* DUM1    -Y(I-1)*DUM2     )/(1.+XJ)
  789 CONTINUE
 2003 CONTINUE
      GO TO (24,22),IFLO
   24 N2=NOP(2)
      HUP(2)=HX(N2)
      N2=NOP(3)
      HUP(3)=HX(N2)
      GO TO 23
   22 N2=NOP(1)
      HUP(2)=HX(N2)
      N2=NLO(1)
      HUP(3)=HX(N2)
   23 CONTINUE
      WRITE(6,124) HUP(2),HUP(3)
      N2=NOP(1)
      XMSV=XMASS(N2)
      IND=1
      KOUNT=0
C ----- PROCEED TO NEXT STATION    --- -----
 6789 PHIM=1.05
      DO 8282 IR=1,3
      GO TO (32,34),IND
   34 GO TO (30,31),IFLO
   31 GO TO (8282,32,32),IR
   30 GO TO (32,8282,8282),IR
   32 NA=NLO(IR)
      NB=NOP(IR)
  770 CALL STEP(DELXF(IR),NA,NB)
```

```
      DO 7188 K=NA,NB
      DO 7199 J=1,NSP
      XS(J)=W(K)*ALP(J,K)/WTMOLE(J)
 7199 CONTINUE
      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
      IF(PHI(K).GT.PHIM) PHIM=PHI(K)
 7188 CONTINUE
C --------- -     ----- CHEMISTRY PACKAGE -----   ---  -  -------
      IF(JCHEM.EQ.0) GO TO 8351
      DO 8355 L=NA,NB
      XN(L)=X(L )+DELXF(IR)
      YN(L)=Y(L)+TAN(TH(L))*DELXF(IR)
      DX=SQRT((XN(L)-X(L))**2+(YN(L)-Y(L))**2)
      IWD=1
      CALL CHEMP(IWD,DX,L)
 8355 CONTINUE
      GO TO 8282
 8351 DO 8302 L=NA,NB
      DO 8302 J=1,NSP
      WDOT(J,L)=0.
      WDOTN(J,L)=0.
 8302 DACH(J,L)=0.
 8282 CONTINUE
      GO TO (774,775),IND
  774 CONTINUE
      CALL COMPS(1)
      J9=NLO(3)
      IF(ISTART.EQ. 2  .AND. XJ .GT. .0)FDIS(J9)=ADUM1
      IF(ISTART.EQ. 2  .AND. XJ .GT. .0)D1   (J9)=ADUM2
      IF(ISTART.EQ. 2  .AND. XJ .GT. .0)S4   (J9)=ADUM3
      IND=2
  775 CONTINUE
      GO TO (19,20),IFLO
   20 CONTINUE
C     ---- - -  ---------------
C----------       CONVERGING SHOCKS      -------- -
C     ---- - -  ---------------
      IXD=0
      IR=2
      NA=NLO(2)
      NB= NOP(2)
      CALL STEP(DELXF(2),NA,NB)
      IR=3
      NA=NLO(3)
      NB= NOP(3)
      CALL STEP(DELXF(3),NA,NB)
      X1=5.
      NB=NB-1
      DO 36 I=NA,NB
      IP=I+1
      X2= (Y(IP)-Y(I))**2*RHO(I)*Q(I)/VISCX(3 )*.25
      IF (X2.LE.X1) X1=X2
   36 CONTINUE
      WRITE(6,104) X1,X2 ,VISCX
      X2= DELXF(3)
      DELXF(3)= AMIN1(X1,X2)
```

```
      WRITE(6,104) X1,X2   ,DELXF(3)
      DELXF(2)=DELXF(3)
C --------- -          LOWER REGION  REGION 3      ---- -  -------
      FAM=1.
      IFAM=1
      IR=3
      IRU=3
      IUP=1
      IRD=3
      CALL SHOCK
      CALL FLOW
      CALL MESH
      NDM=NLO(IR)
      DX2=DELXF(IR)
      DO 135 KX=1,14
      IF(ABS(XN(NDM)-XPRO(KX) ) .LE. DX2) GO TO 136
  135 CONTINUE
      GO TO 137
  136 CONTINUE
      WRITE(6,702) XN(NA)
      WRITE(7,702) XN(NA)
      NA=NLO(IR)
      NB=NOP(IR)
      DO 138 I=NA,NB
      THD=TH(I)/.01745329
C 102 FORMAT(7F10.4)
      WRITE(7,702)PN(I),TN(I),ON(I),THD,EMN(I),YN(I)
C 702 FORMAT(8F10.4)
  138 CONTINUE
      DO 139 I=NA,NB
      WRITE(7,104) (ALP(J,I),J=1,NSP)
  139 CONTINUE
  137 CONTINUE
      GO TO 2001
C --------- -          UPPER REGION  REGION 2      ---- .  -------
   21 FAM=-1.
      IFAM=1
      IR=2
      IRU=2
      IRD=4
      CALL SHOCK
      CALL FLOW
      CALL MESH
      CALL SHKINT
      NC=NLO(IR)
      IF(XN(NC).GE.XSHINT) GO TO 25
      GO TO 2001
C     ---- - - ---------------
C----------       DIVERGING SHOCKS      -------- -
C     ------ -  --------------
   19 IR=1
      IRU=3
      IRD=1
      FAM=-1.
      IFAM=-1
      CALL SHOCK
      IRD=2
      IRU=2
```

```
      FAM=1.
      IFAM=1
      CALL SHOCK
      CALL FLOW
      CALL MESH
      NLO(1)=2
      IMD=0
      IF(ABS(YN(2)-YN(3)).LT. YASL) GO TO 2001
      CALL POINT(1,2,IU,1)
      CALL POINT(2,2,IU,1)
      CALLPOINT(3,NPG,1,IXX)
      NLO(1)=1
      IMD=1
 2001 CONTINUE
      N2=NOP(IR)-1
      N1=NOP(IR)
      IF(ABS(YN(N1)-YN(N2)).LT. YASL) GO TO 2002
      CALL POINT(1,N1,IU,-1)
      CALL POINT(2,N1,IU,-1)
      NOP(IR)=NOP(IR)+1
      IU=NOP(IR)
      CALL POINT(3,N1,IU,IXX)
 2002 CONTINUE
      N1=NLO(IR)
      N2=NOP(IR)
      CALL FLIP(IMD,N1,N2,XMSV)
C     WRITE(6,103) (XMASS(I),I=N1,N2)
  103 FORMAT (7(2XF14.6) )
      NLO(IR)=N1
      NOP(IR)=N2
      IF (IR.EQ. 3) GO TO 21
      DO 2000 I=1,2
 2000 ANG(I)=ANGN(I)
      DO 26 IR=1,3
      IF (NOP(IR) .LT. NMAX(IR) ) GO TO 26
      GO TO 27
   26 CONTINUE
      GO TO 28
   27 DO 29 IR=1,3
      NA=NLO(IR)
      NB=NOP(IR)
      DO 35 I=NA,NB
      THD=TH(I)/.01745329
      WRITE(6,702) P(I),T(I),Q(I),THD ,Y(I)   ,FDIS(I),D1(I),S4(I)
      WRITE(7,702) P(I),T(I),Q(I),THD ,Y(I)   ,FDIS(I),D1(I),S4(I)
   35 CONTINUE
      DO 29 I=NA,NB
      WRITE(6,104)(ALP(J,I),J=1,NSP)
      WRITE(7,104)(ALP(J,I),J=1,NSP)
   29 CONTINUE
      CALL EXIT
   28 CONTINUE
      KOUNT=KOUNT+1
      IF(KOUNT.GE. 8) AFAC=.25
      NA=NLO(3)
      IF (XN(NA) .GE. XSTOP) GO TO 999
      GO TO 6789
   25 IFLO=1
```

```
      CALL MESH
      ITYPE=2
      GO TO 19
 5231 CONTINUE
      CALL ERROR(IERR)
      IIII=1
      GO TO 6789
 1572 CONTINUE
  101 FORMAT(10I5)
  104  FORMAT(7F10.8)
  102 FORMAT(7F10.4)
  702 FORMAT(8F10.4)
  120 FORMAT(//,16X,7H ANG(1),9X,7H ANG(2),8X,5H YASL,11X,5H DELY,10X,
     14H FLO /,10X,  5(2XE14.6) //)
  122 FORMAT(7X,6HXMU(3),10X,5HPU(3),11X,5HQU(3),11X,5HTU(3),11X,6HFMU(3
     1),10X,7HGAMU(3), 9X,7HXMWU(3), 9X,6HDUP(3) / 8(2XE14.6) //)
  121 FORMAT(7X,6HXMU(2),10X,5HPU(2),11X,5HQU(2),11X,5HTU(2),11X,6HFMU(2
     1),10X,7HGAMU(2), 9X,7HXMWU(2), 9X,6HDUP(2) / 8(2XE14.6) //)
  123 FORMAT(9X,6HNLO(1),2X,6HNOP(1),2X,6HNLO(2),2X,6HNOP(2),2X,6HNLO(3)
     1,2X,6HNOP(3),2X,5HITYPE/ 5X,7(3XI5) )
  124 FORMAT (15X,6H HUP2= E14.6,2X,6H HUP3= E14.6 )
  125 FORMAT(5X,111H ALPUP2       1                       2                       3
     1          4                      5                       6                       7    ,/14X,
     2 7(2XE14.6) /)
  126 FORMAT(5X,111H ALPUP3       1                       2                       3
     1          4                      5                       6                       7    ,/14X,
     2 7(2XE14.6) /)
  127 FORMAT (I4, 5(2XE14.6) )
  128 FORMAT (1H1,40X,11H INPUT DATA  /9X, 2H P,14X,2H T,14X,2H G,14X,
     16H THETA,11X,2H Y  )
  129 FORMAT (I4, 9(1XE12.6) )
  131 FORMAT (1H1,45X,11H INPUT DATA /10X,80H      ALP1                ALP2
     1          ALP3              ALP4              ALP5       ,     5H ALP6,10X,
     25H ALP7  )
  400 FORMAT(1H1)
      STOP
      END
```

SUBROUTINE MESH

```
C
C
      COMMON /ZOUT/        JOUT(3),IOUT(3)
      COMMON/MSH/ Y1(150,2),COALT,ICN(3)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK20/ NLO(2),NOP(3),DELXF(3),ANG(2),ANGN(2)
      COMMON/BLK21/ IR,IRD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      DIMENSION  NMPT(3), Y2(150,2)
      DATA NMPT(1),NMPT(2),NMPT(3)/ 0, 0, 0/
      IF(IR.EQ.2) RETURN
      DELX=DELXF(IR)
      NA=NLO(IR)
      NA1=NA+1
      NB1=NOP(IR)
C     IF(XMOUT-XN(NA) .GE. XADD) GO TO 31
      NMPT(IR)=NMPT(IR)+1
   31 CONTINUE
      NB=NMPT(IR)
      NBM=NB-1
      NB2= NMPT(IR)-2
      LUP1=0
      LUP= 0
      KMD=-1
      LC=0
      MD=-1
      FAM1=1.
      AMD=-1.
      IF(IR.EQ.2) FAM1=-1.
      IF(IR.EQ.2) AMD=1.
      ICM=ICN(IR)
      GO TO (1,2),ICM
    2 CONTINUE
C     WRITE(6,8899) NMPT(IR),XMOUT,XADD
C8899 FORMAT (I5,2(2XE14.6) )
C     IF(XMOUT-XN(NA) .GE. XADD) GO TO 32
C     XMOUT=XN(NA)+XADD
C     WRITE(6,8899) NMPT(IR),XMOUT,XADD
      Y2(NA,1)=YN(NA)
      Y2(NB,2)=YN(NB1)
      Y2(NA1,1)= Y(NA)+DELX*TAN(TH(NA)+FAM1*XMU(NA) )
      Y2(NBM,1)= Y(NB1)+DELX*TAN(TH(NB1)-FAM1*XMU(NB1))
   32 CONTINUE
      DO 5 KF=1,2
      DO 20 L1=NA1,NBM
      L=LUP -L1*MD
      DO 15 JZ=NA,NB1
      J1=LUP1-JZ*MD
      DUM=Y1(L,KF)-Y(J1)
      DUM= -AMD*DUM
      IF(DUM.LE.0.) GO TO 10
   15 CONTINUE
      CALL ERROR(101)
      WRITE(6,7010) Y1(L,KF),Y(J1),DUM,J1,JZ,L1,L,KF
   10 GO TO (16,17),KF
   17 DUM=(Y1(L,KF)-Y(NA) )*AMD
```

```
      IF(DUM.LE. 0. ) GO TO 3
   16 CONTINUE
      IU=J1
      IL=J1+MD
      LP=L-KMD
      LM=LP+LC
      RAT=(Y1(L,KE)-Y (IL) )/(Y (IU)-Y (IL) )
      TH1=TH (IL)+RAT*(TH (IU)-TH (IL) )
      XMU1=XMU (IL)+RAT*(XMU (IU)-XMU (IL) )
      A1= TH1+FAM1*XMU1
      Y2(LP,KE)=Y1(L,KE)+DELX*TAN(A1)
      IF(ABS(Y2(L,KE)-Y2(LM,KE) ).LE.COALT) WRITE(6,1002) KE,L,LM,
     1 Y2(L,KE),Y2(LM,KE)
      GO TO (20,19),KE
   19 DUM= (Y2(LP,KE)-YN(NA) )*AMD
      IF ( DUM .LE. 0.) GO TO 3
   20 CONTINUE
      LUP1= NB1+NA
      LUP= NBM+NA
      KMD=0
      LC=1
      MD= 1
      AMD=-AMD
      FAM1=-FAM1
    5 CONTINUE
    3 CONTINUE
      AMD=1.
      IF( IR.EQ. 2) AMD=-1.
      DO 40 LV=NA,NB
      DUM= (Y2(LV,1)-YN(NB1) )*AMD
      IF( DUM .GT. 0. ) GO TO 45
   40 CONTINUE
      GO TO 46
   45 LV1=NMPT(IR)-LV+1
      NMPT(IR)=NMPT(IR)-LV1
   46 CONTINUE
      WRITE(6,1003) LV1,LV,NMPT(IR)
      DO 11 KE=1,2
      DO 11 JZ=NA,NB
   11 Y1(JZ,KE)=Y2(JZ,KE)
      IF(JOUT(IR).NE.0) GO TO 49
      DO 12 I=NA,NB,3
      IP=I+1
      IPP=I+2
      IF (IP .GT. NB ) GO TO 47
      IF (IPP .GT. NB ) GO TO 48
      WRITE(6,1005) I,Y2(I,1),Y2(I,2),IP,Y2(IP,1),Y2(IP,2),IPP,Y2(IPP,1)
     1 ,Y2(IPP,2)
   12 CONTINUE
      GO TO 49
   47 WRITE(6,1005) I,Y2(I,1),Y2(I,2)
      GO TO 49
   48 WRITE(6,1005) I,Y2(I,1),Y2(I,2),IP,Y2(IP,1),Y2(IP,2)
   49 CONTINUE
      IF(NB .LT. 148) GO TO 6
      ICN(IR)=1
      NMPT(IR)=NOP(IR)
      DO 7 I=NA,NB1
```

```
      Y1(I,1)=YN(I)
      Y1(I,2)=YN(I)
    7 CONTINUE
      WRITE(6,1000) Y1
    6 RETURN
    1 ICN(IR)=2
      NB=NOP(IR)
      NMPT(IR)=NOP(IR)
      Y2(NB,2)=YN(NB1)
      Y2(NA,1)=YN(NA)
      DO 25 KE=1,2
      DO 30 L1=NA1,NB
      L=LUP-L1*MD
      LM=L+MD
      A1= TH(LM)+FAM1*XMU(LM)
      Y2(L,KE)=Y1(LM,KE)+DELX*TAN(A1)
      IF(ABS(Y2(L,KE)-Y2(LM,KE) ).LE.COALT) WRITE(6,1002) KE,L,LM,
     1 Y2(L,KE),Y2(LM,KE)
   30 CONTINUE
      LUP=NB+NA
      MD=1
      AMD=-AMD
      FAM1=-FAM1
   25 CONTINUE
      GO TO 46
 7200 FORMAT (3(2XE14.6) ,3I5)
 1000 FORMAT (5(2XE14.6) )
 1003 FORMAT (8I7)
 7001 FORMAT (3(2XE14.6) )
 7000 FORMAT (2(2XE14.6) ,5I5)
 1002 FORMAT (25X ,12H COALESCENCE,2X,3I5,3(2XE14.6) )
 1005 FORMAT ( 3(I5,1XE13.6,1XE13.6 ) )
 7010 FORMAT(3(2XE14.6) , 5I5)
      END
```

```
      SUBROUTINE SHKINT
      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)/2.0
      T2=(DT**3-TIM1*T0)/3.0
      T3=T0/2.0
      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
      P(I,J)=P(I,J)+TIM1/SCALE
      P(I,J+4)=P(I,J+4)+T0/SCALE
      K=I+1
      P(K,J)=P(K,J)+(TIM2-TIM1)/SCALE
      P(K,J+4)=P(K,J+4)+2.0*T1/SCALE
      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 14 J=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 ELEM(M,X,B,D)
      DIMENSION AT(10,11),                          X(10)
      DIMENSION B(10,10),D(10)
      M=M
      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
      O=AT(N,N)
      IT=0
      DO 9 I=N,M
      IF(ABS(AT(I,N))-ABS(O)) 9,9,8
    8 O=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)/O
      IF(M-N)50,50,18
   18 N1=N+1
      DO 30 I=N1,M
      O=AT(I,N)
      DO 30 J=N,M1
   30 AT(I,J)=AT(I,J)-AT(N,J)*O
   32 CONTINUE
   50 X(M)=AT(M,M+1)
      DO 65 N=2,M
      NR=M+1-N
      O=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))/2.0-YN(3)
YN(5)=BB-(YN(2)+YN(6)+YN(3))/2.0
RETURN
END
```

```
SUBROUTINE ETHANE(T)
T=1./(1.1087/T-.09497)
RETURN
END
```

```
SUBROUTINE PROP(T)
T=1./(.786/T+.2381)
RETURN
END
```

```
SUBROUTINE ETH2(T)
T=1.241+.05524*T
RETURN
END
```

```
      SUBROUTINE  SURFAC (IND,L,X,R,DR )
      DIMENSION XRC(100),RRC(100),THC(100),THA(100),PT(100),P(100)
      DATA                  CV/0.01745329/
      I=L
      GO TO (6,7),IND
    7 I=L+2
    6 GO TO (1,2,3,4),I
    1 READ (5,102) CB,COWL
      J=1
      JJ=CB
      DO 15  K=1,50
      P(K)=0.
   15 PT(K)=0.
      READ (5,102) (XRC(K),K=J,JJ)
      READ (5,102) RRC(J)
    5 DO 9 K=J,JJ
      THA(K)=THC(K)
      THC(K)=TAN(THC(K)*CV)
      IF (K.EQ.1 .OR. K.EQ.51) GO TO 9
      RRC(K)=0.5*(THC(K)+THC(K-1))*(XRC(K)-XRC(K-1))+RRC(K-1)
    9 CONTINUE
      IF (I   .EQ. 3) GO TO 19
      WRITE (6,103)
      WRITE (6,105) (XRC(J),RRC(J),THA(J),J=1,JJ)
  103 FORMAT (     55X,25H CENTER BODY CO-ORDINATES //,48X,2H X,14X,2H R,
     112X,6H THETA / )
  105 FORMAT (40X,3(2XE14.6) )
      RETURN
   19 X = XRC(51)
      R = RRC(51)
      WRITE (6,104)
C     WRITE (6,105) (XRC(J),RRC(J),   P(J),J=51,JJ)
      WRITE (6,105) (XRC(J),RRC(J),THA(J),J=51,JJ)
  104 FORMAT  (1H1,57X,24H         COWL CO-ORDINATES //,48X,2H X,14X,2H R,
     1 10X,8H    THETA /)
      RETURN
    2 J=2
      IR=1
      JJ=CB
   13  DO 10 K=J,JJ
      M=K
      IF (X .LE. XRC(K)) GO TO 12
   10 CONTINUE
   12 DD=(THC(M)-THC(M-1))/(XRC(M)-XRC(M-1))
      DD1=X-XRC(M-1)
      R=.5*DD*DD1**2+DD1*THC(M-1)+RRC(M-1)
      DR= DD*D( 1+THC(M-1)
C     PS=P  (M-1)+DD1/(XRC(M)-XRC(M-1))*(P  (M)-P  (M-1))
C     PO=PT(M-1)+DD1/(XRC(M)-XRC(M-1))*(PT(M)-PT(M-1))
      RETURN
    3 J = 51
      JJ = 50.0 + COWL
      READ (5,102) (XRC(K),K=J,JJ)
      READ (5,102) RRC(J)
      READ (5,102) (THC(K),K=J,JJ)
C     READ (5,102) ( PT(K),K=J,JJ)
C     READ (5,102) ( P (K),K=J,JJ)
      GO TO 5
```

```
    4 J = 52
      JJ = 50.0 + COWL
      GO TO 13
  102 FORMAT(7F10.6)
      END
```

```
      SUBROUTINE CUBIC(C,Z)
      DIMENSION C(4)
      ACOS(X)=ATAN(SQRT(1.0-X**2)/X)
      P=-C(3)**2/3.0 + C(2)
      Q=2.0*C(3)**3/27.0 - C(2)*C(3)/3.0 + C(1)
      RSQ =      -0.5*Q/ SQRT(-P**3/27.0)
      IF (ABS(RSQ) .LE. 1.0) GO TO 1
      Z=0.
      RETURN
1     PHI=ACOS( RSQ)
      IF(PHI)900,901,901
  900 PHI=3.141593+PHI
  901 TEM=2.0*SQRT(-P/3.0)
      X1= TEM*COS(PHI/3.0)
      TERM =         PHI/3.0 + 2.09439510
      X2= TEM*COS(TERM )
      TERM =         PHI/3.0 + 4.18879020
      X3= TEM*COS(TERM)
      IF (X2-X3) 150,150,160
  150 Y1=AMAX1(X1,X2)
      Y1=AMIN1(Y1,X3)
      GO TO 175
  160 Y1=AMIN1(X1,X2)
      Y1=AMAX1(Y1,X3)
  175 Y1=Y1-C(3)/3.0
    8 Z=Y1
      RETURN
      END
```

```
      SUBROUTINE COEF (I,T )
      COMMON/COE/ A,B,C,D,E,F,G
      IF(T-1000.)10,10,20
   10 GO TO (15,16,13,11,12,17,14),I
   11 A    = 2.6460849E 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
   20 GO TO (25,26,23,21,22,27,24),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    =-1.6481329E 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    = 2.6707522E 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    =-3.6452940E-16
      F    = 3.8811792E 03
      G    = 5.5970165E 00
   40 RETURN
      END
```

```
      SUBROUTINE UPSC( TUS)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK3/XSN(3),ALPSN(7,3), YSN(3),YS(3),THSN(3),PSN(3),QSN(3)
      COMMON/BLK4/ RHOSN(3),EMSN(3),ASN(3,3),TSN(3),XMWSN(3),HSN(3)
      COMMON/BLK4A/XMUSN(3),XMUS(3),HTSN(3),SIGMA(20),GAMASN(3)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK16/PHI(150),XS(  7),   DACH(7,150)
      COMMON/BLK19/ N2D,IFAM
      COMMON/BLK20/ NLO(3),NOP(3),DELXF(3),ANG(2),ANGN(2)
      COMMON/BLK21/ IR,IPD,IRU,ITYPF,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/FIN,XJ,RF,PR,XLE,EPTH,EPP,EPQ,EPT,RINF,WINF,NSP,JCHEM
      COMMON/UP1/ GAMAUP(3),XMWUP(3),DUP(3),RHOUP(3),HUP(3),ALPUP(7,3)
      COMMON/UP2/XMUUP(3),PUP(3),QUP(3),TUP(3), XUP(3),EMUP(3),WPUP(3)
      XM1(QX3,QX4,QX7)  =     TAN(QX3+QX7*QX4)
      XM3(QZ1,QZ2,QZ3,QZ4 )= QZ1*TAN(QZ3)+QZ2*TAN(QZ4)
      IRDS=IR
      I=3
C STORE DOWNSTREAM PROPERTIES
      N2 =N2D
      YINT=YN(N2)
      YDS=Y(N2)
      XDS=X(N2)
      XINT= XDS+DELXF(IR)
      GO TO (1,2,1),ITYPF
    1 XMUSN(I)=XMUUP(IRU)
      PSN(I)=PUP(IRU)
      THSN(I)=DUP(IRU)
      QSN(I)=QUP(IRU)
      TSN(I)=TUP(IRU)
      EMSN(I)=EMUP(IRU)
      GAMASN(I)=GAMAUP(IRU)
      XMWSN(I)=XMWUP(IRU)
      RHOSN(I)=RHOUP(IRU)
      HSN(I)=HUP(IRU)
      DO 10 J=1,NSP
   10 ALPSN(J,I)=ALPUP(J,IRU)
      IR=IRDS
      RETURN
    2 GO TO (39,40),IFLO
   39 IR=IRU
      GO TO 41
   40 IR=1
   41 N2=NOP(IR)
      NPL=NLO(IR)
      DELX=DELXF(IR)
      GO TO (5,35),IFLO
   35 GO TO (5, 6),IUP
    4 CALL FLIP(0,NPL,N2 ,XMSV)
      CALL STEL(DELXF(IR),NPL,N2)
      IF(JCHEM.EQ.0) GO TO 50
      DO 51    L=NPL,N2
      XN(L)=X(L )+DELXF(IR)
      YN(L)=Y(L)+TAN(TH(L))*DELXF(IR)
      DX=SQRT((XN(L)-X(L))**2+(YN(L)-Y(L))**2)
```

```
      IWD=1
      CALL CHEMP(IWD,DX,L)
   51 CONTINUE
      GO TO 53
   50 DO 55    L=NPL,N2
      DO 55    J=1,NSP
      WDOT(J,L)=0.
      WDOTN(J,L)=0.
   55 DACH(J,L)=0.
   53 CONTINUE
    5 XOLD=X(N2)
      XUP(IR)=X(N2)+DELXE(IR)
      WRITE(6,7789) IR,IRU,N2,NPL,XUP(IR),XINT
      CALL FLOW
      CALL MESH
      IF(XUP(IR)-XINT) 4,6,6
    6 YINTS=(XUP(IR)-XDS)*TAN(FAM*ANG (IRD))+YDS
      WRITE(6,7789) IR,IRU,N2,NPL,XUP(IR),FAM
 7789 FORMAT (4I5,2(2XF14.6) )
      YOLD =(XOLD-XDS     )*TAN(FAM*ANG(IRD) )+YDS
   36 CONTINUE
      IF(IFLO.EQ.2) GO TO 33
      GO TO (28,32,33),IRU
   33 DO 26 JZ=NPL,N2
      IF ( YOLD .LE. Y(JZ) ) GO TO 27
   26 CONTINUE
      CALL ERROR(14)
      GO TO 27
   32 DO 34 JZ=NPL,N2
      IF ( YOLD .GE. Y(JZ) ) GO TO 27
   34 CONTINUE
      CALL ERROR(15)
   27 IU=JZ
      KS=IU-1
      WRITE(6,7790) YINTS,YOLD, Y (JZ) ,JZ,KS,IU
 7790 FORMAT (3(2XF14.6),3I5)
      KL=1
      RAT= (YOLD-Y(KS) )/(Y(IU)-Y(KS)   )
      PSN  (KL)=P (KS)+RAT*(P (IU)-P (KS) )
      QSN(KL)  =Q (KS)+RAT*(Q (IU)-Q (KS) )
      TSN(KL)  =T (KS)+RAT*(T (IU)-T (KS) )
      RHOSN(KL)=RHO (KS)+RAT*(RHO (IU)-RHO (KS) )
      THSN(KL) =TH (KS)+RAT*(TH (IU)-TH (KS) )
      FMSN(KL) =FM (KS)+RAT*(FM (IU)-FM (KS) )
      GAMASN(KL)=GAM (KS)+RAT*(GAM (IU)-GAM (KS) )
      XMWSN(KL) =  W (KS)+RAT*(  W (IU)-  W (KS) )
      HSN(KL)= HX (KS)+RAT*(HX (IU)-HX (KS) )
      DO 13 J=1,NSP
      ALPSN(J,KL)=ALP (J,KS)+RAT*(ALP (J,IU)-ALP (J,KS) )
   13 CONTINUE
      IF(IFLO.EQ.2) GO TO 30
      GO TO (28,29,30),IRU
   30 DO 7 JZ=NPL,N2
      IF (YINTS .LE. YN(JZ) ) GO TO 31
    7 CONTINUE
      CALL ERROR(12)
      GO TO 31
   29 DO 17 JZ=NPL,N2
```

```
      IF (YINTS .GE. YN(JZ) ) GO TO 31
   17 CONTINUE
      CALL ERROR(13)
   31 IU=JZ
      KS=IU-1
      WRITE(6,0790) YINTS,YINT,YOLD, YN(JZ) ,YDS,XOLD,JZ,KS,IU
 0790 FORMAT (6(2XE14.6),3I5)
      RAT= (YINTS-YN(KS) )/(YN(IU)-YN(KS)   )
      KL=2
      PSN   (KL)=PN(KS)+RAT*(PN(IU)-PN(KS) )
      QSN(KL)   =QN(KS)+RAT*(QN(IU)-QN(KS) )
      TSN(KL)   =TN(KS)+RAT*(TN(IU)-TN(KS) )
      RHOSN(KL)=RHON(KS)+RAT*(RHON(IU)-RHON(KS) )
      THSN(KL)  =THN(KS)+RAT*(THN(IU)-THN(KS) )
      EMSN(KL)  =EMN(KS)+RAT*(EMN(IU)-EMN(KS) )
      GAMASN(KL)=GAMN(KS)+RAT*(GAMN(IU)-GAMN(KS) )
      XMWSN(KL) =   WN(KS)+RAT*(   WN(IU)-   WN(KS) )
      HSN(KL)= HXN(KS)+RAT*(HXN(IU)-HXN(KS) )
      DO 15 J=1,NSP
      ALPSN(J,KL)=ALPN(J,KS)+RAT*(ALPN(J,IU)-ALPN(J,KS) )
   15 CONTINUE
      SX=(XINT-XOLD)**2+(YINT-YOLD)**2
      SX=SX**.5
      SN=(XUP(IR)-XOLD)**2+(YINTS-YOLD)**2
      SN=SN**.5
      RAT=SX/SN
      KL=3
      PSN(KL)= PSN(1)+RAT*(PSN(2)-PSN(1) )
      QSN(KL)= QSN(1)+RAT*(QSN(2)-QSN(1) )
      TSN(KL)= TSN(1)+RAT*(TSN(2)-TSN(1) )
      RHOSN(KL)=RHOSN(1)+RAT*(RHOSN(2)-RHOSN(1) )
      THSN(KL)=THSN(1)+RAT*(THSN(2)-THSN(1) )
      EMSN(KL)=EMSN(1)+RAT*(EMSN(2)-EMSN(1) )
      GAMASN(KL)=GAMASN(1)+RAT*(GAMASN(2)-GAMASN(1) )
      HSN(KL)= HSN(1)+RAT*(HSN(2)-HSN(1) )
      XMWSN(KL) = XMWSN(1)+RAT*(XMWSN(2)-XMWSN(1) )
      DO 12 J=1,NSP
      ALPSN(J,KL)=ALPSN(J,1)+RAT*(ALPSN(J,2)-ALPSN(J,1) )
   12 CONTINUE
 3300 CONTINUE
      WRITE(6,3319) I,EMSN(3),THSN(3),TSN(3),PSN(3)
 3319 FORMAT (I5,4(2XE14.6) )
 3325 FORMAT (6(2XE14.6) ,9H UPSC 25 )
      WRITE(6,3325) PSN(1),PSN(2),PSN(3),SX,SN,RAT
      GO TO (37,38),IFLO
   38 CONTINUE
      IF=3
      KF= IRU
      XMUUP (KF)=XMUSN(IF)
      PUP(KF)= PSN(IF)
      THUP (KF)=THSN(IF)
      QUP(KF)= QSN(IF)
      TUP(KF)= TSN(IF)
      EMUP(KF)=EMSN(IF)
      GAMAUP(KF)=GAMASN(IF)
      XMWUP (KF)=XMWSN(IF)
      RHOUP (KF)=RHOSN(IF)
      HUP(KF)= HSN(IF)
```

```
      DO 11 J=1,NSP
      ALPUP(J,KF)=ALPSN(J,IF)
   11 CONTINUE
      IR=IRDS
      IUP=2
      RETURN
   27 NDP= NOP(IR)
      IF (ABS(YINT-YN(NDP) ).GT. YDSL) NOP(IR)=NOP(IR)-1
      IR=IRDS
      RETURN
   28 CALL ERR(R(16))
      RETURN
      END
```

```
      SUBROUTINE THERM (IND,L)
      COMMON/COE/ A,B,C,D,E,F,G
      COMMON/FRSTR/  TIN,UIN,EMINF,GAMINF,CPIN,RO,WTMOLE(7)
      COMMON/PROPT/ H(7),CP(7),DCP(7)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      GO TO (1,2),IND
    1 CONTINUE
      TI=T (L)
      GO TO 3
    2 CONTINUE
      TI=TN(L)
    3 CONTINUE
      DO 10 J=1,7
      CALL COEF (J,TI)
      H(J)=TI*(A+TI*(B/2.+TI*(C/3.+TI*(D/4.+E/5.*TI))))+F
      H(J)=H(J)/WTMOLE(J)*RO*45092.8
      CP(J)=A+TI*(B+TI*(C+TI*(D+E*TI)))
      CP(J)=CP(J)/WTMOLE(J)*RO *45092.8
      DCP(J)=B+TI*(2.*C+TI*(3.*D+4.*E*TI))
      DCP(J)=DCP(J)/WTMOLE(J)*RO *45092.8
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STEP(DELX,N1,NP2)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK21/ IR,IPD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      DIMENSION DELLX(150)
      XM1(QX3,QX4,QX7)=   TAN(QX3+QX7*QX4)
      TFAM=FAM
      FAM=-1.
      IF(IR.EQ.2) FAM=1.
      NP1=NP2-1
      DO 499 K=N1,NP1
      EM1=XM1(TH(K),XMU(K),-FAM)
      EM2=XM1(TH(K+1),XMU(K+1),FAM)
      DELLX(K)=(Y(K+1)-Y(K))/(EM1-EM2)
 1000 FORMAT (3(2XE14.6),I5)
  499 CONTINUE
      DELXM=DELLX(N1)
      DELY=Y(N1+1)-Y(N1)
      DELY=ABS(DELY)
      DO 20 K=N1,NP1
      IF(DELLX(K).LT.DELXM)DELXM=DELLX(K)
      DELYY=Y(K+1)-Y(K)
      DELYY=ABS(DELYY)
      IF(DELYY.LT.DELY) DELY=DELYY
   20 CONTINUE
      DELX=DELXM *.8
      FAM=TFAM
      WRITE(6,1000) DELS,DELX,DELV1,K
      RETURN
      END
```

```
      SUBROUTINE INTER(RAT,KL,N1,N2)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S3I(7,150),S3IN(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/DISS/ FDISP(3),D2P(3),XMUP(3),PP(3),QP(3),RHOP(3),THP(3)
      FDISP(KL)=FDIS(N1)+RAT*(FDIS(N2)-FDIS(N1) )
      XMUP (KL)=XMU  (N1)+RAT*(XMU  (N2)-XMU  (N1)  )
      PP    (KL)=P    (N1)+RAT*(P    (N2)-P    (N1)  )
      D2P   (KL)=D2   (N1)+RAT*(D2   (N2)-D2   (N1)  )
      THP   (KL)=TH   (N1)+RAT*(TH   (N2)-TH   (N1)  )
      QP    (KL)=Q    (N1)+RAT*(Q    (N2)-Q    (N1)  )
      RHOP  (KL)=RHO  (N1)+RAT*(RHO  (N2)-RHO  (N1)  )
      RETURN
      END
```

```
      SUBROUTINE ERROR(IIII)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S31(7,150),S31N(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK16/PHI(150),XS(  7),  DACH(7,150)
      COMMON/BLK20/ NLO(3),NOP(3),DELXF(3),ANG(2),ANGN(2)
      COMMON/BLK21/ IR,IPD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/FIN,XJ,RE,PR,XLE,EPTH,EPP,EPQ,EPT,RINF,WINF,NSP,JCHEM
      WRITE(6,100) IIII
  100 FORMAT(/, 20X,7H ERROR=I5)
      RETURN
      END
```

```
      SUBROUTINE FIND
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK20/ NLO(3),NOP(3),DELXF(3),ANG(2),ANGN(2)
      COMMON/BLK21/ IR,IPD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/FND/ KP,KT,L,KTP1,EMP,EML,RAT
      Y1=YP(KP)
      Y2=Y(KT)
      Y3=Y(KTP1)
      DO 201 KIPP=1,20
      RAT=(Y1-Y2)/(Y3-Y2)
      EM2=EML+RAT*(EMP-EML)
      YBT=Y1
      Y1=YN(L)-DELXF(IR)*EM2
      IF(ABS((Y1-YBT)/(Y3-Y2)).LT. .005) GO TO 202
  201 CONTINUE
      CALL ERROR(201)
  202 CONTINUE
      YP(KP)=Y1
      RETURN
 4150 FORMAT (3I7,4(2XE14.6) )
      END
```

```
      SUBROUTINE  SHOCK
      COMMON/PROPT/H1(7),CP1(7),DCP1(7)
      COMMON/FPSTR/  TIN,UIN,EMINF,GAMINF,CPIN,RO,WTMOLE(7)
      COMMON/BLK1/CPXN(150),CPX(150)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK3/XSN(3),ALPSN(7,3), YSN(3),YS(3),THSN(3),PSN(3),QSN(3)
      COMMON/BLK4/ RHOSN(3),EMSN(3),ASN(3,3),TSN(3),XMWSN(3),HSN(3)
      COMMON/BLK4A/XMUSN(3),XMUS(3),HTSN(3),SIGMA(20),GAMASN(3)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S3I(7,150),S3IN(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK16/PHI(150),XS(   7),   DACH(7,150)
      COMMON/BLK19/ NP1,IFAM
      COMMON/BLK20/ NLO(3),NOP(3),DFLXF(3),ANG(2),ANGN(2)
      COMMON/BLK21/ IR,IRD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/FIN,XJ,RE,PR,XLE,EPTH,EPP,EPQ,EPT,RINF,WINF,NSP,JCHEM
      COMMON/DISS/ FDISP(3),D2P(3),XMUP(3),PP(3),QP(3),RHOP(3),THP(3)
      DIMENSION        CO(4)
      XM1(QX3,QX4,QX7)  =      TAN(QX3+QX7*QX4)
      XM3(QZ1,QZ2,QZ3,QZ4 )= QZ1*TAN(QZ3)+QZ2*TAN(QZ4)
      DFLX=DFLXF(IR)
      NP1= NOP(IR)
      GO TO (200,202,203,204),IRD
  200 NP1=2
      GO TO 202
  203 IRD=1
      GO TO 202
  204 IRD=2
  202 CONTINUE
      THS=ANG(IRD)
      TANA1=TAN(ANG(IRD))
      XN(NP1)=X(NP1)+DFLXF(IR)
      YN(NP1)=Y(NP1)+DFLX*TANA1*FAM
      CALL UPSC(THS)
      IRU=3
      DPREV=.0
      AA=1.
      BB=0.
      YSN(IR)=YN(NP1)
      XSN(IR)=X(NP1)
      THN(NP1)=TH(NP1)
      DOLD=TH(NP1)
      GAMN(NP1)=GAMASN(IRU)
      GAM1=GAMASN(IRU)+1.
      GAM2=GAMASN(IRU)-1.
      DO 215 J=1,NSP
  215 ALPN(J,NP1)=ALPSN(J,IRU)
      HTN(NP1)=HSN(IRU)+QSN(IRU)**2 *.5
      WN(NP1)=XMWSN(IRU)
      DO 3431 II=1,25
      SDS=SIN(DOLD-THSN(IRU) )**2
      CO(1)=(SDS-1.)/EMSN(IRU)**4
      CO(2)=(2.*EMSN(IRU)**2+1.)/EMSN(IRU)**4+((GAMASN(IRU)+1.)**2/4.
```

```
     1+(GAMASN(IRU)-1.)/EMSN(IRU)**2)*SDS
      CO(3)=-(EMSN(IRU)**2+2.) /EMSN(IRU)**2-GAMASN(IRU)*SDS
      CO(4)=1.
      CALL CUBIC(CO,Z)
      OMEGA=SQRT(Z)
      OMEGA=ASIN(OMEGA)
      TERM=(EMSN(IRU)*SIN(OMEGA))**2
      PSHK     =PSN(IRU)*(2.*GAMASN(IRU)*TERM-GAM2)/GAM1
      PN(NP1)=PSHK
      PBAR= PSHK/PSN(IRU)
      TSHK=TSN(IRU)*(GAM2*TERM+2.) /(GAM1*TERM)*PBAR
      TN(NP1)=TSHK
      QN(NP1)= 1.-2.*(PBAR**2-1.)/(EMSN(IRU)**2*(GAM1*PBAR+GAM2)   )
      QN(NP1)= SQRT(QN(NP1))*QSN(IRU)
      RN(NP1)=RO/WN(NP1)*46092.8
      RHON(NP1)=PN(NP1)/ (RN(NP1)*TN(NP1) )
      EMN(NP1)=QN(NP1)/SQRT(GAMN(NP1)*TN(NP1)*RN(NP1) )
      XMUN(NP1)=ASIN(1./EMN(NP1) )
C---------     ------ ---- -   ---       COMPUTE *A* POINT  --------
      N=NP1-1*IFAM
      THA=TH(N)
      XMUA=XMU(N)
      EMR=XM1(THA,XMUA,FAM)
      YA=YN(NP1)-EMR*DELX
      EM1P=XM1(TH(NP1),XMU(NP1),FAM)
      EM1L=XM1(TH(N),XMU(N),FAM)
      DO 3610 KIP=1,10
      RATA=(YA-Y(N))/(Y(NP1)-Y(N))
      EMR=EM1L+RATA*(EM1P-EM1L)
      YAT=YA
      YA=YN(NP1)-EMR*DELX
      IF((ABS(YA-YAT)/ABS(Y(NP1)-Y(N))).LE. .005)GO TO 3616
 3610 CONTINUE
       CALL ERROR(3610)
 3616 RATA=(YA-Y(N))/(Y(NP1)-Y(N))
      CALL INTER(RATA,1,N,NP1)
      VW3=SIN(THN(NP1) )*TAN(XMUN(NP1) )/YN(NP1)*FAM
      VW3=VW3*XJ
      VW1=AB*(D2P(1)/(RHOP(1)*QP(1)**2)-FAM*EDISP(1)*TAN(XMUP(1) ))+BB*
     1 VW3
      DELS=DELX/COS(THN(NP1))
      DELS=ABS(DELS)
      TERM1=RHOP(1)*QP(1)**2
      AB1=TERM1*TAN(XMUP(1) )
      AB1=1./AB1
      TERM3=RHON(NP1)*QN(NP1)**2
      AB3=TERM3*TAN(XMUN(NP1) )
      AB3=1./AB3
      A2 =AB    *AB1+BB   *AB3
      THN(NP1)=THP(1) -FAM*A2*(PN(NP1)-PP(1))-VW1*DELS
      IF(IT.EQ.1) GO TO 220
      DPREZ=DPREV
      IF(ABS(DPREV).LE. .000001) DPREZ=1.
      IF(ABS((DPREV-THN(NP1))/DPREZ).LE.  EPTH   ) GO TO 3652
  220 CONTINUE
      DOLD= AB* THN(NP1)+BB*DPREV
      DPREV= THN(NP1)
      AB=.5
```

```
      PR=.5
 3431 CONTINUE
      CALL ERROR(3431)
 3652 CONTINUE
      ETA=1.
      GO TO (20,21),IFLO
   20 GO TO (22,23),IRD
   21 GO TO (23,22),IRD
   22 ETA=-1.
   23 ANGN(IRD)=OMEGA+ETA*THSN(IRU)
      CALL THERM (2,NP1)
      CPXN(NP1)=0.
      HXN(NP1)=0.
      DO 18 J=1,7
      CPXN(NP1)=CP1 (J)*ALPN(J,NP1) +CPXN(NP1)
      HXN(NP1) =HXN(NP1)    +ALPN(J,NP1)*H1(J)
   18 CONTINUE
      THD= THN(NP1)/.01745329
      WRITE(6,2005)
 2005 FORMAT(/,10X,2H P ,12X,2H T,12X,2H Q,10X,6H THETA,10X,2H M,12X,
     12H H, 9X,9H H TOTAL, 5X,12H DISSIPATION, 5X,2H Y  )
      WRITE(6,2000) NP1,PN(NP1),TN(NP1),QN(NP1),THD,EMN(NP1),HXN(NP1),
     1 HTN(NP1),EDISN(NP1),YN(NP1)
      L=NP1
      WRITE(6,2001)L,ALPN(1,L),ALPN(2,L),ALPN(3,L),ALPN(4,L),ALPN(5,L),
     1  ALPN(6,L)   ,ALPN(7,L)
 2001 FORMAT (I6, 7(2XE14.6) )
 2000 FORMAT (     I4,    9(1XE13.6) )
      OMEGA= OMEGA/.01745329
      THD=THSN(IRU)/.01745329
      WRITE(6,2002) XN(NP1),YN(NP1),OMEGA,PSN(IRU),TSN(IRU),EMSN(IRU)
     1, THD
 2002 FORMAT  (/,5X,12H SHOCK POINT /25X,3H X=E14.6,3H Y=E14.6,7H OMEGA=
     1E14.6//5X,14H UPSTREAM FLOW,8X,3H P=E14.6, 3H T=E14.6,3H M=E14.6,
     1 8H THETA =E14.6 /)
      RETURN
      END
```

```
      SUBROUTINE FLIP(IMD,N1,NPTS,XMSV)
      COMMON/BLK1/CPXN(150),CPX(150)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S3I(7,150),S3IN(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK20/ NLO(3),NOP(3),DFLXF(3),ANG(2),ANGN(2)
      COMMON/BLK21/ IR,IRD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/EIN,XJ,RE,PR,XLE,EPTH,EPP,EPQ,EPT,RINF,WINF,NSP,JCHEM
      COMMON/MSCK/ XMASS(150)
      XMASS(N1)=.0
      GO TO (25,30),IFLO
   30 IF(IR.EQ.1) GO TO 36
      GO TO 40
   25 IF(IR.EQ.2 .OR. IR.EQ.3) GO TO 35
      GO TO 40
   36 QN(N1   )=Q(N1   )
      HTN (N1   )=HT(N1   )
      HXN (N1   )=HX(N1   )
      PN(N1   )=P(N1   )
      TN(N1   )=T(N1   )
      XMUN(N1   )=XMU(N1   )
      XN(N1   )=X(N1   )+DFLXF(IR)
      EMN (N1   )=EM(N1   )
      THN (N1   )=TH(N1   )
      DO 42 J=1,NSP
      ALPN(J,N1   )=ALP(J,N1   )
      S3IN(J,N1   )=ALP(J,N1   )
   42 CONTINUE
   35 QN(NPTS)=Q(NPTS)
      XN(NPTS)=X(NPTS)+DFLXF(IR)
      TN(NPTS)=T(NPTS)
      PN(NPTS)=P(NPTS)
      HXN (NPTS)=HX(NPTS)
      HTN (NPTS)=HT(NPTS)
      THN (NPTS)=TH(NPTS)
      EMN (NPTS)=EM(NPTS)
      XMUN(NPTS)=XMU(NPTS)
      DO 41 J=1,NSP
      ALPN(J,NPTS)=ALP(J,NPTS)
      S3IN(J,NPTS)=S3I(J,NPTS)
   41 CONTINUE
   40 CONTINUE
      DO 10 J1=N1,NPTS
      I=J1+IMD
      TH(I)=THN(J1)
      X(I)=XN(J1)
      Y(I)=YN(J1)
      Q(I)=QN(J1)
      P(I)=PN(J1)
      T(I)=TN(J1)
      RHO(I)=RHON(J1)
      EM(I)=EMN(J1)
      XMU(I)=XMUN(J1)
```

```
      EDIS(I)=EDISN(J1)
      S4(I)=S4N(J1)
      D1(I)=D1N(J1)
      D2(I)=D2N(J1)
      DO 20 J=1,NSP
      S3I(J,I)=S3IN(J,J1)
      ALP(J, I)=ALPN(J,J1)
   20 CONTINUE
      W(I)=WN(J1)
      R(I)=RN(J1)
      GAM(I)=GAMN(J1)
      CPX(I)=CPXN(J1)
      HXN(I)=HX(J1)
      HT(I)=HTN(J1)
      IF (J1.EQ.N1) GO TO 10
      RQAV=(RHO(I)*Q(I)*COS(TH(I))+ RHO(I-1)*Q(I-1)*COS(TH(I-1)))/2.
      LXP=1.+XJ
      XMASS(I)=XMASS(I-1)+RQAV*ABS((Y(I)**LXP-Y(I-1)**LXP))/(1.+XJ)
   10 CONTINUE
      N1=N1+IMD
      NPTS=I
C     RATM=XMSV/XMASS(NPTS)
C     DO 50   I=N1,NPTS
C     Q(I)=RATM*Q(I)
C  50 XMU(I)=ASIN(1./EM(I))
      RETURN
      END
```

```
      SUBROUTINE FLOW
      COMMON/KASE/ CAS1,CAS2
      COMMON/BLK1/CPXN(150),CPX(150)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(2),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S3I(7,150),S3IN(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK16/PHI(150),XS(  7),   DACH(7,150)
      COMMON/BLK20/ NLO(2),NOP(3),DELXF(3),ANG(2),ANGN(2)
      COMMON/BLK21/ IR,IRD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/EIN,XJ,RE,PR,XLE,EPTH,EPP,EPQ,EPT,RINF,WINF,NSP,JCHEM
      COMMON/FND/  KP,KT,L, KW ,EM2P,EM2L,RATB
      COMMON/FRSTR/  TIN,UIN,EMINF,GAMINF,CPIN,RO,WTMOLE(7)
      COMMON/PROPT/H1(7),CP1(7),DCP1(7)
      COMMON /ZOUT/ JOUT(3),IOUT(3)
      COMMON/DISS/ FDISP(3),D2P(2),XMUP(2),PP(3),QP(3),RHOP(3),THP(3)
      XM1(QX3,QX4,QX7)  =     TAN(QX3+QX7*QX4)
      XM3(QZ1,QZ2,QZ3,QZ4 )= QZ1*TAN(QZ3)+QZ2*TAN(QZ4)
C CAS1=0 , CAS2=1  USE WDOT
C CAS1=1 , CAS2=0  USE DACH
      TFAM=FAM
      FAM=-1.
      IF(IR.EQ.2) FAM=1.
      ALPHA=1.
      BETA=.0
      DO 210 JZ=1,2
      GO TO (200,202,202),IR
  202 CALL BODY(JZ)
  200 CONTINUE
      NL=NLO(IR)+1
      N2=NOP(IR)-1
      DO 230 L=NL,N2
      K=L
      EM3=XM3(ALPHA,BETA,TH(K),THN(L))
      XN(L)=X(L)+DELXF(IR)
      YN(L)=Y(L)+DELXF(IR)*EM3
      DO 220 KP=1,2
      KT=L-2+KP
      KW=KT+1
      EM2L=XM1(TH(KT),XMU(KT),-FAM)
      EM2P=XM1(TH(KT+1),XMU(KT+1),-FAM)
      EM2K=0.5*(EM2L+EM2P)
      YP(KP)=YN(L)-DELXF(IR)*EM2K
 4150 FORMAT(2I5,7E13.5)
      CALL FIND
      KZ=KT
      CALL INTER(RATB,KP,KZ,KW)
      FAM=-FAM
  220 CONTINUE
      TERM1=RHOP(1)*QP(1)**2
      TERM2=RHOP(2)*QP(2)**2
      TERM3=RHON(L)*QN(L)**2
      AB1=TERM1*TAN(XMUP(1)  )
      AB1=1./AB1
```

```
      AB2=TERM2*TAN(XMUP(2) )
      AB2=1./AB2
      AB3=TERM3*TAN(XMUN(L) )
      AB3=1./AB3
      TERM4=D2P(1)/TERM1
      TERM5=D2P(2)/TERM2
      TERM6=D2N(L)/TERM3
      VB1=TERM4-FDISP(1)*TAN(XMUP(1) )
      VB3=TERM6-FDISN(L)*TAN(XMUN(L) )
      WB2=TERM5+FDISP(2)*TAN(XMUP(2) )
      WB3=TERM6+FDISN(L)*TAN(XMUN(L) )
      AB1=ALPHA*AB1+BETA*AB3
      AB2=ALPHA*AB2+BETA*AB3
      VB1=ALPHA*VB1+BETA*VB3
      WB2=ALPHA*WB2+BETA*WB3
      DELS=SQRT( (XN(L)-X(L))**2+(YN(L)-Y(L))**2 )
      PN(L)= THP(1)-THP(2)+DELS*(WB2-VB1)+AB1*PP(1)+AB2*PP(2)
      PN(L)= PN(L)/(AB1+AB2)
      THN(L)=THP(1)-AB1*(PN(L)-PP(1))-VB1*DELS
 1000 FORMAT(6H FLOW1,6(2XE14.6) )
      D1A= D1(L)*ALPHA+BETA*D1N(L)
      TERM=RHO(L)*Q(L)*ALPHA+BETA*RHON(L)*QN(L)
      QN(L)=(DELS*D1A-PN(L)+P(L) )/TERM+Q(L)
      DO 13 J=1,7
      ALPN(J,L)=ALP(J,L)+ DACH(J,L)*CAS1+DELS*S3I(J,L)  /TERM
     1+DELS* WDOT(J,L)/TERM*CAS2
C     ALPN(J,L)=ALP(J,L)+DELS*(WDOT(J,L)+S3I(J,L) )/TERM
      IF(ALPN(J,L).LT.1.1E-10) ALPN(J,L)=1.1E-10
   13 CONTINUE
      HTN(L)=DELS*S4 (L)/TERM+HT(L)
      HXN(L)=HTN(L)-.5*QN(L)**2
 1002 FORMAT (6H FLOW2,7(2XE14.6))
      TN(L)=T(L)
      T1=TN(L)
      DO 10 KE=1,15
      IF (KE.GT.1) GO TO 16
      CALL THERM(2,L)
      HE1=.0
      DO 19 J=1,NSP
   19 HE1=HE1+ALPN(J,L)*H1(J)
      IF(HXN(L)-HE1) 17,14,18
   18 TN(L)=T1+ 5.
      GO TO 16
   17 TN(L)=T1- 5.
   16 CONTINUE
      T2=TN(L)
      CALL THERM(2,L)
      HE2=.0
      DO 15 J=1,NSP
   15 HE2=HE2+ALPN(J,L)*H1(J)
      IF (ABS((HXN(L)-HE2)/HXN(L) ).LE. .00001) GO TO 14
      TN(L)= T1-(HE1-HXN(L) )/(HE2-HE1)*(T2-T1)
      HE1=HE2
      T1=T2
   10 CONTINUE
 1003 FORMAT(6H FLOW3,2X,7(2XE14.6),I3)
      WRITE(6,1003) T1,T2,TN(L),T(L),HE1,HE2,HXN(L),L
      WRITE(6,1003) PN(L),PP(1),PP(2),QN(L),QP(1),QP(2),THN(L),L
```

```
         CALL ERROR(1234)
   14 CONTINUE
  230 CONTINUE
         CALL COMPS(2)
      ALPHA=.5
      BETA=.5
  210 CONTINUE
      FAM=TFAM
      NL=NLO(IR)
      N2=NOP(IR)
      JOUT(IR)=JOUT(IR)+1
      IF(JOUT(IR).LT.IOUT(IR) ) RETURN
      JOUT(IR)=0
      WRITE(6,2100)  XN(NL),IR
      WRITE(6,2005)
      DO 260 L=NL,N2
      THD= THN(L )/.01745329
      WRITE(6,2000)  L ,PN( L ),TN( L ),GN( L ),THD,EMN( L ),HXN( L ),
     1 HTN( L ),FDISN( L ),YN( L )
  260 CONTINUE
      IF(JCHEM.EQ.0) RETURN
      WRITE(6,2100)  XN(NL),IR
      DO 270 L=NL,N2
      WRITE(6,2001)L,ALPN(1,L),ALPN(2,L),ALPN(3,L),ALPN(4,L),ALPN(5,L),
     1 ALPN(6,L),ALPN(7,L) ,WN(L),GAMN(L)
  270 CONTINUE
 2000 FORMAT(I4,9(1XE13.6) )
 2001 FORMAT (I4,9(1XE12.6) )
 2100 FORMAT (1H1,  40X,4H X = E14.6 ,2X,7H REGION,I3 /)
 2005 FORMAT(10X,2H P ,12X,2H T,12X,2H Q,10X,6H THETA,10X,2H M,12X,2H H,
     1 9X,8H H TOTAL, 5X,12H DISSIPATION, 5X,2H Y   )
      RETURN
      END
```

```
      SUBROUTINE POINT ( ID,NPO,IU,IEM)
      COMMON/BLK1/CPXN(150),CPX(150)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S3I(7,150),S3IN(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK21/ IR,IRD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/EIN,XJ,RE,PR,XLE,EPTH,EPP,EPQ,EPT,RINF,WINF,NSP,JCHEM
      COMMON/POYNT/ YASL
      DIMENSION DAL(7),DS3(7)
      GO TO (1,2,3), ID
    1 DY = YN(NPO)
      DQ = QN(NPO)
      DT = TN(NPO)
      DTH= THN(NPO)
      DMU= XMUN(NPO)
      DP=PN(NPO)
      DRHO=RHON(NPO)
      DHT=HTN(NPO)
      DW=WN(NPO)
      DH =HXN(NPO)
      DM =EMN(NPO)
      DFIS=FDISN(NPO)
      DD1=D1N(NPO)
      DD2=D2N(NPO)
      DS4=S4N(NPO)
      DO 10 J=1,NSP
      DS3(J)=S3IN(J,NPO)
   10 DAL(J)=ALPN(J,NPO)
      RETURN
    2 NM2= NPO+IEM
      RAT= YASL*.5      /(YN(NPO)-YN(NM2) )
      RAT=ABS(RAT)
      EM=IEM
      IF( IR.EQ.2) EM=1.
      YN(NPO)=YN(NM2)-EM*YASL*.5
      THN(NPO) = RAT*(THN(NPO)-THN(NM2))+THN(NM2)
      PN(NPO) = RAT*( PN(NPO) -PN(NM2)) + PN (NM2)
      QN(NPO) = RAT*( QN(NPO) -QN(NM2)) + QN (NM2)
      TN(NPO) = RAT*( TN(NPO) -TN(NM2)) + TN (NM2)
      XMUN(NPO)= RAT*( XMUN(NPO)-XMUN(NM2))+ XMUN(NM2)
      FDISN(NPO)= RAT*(FDISN(NPO)-FDISN(NM2))+FDISN(NM2)
      HTN (NPO)= RAT*(  HTN(NPO)- HTN(NM2))+  HTN(NM2)
      HXN (NPO)= RAT*(  HXN(NPO)- HXN(NM2))+  HXN(NM2)
      EMN (NPO)= RAT*(  EMN(NPO)- EMN(NM2))+  EMN(NM2)
      D1N (NPO)= RAT*(  D1N(NPO)- D1N(NM2))+  D1N(NM2)
      WN  (NPO)= RAT*(  WN (NPO)- WN (NM2))+  WN (NM2)
      RHON(NPO)= RAT*( RHON(NPO)-RHON(NM2))+ RHON(NM2)
      D2N (NPO)= RAT*(  D2N(NPO)- D2N(NM2))+  D2N(NM2)
      S4N (NPO)= RAT*(  S4N(NPO)- S4N(NM2))+  S4N(NM2)
      WRITE(6,1000)  YN(NPO),YN(NM2),FASL,EM,TN(NPO)
 1000 FORMAT (6H POINT, 5(2XE14.6) )
      DO 11 J=1,NSP
      S3IN(J,NPO)=RAT*(S3IN(J,NPO)-S3IN(J,NM2))+S3IN(J,NM2)
```

```
   11 ALPN(J,NPO)=RAT*(ALPN(J,NPO)-ALPN(J,NM2))+ALPN(J,NM2)
      RETURN
    3 YN(IU)  =  DY
      PN(IU)  =  DP
      QN(IU)  =  DQ
      TN(IU)  =  DT
      THN(IU)  = DTH
      XMUN(IU)=  DMU
 2000 FORMAT  (7H POINT2,5(2XE14.6) )
      WRITE(6,2000)  YN(IU),PN(IU),TN(IU),QN(IU),THN(IU)
      RHON(IU)=DRHO
      HTN(IU)=DHT
      KB=-1
      IF(IU.EQ.1) KB=1
      XN(IU)=XN(IU+KB)
      HXN(IU)=DH
      EMN(IU)=DM
      WN(IU)=DW
      EDISN(IU)=DEIS
      D1N(IU)=DD1
      D2N(IU)=DD2
      S4N(IU)=DS4
      DO 12  J=1,NSP
      S3IN(J,IU)=DS3(J)
   12 ALPN(J,IU)=DAL(J)
      RETURN
      END
```

```
      SUBROUTINE BODY(JXT)
      COMMON/FRSTR/  TIN,UIN,EMINF,GAMINF,CPIN,RO,WTMOLE(7)
      COMMON/PROPT/H1(7),CP1(7),DCP1(7)
      COMMON/BLK1/CPXN(150),CPX(150)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S3I(7,150),S3IN(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK16/PHI(150),XS(  7),  DACH(7,150)
      COMMON/BLK20/ NLO(3),NOP(3),DFLXF(3),ANG(3),ANGN(3)
      COMMON/BLK21/ IR,IPD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/EIN,XJ,RF,PR,XLE,EPTH,EPP,EPQ,EPT,RINF,WINF,NSP,JCHEM
      COMMON/ END/ KP,NP1,L,NPPS,EM1R,EM1L,RATH
      COMMON/DISS/ FDISP(3),D2P(3),XMUP(3),PP(3),QP(3),RHOP(3),THP(3)
      XM3(QZ1,QZ2,QZ3,QZ4 )= QZ1*TAN(QZ3)+QZ2*TAN(QZ4)
      XM1(QX3,QX4,QX7)=    TAN(QX3+QX7*QX4)
C IR=2 REGION 2    UPRUNNING WAVE
C IR=3 REGION 3 DOWNRUNNING WAVE
      NP1=NLO(IR)
      L=NP1
      NPPS=NP1+1
      XN(L)=X(L)+DFLXF(IR)
      YN(L)= DFLXF(IR)*XM3(ALPHA,BETA,TH(L),THN(L) )
      CALL SURFAC(IPD,2,XN(NP1),YN(NP1),THN(NP1) )
      EM1L=XM1(TH (L) ,XMU (L) , FAM)
      EM1R=XM1(TH (NPPS),XMU (NPPS), FAM)
      KP=1
      YP(KP)=(Y(NPPS)+Y(NP1) )*.5
      CALL FIND
      CALL INTER(RATH,1,L,NPPS)
      TERM= RHOP(1)*QP(1)**2
      A12=1./(TERM*TAN(XMUP(1)))
      VW2=D2P(1)/TERM-FAM*FDISP(1)*TAN(XMUP(1) )
      VW3= D2N(L)/(RHON(L)*QN(L)**2)-FAM*FDISN(L)*TAN(XMUN(L) )
      VW3= ALPHA*VW2+BETA*VW3
      DELS= DFLXF(IR)**2+(YN(L)-Y(L))**2
      DELS= SQRT(DELS)
      PN(L)= PP(1)-FAM*(THN(L)-THP(1) +VW3*DELS)/A12
      D1A= D1(L)*ALPHA+BETA*D1N(L)
      TERM=RHO(L)*Q(L)*ALPHA+BETA*RHON(L)*QN(L)
      QN(L)=      DELS*D1A-PN(L)+P(L)
      QN(L)=QN(L)/TERM +Q(L)
      WRITE(6,1000) QN(L),Q(L),THP(1),PP(1),RHOP(1),FDISP(1)
      WN(L)=0.0
      DO 13 J=1,7
      ALPN(J,L)=ALP(J,L)+DELS*(WDOT(J,L)+S3I(J,L) )/TERM
      IF(ALPN(J,L).LT.1.1E-10) ALPN(J,L)=1.1E-10
      WN(L)=WN(L)+ALPN(J, L)/WTMOLE(J)
   13 CONTINUE
      WRITE(6,1002) (ALPN(J,L),J=1,7)
      WN(L)=1./WN(L)
      RN(L)=RO/WN(L)*45092.8
      HTN(L)=DELS*S4  (L)/TERM+HT(L)
      HXN(L)=HTN(L)-.5*QN(L)**2
```

```
      TN(L)=T(L)
      T1=TN(L)
      WRITE(6,1003) T1,T2,TN(L),T(L),HE1,HE2,HXN(L)
      DO 10 KE=1,15
      IF (KE.GT.1) GO TO 16
      CALL THERM(2,L)
      HE1=.0
      DO 19 J=1,NSP
   19 HE1=HE1+ALPN(J,L)*H1(J)
      IF(HXN(L)-HE1) 17,16,18
   18 TN(L)=T1+ 5.
      GO TO 16
   17 TN(L)=T1- 5.
   16 CONTINUE
      WRITE(6,1003) T1,T2,TN(L),T(L),HE1,HE2,HXN(L)
      T2=TN(L)
      CALL THERM(2,L)
      CPXN(L)= .0
      HE2=.0
      DO 15 J=1,NSP
      CPXN(L)=CP1 (J)*ALPN(J,L)+CPXN(L)
   15 HE2=HE2+ALPN(J,L)*H1(J)
      IF (ABS((HXN(L)-HE2)/HXN(L) ).LE. .00001) GO TO 14
      TN(L)= T1-(HE1-HXN(L) )/(HE2-HE1)*(T2-T1)
      HE1=HE2
      T1=T2
   10 CONTINUE
      CALL ERROR(1234)
      WRITE(6,1003) T1,T2,TN(L),T(L),HE1,HE2,HXN(L)
      WRITE(6,1002) (ALPN(J,L),J=1,7)
      WRITE(6,1000) QN(L),Q(L),THP(1),PP(1),RHOP(1),FDISP(1)
 1000 FORMAT(6H BODY1,6(2XE14.6) )
 1001 FORMAT(6H BODY2,2(2XE14.6) ,2I5 )
 1002 FORMAT (6H BODY3,7(2XE14.6) )
 1003 FORMAT(6H BODY1,2X,7(2XE14.6) )
   14 CONTINUE
      GAMN(L)=CPXN(L)/(CPXN(L)-RN(L) )
      RHON(L)= PN(L)/(RN(L)*TN(L) )
      FMN(L)=QN(L) / SQRT(GAMN(L)*RN(L)*TN(L) )
      XMUN(L)=ASIN(1./FMN(L))
      RETURN
      END
```

```
      SUBROUTINE POCUS(TI,PRESSI,RHOI,ALPHI,DT,TN,        ALPHN)
      DIMENSION ALPHI(7),ALPHN(7),AD(10,10),CI(10),Y(7),YN(7),ALPHA(7)
      DIMENSION T0(7),T1(7),B(7),C(7),D(7),F(7),G(7),Z(7)
      DATA I53/0/
      IF(I53.GT.0) GO TO 400
      T0(1)=6.0
      T0(2)=6.0
      T0(3)=0.5
      T0(4)=0.5
      T0(5)=0.5
      T0(6)=0.5
      T0(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
      F(1)=0.0
      F(2)=0.0
      F(3)=6.3657
      F(4)=38.9184
      F(5)=2.5521
      F(6)=4.3679
      F(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)=1.062
      Z(7)=1.75
      I53=1
  400 CONTINUE
      KASE=1
C     IF(KASE.EQ.2) PRESSI=PRESSI*.25
C     IF(KASE.EQ.3) PRESSI=.2*PRESSI
      PSSSS=PRESSI
      MTEST=0
      KTEST=0
      FLO=1.0
      DLTI=0.0
      EPS=.001
      TIME0=1.38725E-5*FLO
      DT=DT/TIME0
      P0=PRESSI*1.01325E6
      RHO0=P0*1.924465E-10
      RHOI=RHOI*.5154/RHO0
      PRESSI=1.0
      HI=0.0
      T=TI
      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
      NU=0
      MU=0
      JJJ = 25
      JJ=0
C     T = TI
C     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*FLO
      DUM2=DUM1*RHO0/16.
   35 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=-(F5/2.+2.*B5*Y(1))*SUMY
      CC1=B5*Y(1)**2*SUMY
      CC=GAMMA*(Y(2)+Y(1)/2.)
      C1=F5*CC*SUMY+CC1
      A11=DELT/+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)/2.0
      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=-(F8/2.+2.*B8*Y(1))*SUMY
      CC1=B8*Y(1)*Y(1)*SUMY
  103 BB=GAMMA*(Y(2)+Y(1)/2.)
      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)/2.
      IF(YN(2).LT.0.0) YN(2)=0.0
      YN(5)=BB-YN(2)/2.0
      GO TO 99
    6 CONTINUE
C     KOUNT=1
C     IF(KASE.EQ.2) CALL ETHANE(T)
C     IF(KASE.EQ.3) CALL PROP(T)
      F1=3.E14*EXP (-8.91/T)*DUM1
      F1=2.24  E14*EXP (-8.844/T)*DUM1
      F2=3.E14*EXP (-4.03/T)*DUM1
      F3=3.E14*EXP (-3.02/T)*DUM1
      F4=F3
      F5=1.85E17*EXP (-54./T)/T*DUM1
      F6=9.66E18*EXP (-62.2/T)/T*DUM1
      F7=8.00E16*EXP (-52.5/T)/T*DUM1
      F8=5.80E16*EXP (-60.6/T)/T*DUM1
      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
```

```
      B5=1.E16*DUM2
      B6=1.E17*DUM2
      B7=1.E16*DUM2
      B8=6.E14*DUM2
C     IF(KASE.EQ.2) CALL ETH2(T)
      DUM1=(Y(2)+Y(4)+Y(3))/2.
      DUM2=(Y(1)+Y(6))/2.+Y(3)
      DUM3=Y(1)/2.+Y(6)+Y(2)
      DUM4=F1*Y(1)*DUM1+B1*Y(2)*Y(4)
      DUM5=F2*Y(2)*DUM2+B2*Y(1)*Y(4)
      DUM6=F3*Y(6)*DUM3+B3*Y(1)*Y(2)
      DUM7=F4*Y(4)*Y(6)-B4*Y(2)*Y(3)
      DUM8=(F2/2.-B7*SUMY)*Y(2)+B2*Y(6)
      DUM9=(F1/2.-B7*SUMY)*Y(1)+B1*Y(6)
      DUM10=(F2/2.-B1)*Y(2)+(B2-F1/2.)*Y(1)
      DUM11=(F1/2.-B2)*Y(1)-F3*Y(6)
      DUM12=F1*DUM1-B3*Y(3)-F3/2.*Y(6)
      DUM13=(F8*SUMY+F1*Y(1))/2.
      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
      B72=2.*B4*Y(3)-DUM9-F2*DUM2
      B71=-(DUM12+DUM8+DUM17)
      B17=SUMY*(F7-F5/2.)-DUM10-DUM14-2.*F3*DUM3
      B79=F6*SUMY-DUM11+(2.*B4-F2)*Y(2)
      B92=-B4*Y(3)
      B97=DUM14+DUM15
      B11=DUM12-F5*SUMY/2.-(F2/2.+B7*SUMY)*Y(2)-B2*Y(6)-DUM17-2.*B5*DUM1
     16
      B22=-SUMY*(2.*B8*Y(2)+B7*Y(1))-B1*Y(6)+F2*DUM2-DUM13+B92
      B77=-(DUM14+SUMY*F7+(F1/2.+B2)*Y(1)+(B1+F2/2.)*Y(2)+2.*DUM15)
      B99=DUM11-(F1/2.*Y(1)+F6*SUMY+B4*Y(2))
      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))/2.)
      CC=GAMMA*(Y(4)+Y(3)+(Y(1)+Y(6))/2.)
      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+F2*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-F(I)*ALPHA(I)/2.
      CH=CH+D(I)*ALPHA(I)
      GO TO 505
  502 IF(TT-TO(I)) 503,503,504
  503 BH=BH-B(I)*ALPHA(I)/2.
      CH=CH+G(I)*ALPHA(I)
      GO TO 505
  504 AH=AH+C(I)*ALPHA(I)
      BH=BH+ALPHA(I)*(C(I)*TO(I)-B(I)/2.)
      CH=CH+ALPHA(I)*(G(I)+C(I)*TO(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
   16 IF(JJ) 31,31,22
   31 ERR1=TT-T
      IF(ABS(TT/T-1.0).LE.EPS) GO TO 27
```

```
   24 GAM1=GAMMA
      GAMMA=.99*GAMMA
  130 GAM2=GAMMA
      DELTA=(GAMMA-1.)/DT
      JJ=JJ+1
C     IF (JJ-JJJ) 84,84,12
      IF (JJ-JJJ) 14,14,12
C  84 IF (KOUNT.EQ.1) GO TO 14
C     T=TSAVE
C     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(1H0,22H JJ IS GREATER THAN JJJ)
   27 TN=T
      DO 28 J=1,7
   28 ALPHN(J)=ALPHA(J)
      DLTN=DELTA
      DT=DT*TIME0
      RETURN
      END
```

```
      SUBROUTINE CHEMP(IND,DX,L)
      COMMON/FRSTR/  TIN,UIN,FMINF,GAMINF,CPIN,RO,WTMOLF(7)
      COMMON/FUDGE/ AFAC
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK16/PHI(150),XS(   7),   DACH(7,150)
      COMMON /IO/ IOCHEM
      DIMENSION  ALPHN(7),ASAVE(7), ALPHA(7)
      DELTAT=4.E-7
      GO TO (1,2),IND
    1 CONTINUE
      TI=T (L)
      P1=P (L)
      U1=Q (L)
      RHO1=RHO (L)
      GO TO  3
    2 CONTINUE
      TI=TN(L)
      P1=PN(L)
      U1=QN(L)
      RHO1=RHON(L)
    3 TERM=RHO1*U1
      DELTAX=U1*DELTAT
      JER=INT(DX/DELTAX)
      IF (JER.EQ.0) JER=1
      DELX=DX/FLOAT(JER)
      TIME=DX/U1
      TSAVE=TI
      GO TO (4,5),IND
    4 DO 201 J=1,7
      ALPHA(J)=ALP(J,L)
  201 ASAVE(J)=ALP(J,L)
      GO TO 6
    5 DO 202 J=1,7
      ALPHA(J)=ALPN(J,L)
  202 ASAVE(J)=ALPN(J,L)
    6 DT=DELX/U1
      RH=P1/(TI*RO*4592.8)
      TI=TI/1000.
      PCH=P1/2116.
      DO 10 JERRY=1,JER
      DUM=0.0
      DO 96 J=1,7
   96 DUM=DUM+ASAVE(J)/WTMOLF(J)
      RHOI=RH/DUM
        IF(IOCHEM.EQ.0)
     1WRITE(6,250) TI,PCH,RHOI,ASAVE,DT,TCHN ,ALPHN
  250 FORMAT(16HPOCUS FROM HOCUS ,10F11.3/17X,10F11.3/)
      CALL POCUS(TI,PCH,RHOI,ASAVE,DT,TCHN,ALPHN)
      IF(JERRY.NE.1) GO TO 100
      DO 110 J=1,7
  110 WDOT(J,L)=TERM*(ALPHN(J)-ASAVE(J))/DX * AFAC
C     WRITE(6,1001) U1 ,RHO1,DX,DELTAX,TCHN,DT,TERM,JER,L
C     WRITE(6,1000) (WDOT (J,L),J=1,7)
C1001 FORMAT          (7(2XE14.8) ,2I5)
 1000 FORMAT          (7(2XE14.8) )
```

```
  100 CONTINUE
      IF(JERRY.EQ.JER)GO TO 10
      TI=TCHN
      DO 20 J=1,7
 20   ASAVE(J)=ALPHN(J)
 10   CONTINUE
      DO 40 J=1,7
      DACH(J,L)=ALPHN(J)-ALPHA(J)
   40 WDOTN(J,L)=TERM*(ALPHN(J)-ASAVE(J))/DX   *AFAC
C     WRITE(6,1000) (DACH(J,L ),J=1,7)
C     WRITE(6,1000) (WDOTN(J,L),J=1,7)
      RETURN
      END
```

```
      SUBROUTINE  COMPS(IND)
      COMMON/EDVI/ FACTOR (3) ,VISCX(3)
      COMMON/FRSTR/  TIN,UIN,EMINF,GAMINF,CPIN,RO,WTMOLE(7)
      COMMON/BLK1/CPXN(150),CPX(150)
      COMMON/BLK2/XMU(150),XMUN(150),WDOT(7,150),WDOTN(7,150)
      COMMON/BLK5/S4(150),S4N(150),D1(150),D1N(150),D2(150),D2N(150)
      COMMON/BLK6/HTN(150),HT(150) ,YP(9),Y(150),YN(150),X(150),XN(150)
      COMMON/BLK7/S3I(7,150),S3IN(7,150),FDIS(150),FDISN(150)
      COMMON/BLK8/TH(150),THN(150),Q(150),QN(150),T(150),TN(150)
      COMMON/BLK12/HX(150),HXN(150),ALP(7,150),ALPN(7,150)
      COMMON/BLK13 /P(150),PN(150),RHO(150),RHON(150), W(150),WN(150)
      COMMON/BLK15/ R(150),RN(150),GAM(150),GAMN(150),EM(150),EMN(150)
      COMMON/BLK16/PHI(150),XS(  7),  DACH(7,150)
      COMMON/BLK20/ NLO(2),NOP(3),DELXF(3),ANG(2),ANGN(2)
      COMMON/BLK21/ IR,IRD,IRU,ITYPE,FAM,IFLO,IUP,ALPHA,BETA
      COMMON/BLK22/FIN,XJ,RF,PR,XLF,EPTH,EPP,EPG,EPT,RINF,WINF,NSP,JCHEM
      COMMON/PROPT/H1(7),CP1(7),DCP1(7)
      DIMENSION DADN(7),D2ADN(7)
      SCM=PR*XLF
      GO TO (2,1),IND
    1 CONTINUE
      NP1=NOP(IR)+1
      NP2=NOP(IR)-1
      TN(NP1)=TN(NP2)
      QN(NP1)=QN(NP2)
      THN(NP1)=THN(NP2)
      NQ1=NLO(IR)-1
      NQ2=NLO(IR)+1
      TN(NQ1)=TN(NQ2)
      QN(NQ1)=QN(NQ2)
      THN(NQ1)=THN(NQ2)
      DO  60  J=1,NSP
      ALPN(J,NP1)=ALPN(J,NP2)
   60 ALPN(J,NQ1)=ALPN(J,NQ2)
      NA=NLO(IR)
      NN=NOP(IR)
      YN(NQ1)=2.*YN(NA)       -YN(NQ2)
      YN(NP1)=2.*YN(NN )      -YN(NP2)
      DUM=0.5*(RHO (NA)*Q (NA)+RHO ( NN   )*Q (NN   ))
      DO 53  II=NA,NN
      M=II
      IM=II-1
      IF(RHO (NA)*Q (NA).GT.DUM) M=NN
      IF(RHO (NA)*Q (NA).GT.DUM) IM=NA +1
      IF(RHO (M)*Q (M)-DUM) 53,54,54
   53 CONTINUE
   54 RHALF=Y (M)-(Y (M)-Y (IM))*(RHO (M)*Q (M)-DUM)/(RHO (M)*Q (M)-RHO
     1 (IM)*Q (IM)) -Y(NA)
      RHALF=ABS(RHALF)
      VISC   =FACTOR(IR)*RHALF*RHO(NA)*Q(NA)
      VISCX(IR)=VISC
      DMUDN=.0
      DKDN= .0
      WRITE(6,1001) VISC
      DO 12 I=NA,NN
      DELY1=YN(I)-YN(I-1)
      DELY2=YN(I+1)-YN(I)
      SUM=DELY1+DELY2
```

```
      RATIO1=DELY1/DELY2
      RATIO2=DELY2/DELY1
      DUDN    =(QN(I+1)*RATIO1-QN(I)*(RATIO1-RATIO2)-QN(I-1)*RATIO2)/SUM
      D2UDN=2.*(QN(I+1)*DELY1/SUM-QN(I)+QN(I-1)*DELY2/SUM)/DELY1/DELY2
      DTDN    =(TN(I+1)*RATIO1-TN(I)*(RATIO1-RATIO2)-TN(I-1)*RATIO2)/SUM
      D2TDN   =2.*(TN(I+1)*DELY1/SUM-TN(I)+TN(I-1)*DELY2/SUM)/DELY1/DELY2
      DTHDN=(THN(I+1)*RATIO1-THN(I)*(RATIO1-RATIO2)-THN(I-1)*RATIO2)/SUM
      D2THDN =2.*(THN(I+1)*DELY1/SUM-THN(I)+THN(I-1)*DELY2/SUM)/DELY1/
     1DELY2
      CALL THERM (2,I)
      CPXN(I)=.0
      HXN(I)=0.0
      WN(I)=0.0
      DO 17 J=1,7
      WN(I)=WN(I)+ALPN(J, I)/WTMOLE(J)
      HXN(I)=HXN(I)+ALPN(J, I)*H1(J)
   17 CPXN(I)=CP1 (J)*ALPN(J,I)+CPXN(I)
      WN(I)=1./WN(I)
      RN(I)=RO/WN(I)*45092.8
      GAMN(I)=CPXN(I)/(CPXN(I)-RN(I) )
      RHON(I)= PN(I)/(RN(I)*TN(I) )
      EMN(I)=QN(I) / SQRT(GAMN(I)*RN(I)*TN(I) )
      XMUN(I)=ASIN(1./EMN(I))
C     DMUDN=DTDN*VISC*(1.5/TN(I)-1./(TN(I)+198.6) )
C     VISC= 2.27E-8*(1.8*TN(I) )**1.5/(1.8*TN(I)+198.6 )
C     VISC=VISC*FACTOR
      COND=VISC*CPXN(I)/PR
      DUM=.0
      DO 16 J=1,NSP
   16 DUM=DUM+ALPN(J,I)*DCP1(J)
C     DKDN= DMUDN*CPXN(I)/PR+VISC*DTDN/PR*DUM
      DPRO=0.
      SUM1=0.
      SUM2=.0
      SUM3=.0
      TERM1=RHON(I)*QN(I)
      AC2=XLE/PR*VISC
      IF(ABS(YN(I)) .LE. .00001) GO TO 18
      AC1=XLE/PR*COS(THN(I))*VISC/YN(I)*XJ+XLE/PR*DMUDN
      GO TO 19
   18 DO 23 J=1,NSP
      DADN(J)=(ALPN(J,I+1)*RATIO1-ALPN(J,I)*(RATIO1-RATIO2)-ALPN(J,I-1)*
     1  *RATIO2)/SUM
      D2ADN(J)    =2.*(ALPN(J,I+1)*DELY1/SUM-ALPN(J,I)+ALPN(J,I-1)*DEL
     1Y2/SUM)/DELY1/DELY2
      S3IN(J,I)=TERM1*(ALPN(J,I)-ALP(J,I))/DELXF(IR)
      IF(XJ.EQ. .0) S3IN(J,I)=AC2*D2ADN(J)
      DPRO= H1(J)*WDOTN(J,I)+H1(J)* S3IN(J,I)+DPRO
      SUM1=H1(J)*DADN(J) +SUM1
      SUM2= H1(J)*D2ADN (J)+SUM2
   23 SUM3=     DADN (J)*CP1(J)+SUM3
      DDIF=(DMUDN*SUM1+DTDN*VISC*SUM3+VISC*SUM2)/SCM
      TERM=RHON(I)*QN(I)*CPXN(I)*TN(I)
      GO TO 24
   19 DO 11 J=1,NSP
      DADN(J)     =(ALPN(J, I+1)*RATIO1-ALPN(J, I)*
     1(RATIO1-RATIO2)-ALPN(J, I-1)*RATIO2)/SUM
      D2ADN(J)    =2.*(ALPN(J,I+1)*DELY1/SUM-ALPN(J,I)+ALPN(J,I-1)*DEL
```

```
     1Y2/SUM)/DELY1/DELY2
      S3IN(J,I)=AC1*DADN (J)+AC2*D2ADN (J)
      DPRO= H1(J)*WDOTN(J,I)+H1(J)* S3IN(J,I)+DPRO
      SUM1=H1(J)*DADN(J) +SUM1
      SUM2= H1(J)*D2ADN (J)+SUM2
   11 SUM3=      DADN (J)*CP1(J)+SUM3
      DDIF=(DMUDN*SUM1-DTDN*VISC*SUM3+VISC*SUM2)/SCM
      TERM=RHON(I)*QN(I)*CPXN(I)*TN(I)
      D2N(I)=(SIN(THN(I))/(YN(I)*3.)*DUDN*VISC+4.*COS(THN(I))*QN(I)*VISC
     1*DTHDN/(YN(I)*3.) -4.*VISC*QN(I)*SIN(THN(I))*COS(THN(I))/YN(I)**2)
     2.*XJ+4.*VISC*DUDN*DTHDN/3.+4.*VISC*QN(I)*D2THDN/3.+4.*QN(I)*DMUDN
     3 *DTHDN/3.-2.*QN(I)* SIN(THN(I))*DMUDN/(3.*YN(I))*XJ
      S4N(I) =DDIF+COND*COS(THN(I)) *DTDN/ YN(I)*XJ+COND*D2TDN+DKDN*DTDN
     1+4.*VISC*QN(I)**2/3.*(DTHDN**2-SIN(THN(I))*DTHDN)+VISC*DUDN**2+
     2 VISC*QN(I)*(COS(THN(I))*DUDN/YN(I)*XJ+D2UDN)+QN(I)*DUDN*DMUDN
      D1N(I) = VISC*COS(THN(I))*DUDN/YN(I)*XJ+VISC*D2UDN+DUDN*DMUDN
      FDISN(I)=S4N(I)/TERM-D1N(I) *(CPXN(I)*TN(I)+QN(I)**2)/(TERM*QN(I))
     1 -DPRO/TERM-SIN(THN(I))/YN(I)*XJ
C     WRITE(6,1002) D1N(I),S4N(I),DPRO,FDISN(I) ,TERM,CPXN(I),I
      GO TO 12
   24 CONTINUE
      D2N(I)= .0
      D1N(I) =          VISC*D2UDN
C     D1N(I)=TERM1*(QN(I)-Q(I))/DELXF(IR)+(PN(I)-P(I))/DELXF(IR)
      S4N(I) =DDIF +COND*D2TDN+DKDN*DTDN
     1+4.*VISC*QN(I)**2/3.*(DTHDN**2-SIN(THN(I))*DTHDN)+VISC*DUDN**2+
     2    VISC*QN(I)*  D2UDN
C     S4N(I)=TERM1*(HTN(I)-HT(I))/DELXF(IR)
      FDISN(I)=S4N(I)/TERM-D1N(I) *(CPXN(I)*TN(I)+QN(I)**2)/(TERM*QN(I))
     1 -DPRO/TERM-.5*(QN(I)-Q(I))/(TAN(XMUN(I))**2*QN(I)*DELXF(IR) )*XJ
   12 CONTINUE
      RETURN
C ////////////////////////////////////////////////////////////////////
    2 CONTINUE
      DO 3052 IR=1,3
      IF(IR .GT. 1 .AND. ITYPE .EQ. 3) RETURN
      NO1=NLO(IR)-1
      NO2=NLO(IR)+1
      NP1=NOP(IR)+1
      NP2=NOP(IR)-1
      T (NO1)=T (NO2)
      Q (NO1)=Q (NO2)
      TH (NO1)=TH (NO2)
      NA=NLO(IR)
      NB=NOP(IR)
      Y (NO1)=2.*Y (NA)       -Y (NO2)
      Y (NP1)=2.*Y (NB)       -Y (NP2)
      DO  50  J=1,NSP
      ALP(J,NP1)=ALP(J,NP2)
   50 ALP (J,NO1)=ALP (J,NO2)
      Q(NP1)=Q(NP2)
      T(NP1)=T(NP2)
      TH(NP1)=TH(NP2)
      DUM=0.5*(RHO (NA)*Q (NA)+RHO ( NB  )*Q (NB  ))
      DO 51  II=NA,NB
      M=II
      IM=II-1
      IF(RHO (NA)*Q (NA).GT.DUM) M=NB
```

```
      IF(RHO (NA)*Q (NA).GT.DUM) IM=NA +1
      IF(RHO (M)*Q (M)-DUM) 51,52,52
   51 CONTINUE
   52 RHALF=Y (M)-(Y (M)-Y (IM))*(RHO (M)*Q (M)-DUM)/(RHO (M)*Q (M)-RHO
     1 (IM)*Q (IM)) -Y(NA)
      RHALF=ABS(RHALF)
      VISC  =FACTOR(IR)*RHALF*RHO(NA)*Q(NA)
      VISCX(IR)=VISC
      WRITE(6,1001) VISC
      DKDN= .0
      DMUDN=.0
      DO 13 I=NA,NB
      DELY1=Y (I)-Y (I-1)
      DELY2=Y (I+1)-Y (I)
      SUM=DELY1+DELY2
      RATIO1=DELY1/DELY2
      RATIO2=DELY2/DELY1
      DUDN    =(Q (I+1)*RATIO1-Q (I)*(RATIO1-RATIO2)-Q (I-1)*RATIO2)/SUM
      D2UDN =2.*(Q (I+1)*DELY1/SUM-Q (I)+Q (I-1)*DELY2/SUM)/DELY1/DELY2
      DTDN    =(T (I+1)*RATIO1-T (I)*(RATIO1-RATIO2)-T (I-1)*RATIO2)/SUM
      D2TDN  =2.*(T (I+1)*DELY1/SUM-T (I)+T (I-1)*DELY2/SUM)/DELY1/DELY2
      DTHDN  =(TH(I+1)*RATIO1-TH(I)*(RATIO1-RATIO2)-TH(I-1)*RATIO2)/SUM
      D2THDN =2.*(TH (I+1)*DELY1/SUM-TH (I)+TH (I-1)*DELY2/SUM)/DELY1/
     1DELY2
      CALL THERM (1,I)
      COND=VISC*CPX(I)/PR
      DUM=.0
      DO 15 J=1,NSP
   15 DUM=DUM+ALP (J,I)*DCP1(J)
      DPRO=0.
      SUM1=.0
      SUM2=.0
      SUM3=.0
      AC2=XLE/PR*VISC
      IF(ABS(Y(I) ) .LE. .00001) GO TO 21
      AC1=XLE/PR*COS(TH (I))*VISC/Y (I)*XJ+XLE/PR*DMUDN
      GO TO 22
   21 DO 26 J=1,NSP
      DADN(J)      =(ALP (J, I+1)*RATIO1-ALP (J, I)*
     1(RATIO1-RATIO2)-ALP (J, I-1)*RATIO2)/SUM
      D2ADN(J)     =2.*(ALP (J,I+1)*DELY1/SUM-ALP (J,I)+ALP (J,I-1)*DEL
     1Y2/SUM)/DELY1/DELY2
      S3I (J,I)= 0.0
      IF(XJ.EQ. .0) S3I (J,I)=AC2*D2ADN(J)
      DPRO= H1(J)*WDOT(J,I) +H1(J)* S3I(J,I) +DPRO
      SUM1=H1(J)*DADN(J) +SUM1
      SUM2= H1(J)*D2ADN (J)+SUM2
   26 SUM3=     DADN (J)*CP1(J)+SUM3
      DDIF=(DMUDN*SUM1+DTDN*VISC*SUM3+VISC*SUM2)/SCM
      TERM=RHO (I)*Q (I)*CPX (I)*T (I)
      GO TO 25
   22 DO 10 J=1,NSP
      DADN(J)      =(ALP (J, I+1)*RATIO1-ALP (J, I)*
     1(RATIO1-RATIO2)-ALP (J, I-1)*RATIO2)/SUM
      D2ADN(J)     =2.*(ALP (J,I+1)*DELY1/SUM-ALP (J,I)+ALP (J,I-1)*DEL
     1Y2/SUM)/DELY1/DELY2
      S3I(J,I)   =AC1*DADN(J)+AC2*D2ADN(J)
      DPRO= H1(J)*WDOT(J,I) +H1(J)* S3I(J,I) +DPRO
```

```
      SUM1=H1(J)*DADN(J) +SUM1
      SUM2= H1(J)*D2ADN (J)+SUM2
   10 SUM3=     DADN (J)*CP1(J)+SUM3
      DDIF=(DMUDN*SUM1+DTDN*VISC*SUM3+VISC*SUM2)/SCM
      TERM=RHO (I)*Q (I)*CPX (I)*T (I)
      D2 (I)=(SIN(TH (I))/(Y (I)*3.)*DUDN*VISC+4.*COS(TH (I))*Q (I)*VISC
     1 *DTHDN/(Y (I)*3.)-4.*VISC*Q (I)*SIN(TH (I))*COS(TH (I))/Y (I)**2
     2)*XJ+4.*VISC*DUDN*DTHDN/3.+4.*VISC*Q (I)*D2THDN/3.+4.*Q (I)*DMUDN
     3 *DTHDN/3.-2.*Q (I)* SIN(TH (I))*DMUDN/(3.*Y (I))*XJ
      S4(I) =DDIF+COND*COS(TH (I)) *DTDN/ Y (I)*XJ+COND*D2TDN+DKDN*DTDN+
     1 4.*VISC*Q (I)**2/3.*(DTHDN**2-SIN(TH (I))*DTHDN)+VISC*DUDN**2+
     2 VISC*Q (I)*(COS(TH (I))*DUDN/Y (I)*XJ+D2UDN)+Q (I)*DUDN*DMUDN
      D1(I) = VISC*COS(TH (I))*DUDN/Y (I)*XJ+VISC*D2UDN+DUDN*DMUDN
      FDIS (I)=S4(I)/TERM-D1 (I)*(CPX (I)*T (I)+Q (I)**2)/(TERM*Q (I) )
     1 -DPRO/TERM-SIN(TH (I))/Y (I)*XJ
      GO TO 13
   25 CONTINUE
      TERM1=RHO (I)*Q (I)
      D2 (I)= .0
      D1 (I) =        VISC*D2UDN
      S4 (I) =DDIF +COND*D2TDN+DKDN*DTDN
     1+4.*VISC*Q (I)**2/3.*(DTHDN**2-SIN(TH (I))*DTHDN)+VISC*DUDN**2+
     2   VISC*Q (I)*  D2UDN
      FDIS (I)=S4(I)/TERM-D1 (I)*(CPX (I)*T (I)+Q (I)**2)/(TERM*Q (I) )
     1 -DPRO/TERM
   13 CONTINUE
 3052 CONTINUE
      RETURN
 1001 FORMAT(5H CAL2,5(2XE14.6) ,I5)
 1002 FORMAT (7H COMPS2, 6(2XE14.6) ,I5)
 1003 FORMAT (7(2XE14.6) )
 1004 FORMAT(8H  COMPS4,7(2XE14.6),I5)
 1005 FORMAT (5(2XE14.6) )
 1007 FORMAT (7H COMPS7 ,8(2XE14.6) )
 1008 FORMAT (7H COMPS8 ,4(2XE14.6) )
      END
```

```
      COMMON    YY(200),YA(200) ,XSTA(5),NPT(5),II(6000)
      COMMON    P(200),T(200),U(200),TH(200),FM(200),Y(200),YP(200,5)
      COMMON    ALP(7,200),Y1(200,5),Y2(200,5),Y3(200,5), Y4(200,5)
      COMMON     Y5(200,5),Y6(200,5),Y7(200,5),Y8(200,5), Y9(200,5)
      COMMON ICAS, NCURV
      EQUIVALENCE(DY,SCLY)
      EQUIVALENCE(DX,SCLX)
  100 FORMAT (7F10.6)
  101 FORMAT (6F10.4)
  105 FORMAT(A4)
C     ICAS=1   SPECIF PLOT
C     ICAS=2   FLOW PROPERTIES PLOT
C     NCURV= NO. OF CURVES PER PLOT (X STATIONS)
      CALL PLOTS(II,6000)
      CALL PLOT(.0, 0.,-3)
    1 CONTINUE
      READ(5,100) ACAS,ACURV
      ICAS=ACAS
      NCURV=ACURV
      DO 22 LC=1,NCURV
      READ(5,100) XSTA(LC),APT
      NPT(LC)=APT
C     NPT= NO. OF POINTS IN PROFILE
      NP=NPT(LC)
      WRITE(6,110) XSTA(LC)
  110 FORMAT (10X,23H PROFILES AT STATION X=,F10.4)
      DO 12 I=1,NP
      READ(5,101) P(I),T(I),U(I),TH(I),FM(I),Y(I)
      WRITE(6,101) P(I),T(I),U(I),TH(I),EM(I),Y(I)
   12 CONTINUE
      DO 21 J=1,NP
      READ(5,100)(ALP(K,J),K=1,7)
C     WRITE(6,100)(ALP(K,J),K=1,7)
   21 CONTINUE
      DO 22 J=1,NP
      Y1(J,LC)=ALP(4,J)
C     Y1=H2
      Y2(J,LC)=ALP(5,J)
C     Y2= O2
      Y3(J,LC)=ALP(3,J)
C     Y3= H2O
      Y4(J,LC)=ALP(7,J)
C     Y4= N2
      Y5(J,LC)=P(J)
C     Y5=PRESSURE - P
      Y6(J,LC)=T(J)
C     Y6=TEMPERATURE - T
      Y7(J,LC)=U(J)
C     Y7=VELOCITY - U
      Y8 (J,LC)=TH(J)
C     Y8= FLOW ANGLE - TH
      Y9 (J,LC)=FM(J)
C     Y9= MACH NUMBER - FM
      YP(J,LC)=Y(J)
   22 CONTINUE
C
C     PROGRAM SPLIT HERE
      CALL PART2
      GO TO 1
      END
```

```
      SUBROUTINE PART2
      COMMON    YY(200),YA(200) ,XSTA(5),NPT(5),II(6000)
      COMMON    P(200),T(200),U(200),TH(200),EM(200),Y(200),YP(200,5)
      COMMON    ALP(7,200),Y1(200,5),Y2(200,5),Y3(200,5), Y4(200,5)
      COMMON     Y5(200,5),Y6(200,5),Y7(200,5),Y8(200,5), Y9(200,5)
      COMMON ICAS, NCURV
      EQUIVALENCE(DY,SCLY)
      EQUIVALENCE(DX,SCLX)
      DATA DONE/4HDONE/
  100 FORMAT (7F10.6)
  101 FORMAT (6F10.4)
  105 FORMAT(A4)
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
      WRITE(6,101) DY,SCLY,DX,SCLX
      WRITE(6,101) XO,XM,SIZX,YO,YM,SIZY
C     Y1=H2
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14H H2 FRACTION   , 14,SIZX, 90.,XO,DX)
      DO 24 LC=1,NCURV
      WRITE(6,111) XSTA(LC)
  111 FORMAT (10X,23H PROFILES AT STATION X= F10.4,23H ARE NOW BEING PLO
     1TTED  //)
      NP=NPT(LC)
      DO 25 J=1,NP
      YA(J)=Y1(J,LC)
   25 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
      YY(NP+1)=YO
      YY(NP+2)=SCLY
      CALL LINE(YY,YA,NP,1,0,3)
   24 CONTINUE
      XNU=SIZY+2.
      YNU=.0
      CALL PLOT(XNU,YNU,-3)
C     Y2= O2
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
      WRITE(6,101) DY,SCLY,DX,SCLX
      WRITE(6,101) XO,XM,SIZX,YO,YM,SIZY
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14H O2 FRACTION   , 14,SIZX, 90.,XO,DX)
      DO 26 LC=1,NCURV
      NP=NPT(LC)
      DO 27 J=1,NP
      YA(J)=Y2(J,LC)
   27 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
      YY(NP+1)=YO
      YY(NP+2)=SCLY
      CALL LINE(YY,YA,NP,1,0,3)
   26 CONTINUE
      XNU=SIZY+2.
      YNU=.0
```

```
      CALL PLOT(XNU,YNU,-3)
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
      WRITE(6,101) DY,SCLY,DX,SCLX
      WRITE(6,101) XO,XM,SIZX,YO,YM,SIZY
C     Y3= H2O
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14H H2O FRACTION  , 14,SIZX, 90.,XO,DX)
      DO 35 LC=1,NCURV
      NP=NPT(LC)
      DO 28 J=1,NP
      YA(J)=Y3(J,LC)
   28 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
      YY(NP+1)=YO
      YY(NP+2)=SCLY
      CALL LINE(YY,YA,NP,1,0,3)
   35 CONTINUE
      XNU=SIZY+2.
      YNU=.0
      CALL PLOT(XNU,YNU,-3)
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
C     Y4= N2
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14H N2 FRACTION  , 14,SIZX, 90.,XO,DX)
      DO 36 LC=1,NCURV
      NP=NPT(LC)
      DO 29 J=1,NP
      YA(J)=Y4(J,LC)
   29 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
      YY(NP+1)=YO
      YY(NP+2)=SCLY
      CALL LINE(YY,YA,NP,1,0,3)
   36 CONTINUE
      XNU=SIZY+2.
      YNU=.0
      CALL PLOT(XNU,YNU,-3)
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
C     Y5=PRESSURE - P
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14H PRESSURE      , 14,SIZX, 90.,XO,DX)
      DO 37 LC=1,NCURV
      NP=NPT(LC)
      DO 30 J=1,NP
      YA(J)=Y5(J,LC)
   30 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
      YY(NP+1)=YO
      YY(NP+2)=SCLY
```

```
      CALL LINE(YY,YA,NP,1,0,3)
   37 CONTINUE
      XNU=SIZY+2.
      YNU=.0
      CALL PLOT(XNU,YNU,-3)
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
C     Y6=TEMPERATURE - T
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14H TEMPERATURE  , 14,SIZX, 90.,XO,DX)
      DO 38 LC=1,NCURV
      NP=NPT(LC)
      DO 31 J=1,NP
      YA(J)=Y6(J,LC)
   31 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
      YY(NP+1)=YO
      YY(NP+2)=SCLY
      CALL LINE(YY,YA,NP,1,0,3)
   38 CONTINUE
      XNU=SIZY+2.
      YNU=.0
      CALL PLOT(XNU,YNU,-3)
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
C     Y7=VELOCITY - U
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14H VELOCITY     , 14,SIZX, 90.,XO,DX)
      DO 39 LC=1,NCURV
      NP=NPT(LC)
      DO 32 J=1,NP
      YA(J)=Y7(J,LC)
   32 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
      YY(NP+1)=YO
      YY(NP+2)=SCLY
      CALL LINE(YY,YA,NP,1,0,3)
   39 CONTINUE
      XNU=SIZY+2.
      YNU=.0
      CALL PLOT(XNU,YNU,-3)
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
C     Y8= FLOW ANGLE - TH
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14HFLOW ANGLE    , 14,SIZX, 90.,XO,DX)
      DO 40 LC=1,NCURV
      NP=NPT(LC)
      DO 33 J=1,NP
      YA(J)=Y8(J,LC)
   33 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
```

```
      YY(NP+1)=YO
      YY(NP+2)=SCLY
      CALL LINE(YY,YA,NP,1,0,3)
   40 CONTINUE
      XNU=SIZY+2.
      YNU=.0
      CALL PLOT(XNU,YNU,-3)
      READ(5,100) XM,XO,SIZX,YO,YM,SIZY
      SCLX= (XM-XO)/SIZX
      SCLY= (YM-YO)/SIZY
C     Y9= MACH NUMBER = EM
      CALL AXIS(.0,.0,3H Y ,-3,SIZY,.0,YO,DY)
      CALL AXIS(.0,.0,14HMACH NUMBER   , 14,SIZX, 90.,XO,DX)
      DO 41 LC=1,NCURV
      NP=NPT(LC)
      DO 34 J=1,NP
      YA(J)=Y9(J,LC)
   34 YY(J)=YP(J,LC)
      YA(NP+1)=XO
      YA(NP+2)=SCLX
      YY(NP+1)=YO
      YY(NP+2)=SCLY
      CALL LINE(YY,YA,NP,1,0,3)
   41 CONTINUE
      XNU=SIZY+2.
      YNU=.0
      CALL PLOT(XNU,YNU,-3)
      READ(5,105) DUNN
      IF(DONE.EQ.DUNN) GO TO 50
      RETURN
   50 CONTINUE
      CALL PLOT(2.,2.,999)
      RETURN
      END
```

TABLE 2 Input Cards

Card No. 1

SYMBOL	DESCRIPTION	COLS.	FORMAT
IJ	0 for 2D, 1 for Axisymmetric	1-5	I5
IOUT(1)	printed output for region 1 every IOUT step	6-10	I5
IOUT(2)	printed output for region 2 every IOUT step	11-15	I5
IOUT(3)	printed output for region 3 every IOUT step	16-20	I5
NSAVE	not used	21-25	I5
JCHEM	0 frozen flow, 1 finite rate	26-30	I5
ISTART	0 initial profile input according to format I	31-35	I5
	1 initial profile input according to format II		
	see pages 66-68		

Card No. 2

SYMBOL	DESCRIPTION	COLS.	FORMAT
NMAX(1)	Maximum number of points permitted in region 1. If this number is reached the program terminates and punches results at the last station	1-5	I5
NMAX(2)	same as above except for region 2	6-10	I5
NMAX(3)	same as above except for region 3	11-15	I5

NMAX (1) < NMAX (2) < NMAX (3) < 150

Card No. 3

SYMBOL	DESCRIPTION	COLS.	FORMAT
XPRO(I)	X-stations at which calculated profile data is to be punches-to be used later for plotter- MAX number 14 (2 cards)	1-10 11-20 ⋮	7F10.4

Card No. 4

SYMBOL	DESCRIPTION	COLS.	FORMAT
PR	Prandtl number - constant (1.0)	1-10	7F10.4
XLE	Lewis number - (1.0)	11-20	
FACTOR(1)	Empirical coefficient (K) in viscosity model for region 1	21-30	
FACTOR(2)	" " " " " 2	31-40	
FACTOR(3)	" " " " " 3	41-50	
	Typical value of K = .02		

Card No. 5

SYMBOL	DESCRIPTION	COLS.	FORMAT
CB	Number of coordinates on lower wall	1-10	7F10.6
COWL	Number of coordinated on upper wall	11-20	

Card No. 6

SYMBOL	DESCRIPTION	COLS.	FORMAT
XRC(J)	X coordinates of lower wall (ft)	1-10	7F10.6
	C_B values required (MAX = 100)	11-20	

Card No. 7

SYMBOL	DESCRIPTION	COLS.	FORMAT
RRC(1)	First y coordinate of lower wall (ft)	1-10	F10.6

Card No. 8

SYMBOL	DESCRIPTION	COLS.	FORMAT
THC(J)	Lower wall angle at above x-coordinate (degrees)	1-10	7F10.6
	CB values required	11-20 ⋮	

Card No. 9

SYMBOL	DESCRIPTION	COLS.	FORMAT
XRC(J)	x-coordinates of upper wall (ft)	1-10	7F10.6
	cowl values required	11-20	

Card No. 10

SYMBOL	DESCRIPTION	COLS.	FORMAT
RRC(cowl)	First y coordinates of upper wall (ft)	1-10	F10.6

Card No. 11

SYMBOL	DESCRIPTION	COLS.	FORMAT
THC(J)	Upper wall angle at above x-coordinate (degrees)	1-10	7F10.6
	cowl values required	11-20	

Card No. 12

SYMBOL	DESCRIPTION	COLS.	FORMAT
EPP	Not used	1-10	7F10.4
EPTH	Error criteria for flow angle in the shock wave point calculation	11-20	

Card No. 13

SYMBOL	DESCRIPTION	COLS.	FORMAT
ANG(1)	Magnitude of the initial shock wave angle in region 3 (degrees)	1-10	7F10.4
ANG(2)	" " " " " " " " " 2 (degrees)	11-20	
DYASL	Maximum distance, Δy, between the shock point and lost mesh point	21-30	

SYMBOL	DESCRIPTION	COLS.	FORMAT
DELY	Not used	31-40	
XBP	Initial x-coordinate (ft)	41-50	
FLO	1 Diverging Shocks 2 converging shocks	51-60	
XSTOP	Maximum x-station calculation will proceed to (ft)		

Card No. 14

SYMBOL	DESCRIPTION	COLS.	FORMAT
PUP(2)	Upstream pressure for region(2)(psf)	1-10	7F10.4
TUP(2)	Upstream temperature for region (2) (°K)	11-20	
EMUP(2)	Upstream Mach number for region 2	21-30	
GAMAUP(2)	Upstream Gamma for region 2	31-40	
XMWUP(2)	Upstream molecular weight for region 2	41-50	

Card No. 15

SYMBOL	DESCRIPTION	COLS.	FORMAT
PUP(3)	Upstream pressure for region 3 (psf)	1-10	7F10.4
TUP(3)	Upstream temperature for region 3(°K)	11-20	
EMUP(3)	" " Mach number " " " 3	21-30	
GAMAUP(3)	Upstream Gamma " " " 3	31-40	
XMWUP(3)	Upstream Molecular Weight " " 3	41-50	

Card No. 16

DUP(2)	Upstream flow angle with sign for region (2) (degrees)	1-10	7F10.4
DUP(3)	" " " " " " " "(3) (degrees)	11-20	
DXN	Not used	21-30	
DIN	Not used	31-40	

SYMBOL	DESCRIPTION	COLS.	FORMAT
DXIN	Not used	41-50	
COALT	Characteristics coalescence criteria on Δy i.e. minimum distance between mesh points	51-60	

Card No. 17

SYMBOL	DESCRIPTION	COLS.	FORMAT
ALPUP(J,2)	Species mass fraction upstream of region 2	1-10 11-20 ⋮	7F10.4
ALPUP(J,3)	" " " " " " " region 3	1-10 11-20 ⋮	7F10.4

Card No. 18

SYMBOL	DESCRIPTION	COLS.	FORMAT
ITYPE	1 uniform flow in region 1 2 nonuniform flow in region 1	1-5	I5

Card No. 19

SYMBOL	DESCRIPTION	COLS.	FORMAT
NLO(1)	Lower index number for storage of data in region 1	1-5	I5
NOP(1)	Upper " " " " " region 1	6-10	
NLO(2)	Lower " " " " " region 2	11-15	
NOP(2)	Upper " " " " " region 2	16-20	
NLO(3)	Lower " " " " " region 3	21-25	
NOP(3)	Upper " " " " " region 3	26-30	

Initial Profile

FORMAT I - If ISTART = 0 the initial profile is read in as follows

Card No. 20

SYMBOL	DESCRIPTION	COLS.	FORMAT
Y(I)	Y coordinatss of data line in region 1 (ft)	1-10	7F10.4
	(NOP(I) - NLO(I) + 1)/, cards required	11-20	

Card No. 21

SYMBOL	DESCRIPTION	COLS.	FORMAT
P(I)	Pressure at above y-coordinates (psf)	1-10	7F10.4
T(I)	Temperature " " " " (^oK)	11-20	
Q(I)	Velocity " " " "(ft/sec)	21-30	
TH(I)	Flow angle " " " (degrees)	31-40	
	NOP(I) - NLO(I) + 1 cards required		

Card No. 22

SYMBOL	DESCRIPTION	COLS.	FORMAT
ALP(1,I)	Mass fraction of H at above y-coordinates in region 1	1-10	7F10A
ALP(2,I)	" " " O " " "	11-20	
ALP(3,I)	" " " H_2O " "	21-30	
ALP(4,I)	" " " H_2 " "	31-40	
ALP(5,I)	" " " O_2 " "	41-50	
ALP(6,I)	" " " OH " "	51-60	
ALP(7,I)	" " " N_2 " "	61-70	

Repeat cards 21 and 22 for regions 2 and 3.

Input region 1 CARDS 20 followed by Cards 21

" " " 2 " " " " " "

" " " 3 " " " " " "

Format II (Computer punches data according to this format) If Istart = 1, the input is

Card No. 20

SYMBOL	DESCRIPTION	COLS.	FORMAT
P(I)	Pressure at y in Region I (psf)	1-10	7F10.6
T(I)	Temperature " " " (^{o}K)	11-20	
Q(I)	Velocity " " " (ft/sec)	21-30	
TH(I)	Flow Angle " " " (degrees)	31-40	
	B L A N K	41-50	
Y(I)	Y-coordinate " " (ft)	51-60	

There are $\sum_{I=1}^{3}$ (NOP(I) - NLO(I)+1) cards

Card No. 21

SYMBOL	DESCRIPTION	COLS.	FORMAT
ALP(1,I)	Mass fraction of H at Y(I) in region 1	1-10	7F10.6
ALP(2,I)	" " " O " " "	11-20	
ALP(3,I)	" " " H_2O " " "	21-30	
ALP(4,I)	" " " H_2 " " "	31-40	
ALP(5,I)	" " " O_2 " " "	41-50	
ALP(6,I)	" " " OH " " "	51-60	
ALP(7,I)	" " " N_2 " " "	61-70	

Same number of cards as card 20

Input region 3 Cards 20 followed by Card 21

THEN " 1 " " " " 21

THEN " 2 " " " " 21

Table 3 Sample Input Cards

Card No.							
1	0 1 10	4	0	1	1		
2	4	40 148					
3	.3	.325	.35	.375	.40	.475	.50
	.55	.60	.65	.70	.75	.80	.85
4	.75	1.0	.000001	.00001	.005		
5	8.	5.					
6	.0	.08	.10	.12	.14	.2	.3
	1.						
7	.0						
8	-10.	-11.	-13.	-13.	-13.	-10.	-5.
	-25.						
9	.0	1.0	2.0	3.0	4.0		
10	10.						
11	.0	.0	.0	.0	.0		
12	.0001	.00001	.0001	.0001			
13	21.5	21.5	.032	.002	.2753	2.	.5
14	1550.	835.	3.15	1.342	28.849		
15	1727.	860.	2.8	1.342	28.849		
16	.0	-3.	.00135	2.	.00833	5.0001	
17	.0	.0	.0	.0	.232	.000	.768
	.0	.0	.0	.0	.232	.000	.768
18	1						
19	2	5 9	13 50	192			
20	2116.	850.	5127.	.0		1.5	
	2116.	850.	5127.	.0		1.7	
	2116.	850.	5127.	.0		1.9	
	2116.	850.	5127.	.0		2.2	
21	.0	.0	.0	.0	.232	.000	.768
	.0	.0	.0	.0	.232	.000	.768
	.0	.0	.0	.0	.232	.000	.768
	.0	.0	.0	.0	.232	.000	.768
20	2116.0	900.	5200.	.0		10.	
	2116.0	900.	5200.	.0		9.8	
	2116.0	900.	5200.	.0		9.6	
	2116.0	900.	5200.	.0		9.4	
	2116.0	900.	5200.	.0		9.2	
	2116.0	900.	5200.	-3.0			
21	.0	.0	.0	.0	.232	.0	.768
	.0	.0	.0	.0	.232	.0	.768
	.0	.0	.0	.0	.232	.0	.768
	.0	.0	.0	.0	.232	.0	.768
	.0	.0	.0	.0	.232	.0	.768

Table 3 Sample Input Cards Region 3

Card 20

INPUT DATA

	P	T	G	THETA	Y
50	.161878E+04	.472295E+03	.962542E+04	-.110616E+02	-.141000E-01
51	.1[illegible]1337E+04	.492651E+03	.941072E+04	-.105264E+02	-.500000E-02
52	.159360E+04	.580845E+03	.868667E+04	-.100837E+02	.620000E-02
53	.162286E+04	.881114E+03	.752413E+04	-.853350E+01	.216000E-01
54	.160431E+04	.151730E+04	.668093E+04	-.817460E+01	.345000E-01
55	.157931E+04	.211469E+04	.628407E+04	-.976780E+01	.428000E-01
56	.156042E+04	.261009E+04	.605527E+04	-.117698E+02	.500000E-01
57	.163779E+04	.287623E+04	.584449E+04	-.120026E+02	.581000E-01
58	.177915E+04	.294201E+04	.564362E+04	-.105408E+02	.668000E-01
59	.192375E+04	.298115E+04	.548605E+04	-.892710E+01	.750000E-01
60	.205479E+04	.301795E+04	.536062E+04	-.747740E+01	.828000E-01
61	.216958E+04	.304547E+04	.525697E+04	-.615650E+01	.904000E-01
62	.226707E+04	.306244E+04	.517287E+04	-.490330E+01	.977000E-01
63	.234483E+04	.307296E+04	.510814E+04	-.372420E+01	.104800E+00
64	.240441E+04	.308264E+04	.505923E+04	-.261260E+01	.111700E+00
65	.244878E+04	.309457E+04	.502158E+04	-.159200E+01	.118500E+00
66	.248164E+04	.310823E+04	.499227E+04	-.693800E+00	.125100E+00
67	.250698E+04	.312144E+04	.496915E+04	.630000E-01	.131700E+00
68	.252636E+04	.313276E+04	.494964E+04	.668900E+00	.138200E+00
69	.254827E+04	.314165E+04	.493137E+04	.111890E+01	.144600E+00
70	.256757E+04	.314842E+04	.491321E+04	.142140E+01	.151000E+00
71	.258550E+04	.315291E+04	.489554E+04	.160290E+01	.157200E+00
72	.260057E+04	.315409E+04	.487940E+04	.169910E+01	.163400E+00
73	.261189E+04	.314872E+04	.486549E+04	.173270E+01	.169400E+00
74	.261964E+04	.312356E+04	.485498E+04	.167820E+01	.175400E+00
75	.262406E+04	.304785E+04	.485343E+04	.143640E+01	.181300E+00
76	.262725E+04	.286092E+04	.486974E+04	.933300E+00	.186700E+00
77	.263116E+04	.254071E+04	.490730E+04	.378200E+00	.191500E+00
78	.262787E+04	.214573E+04	.495905E+04	.148500E+00	.195600E+00
79	.253274E+04	.168669E+04	.502472E+04	.593500E+00	.200100E+00
80	.249205E+04	.102358E+04	.509866E+04	.161340E+01	.211000E+00
81	.234558E+04	.931335E+03	.514089E+04	.135440E+01	.220600E+00
82	.224374E+04	.914548E+03	.516696E+04	.777400E+00	.230300E+00
83	.217721E+04	.906951E+03	.518395E+04	.366700E+00	.240100E+00
84	.214128E+04	.902905E+03	.519330E+04	.146300E+00	.250000E+00
85	.212528E+04	.901076E+03	.519752E+04	.486000E-01	.260000E+00
86	.211958E+04	.900416E+03	.519904E+04	.101000E-01	.270000E+00
87	.211840E+04	.900276E+03	.519936E+04	-.660000E-02	.280000E+00
88	.211896E+04	.900342E+03	.519923E+04	-.173000E-01	.290000E+00
89	.211992E+04	.900526E+03	.519905E+04	-.254000E-01	.300000E+00
90	.212049E+04	.901060E+03	.519947E+04	-.296000E-01	.310000E+00
91	.212152E+04	.899197E+03	.520425E+04	-.354000E-01	.326000E+00
92	.212019E+04	.911227E+03	.520984E+04	-.453000E-01	.347800E+00

Table 3 Sample Input Cards - Region 3

Species

Card 21

INPUT DATA

		ALP1	ALP2	ALP3	ALP4	ALP5	ALP6
50	.164236E-02	.[illegible]1000E-05	.771302E-02	.855397E+00	.256588E-01	.780000E-06	.113582E+00
51	.198913E-02	.[illegible]7000E-05	.114067E-01	.813577E+00	.310774E-01	.230000E-06	.143948E+00
52	.328375E-02	.[illegible]6000E-06	.282199E-01	.669272E+00	.471148E-01	.154000E-05	.252107E+00
53	.693313E-02	.[illegible]7500E-04	.866358E-01	.395152E+00	.541208E-01	.792800E-04	.457968E+00
54	.936815E-02	.[illegible]1510E-03	.183006E+00	.180107E+00	.114627E-01	.169302E-02	.614041E+00
55	.933729E-02	.[illegible]5979E-02	.287144E+00	.814121E-01	.266482E-02	.840201E-02	.688380E+00
56	.729032E-02	.[illegible]3160E-01	.198826E+00	.296939E-01	.880201E-02	.229521E-01	.731114E+00
57	.382837E-02	.[illegible]7163E-01	.129296E+00	.816803E-02	.422253E-01	.345517E-01	.755214E+00
58	.210259E-02	.[illegible]9568E-01	.855390E-01	.310638E-02	.801058E-01	.327803E-01	.764407E+00
59	.161296E-02	.[illegible]7780E-01	.696656E-01	.210302E-02	.957652E-01	.310137E-01	.767062E+00
60	.147499E-02	.[illegible]9067E-01	.650219E-01	.187385E-02	.100212E+00	.307388E-01	.767773E+00
61	.142030E-02	.[illegible]8516E-01	.636575E-01	.180686E-02	.101460E+00	.308542E-01	.767949E+00
62	.138308E-02	.[illegible]6528E-01	.630982E-01	.176764E-02	.102183E+00	.308957E-01	.767990E+00
63	.135401E-02	.[illegible]5028E-01	.627682E-01	.173717E-02	.102775E+00	.306653E-01	.767998E+00
64	.134256E-02	.[illegible]4720E-01	.625937E-01	.172645E-02	.102944E+00	.309215E-01	.768000E+00
65	.135464E-02	.[illegible]6746E-01	.625659E-01	.174242E-02	.102508E+00	.311545E-01	.768000E+00
66	.138300E-02	.[illegible]369E-01	.626418E-01	.177710E-02	.101654E+00	.315067E-01	.768000E+00
67	.141325E-02	.[illegible]4051E-01	.627629E-01	.181448E-02	.100754E+00	.318495E-01	.768000E+00
68	.143714E-02	.[illegible]6721E-01	.628854E-01	.184260E-02	.100068E+00	.320945E-01	.768000E+00
69	.145022E-02	.[illegible]8252E-01	.629831E-01	.185861E-02	.996544E-01	.322285E-01	.768000E+00
70	145634E-02	.[illegible]9087E-01	.630412E-01	.186564E-02	.994450E-01	.322823E-01	.768000E+00
71	145831E-02	.[illegible]9630E-01	.630513E-01	.186705E-02	.993760E-01	.322818E-01	.768000E+00
72	145652E-02	.[illegible]9746E-01	.630031E-01	.186198E-02	.994980E-01	.322067E-01	.768000E+00
73	.143843E-02	.[illegible]8172E-01	.628543E-01	.183365E-02	.100133E+00	.319239E-01	.768000E+00
74	.137592E-02	.[illegible]1563E-01	.624167E-01	.174574E-02	.102269E+00	.310360E-01	.768000E+00
75	.123357E-02	.[illegible]5159E-01	.610127E-01	.153744E-02	.107966E+00	.287351E-01	.768000E+00
76	.103030E-02	.[illegible]8836E-01	.570010E-01	.119410E-02	.119743E+00	.241478E-01	.768000E+00
77	.829520E-03	.[illegible]9577E-01	.489617E-01	.821150E-03	.137956E+00	.174743E-01	.768000E+00
78	.659780E-03	.[illegible]5313E-01	.384035E-01	.501240E-03	.159466E+00	.104379E-01	.768000E+00
79	.482770E-03	.[illegible]4135E-01	.251995E-01	.228860E-03	.184625E+00	.405072E-02	.768000E+00
80	.105090E-03	.[illegible]5830E-02	.299369E-02	.365500E-04	.225689E+00	.268250E-03	.768000E+00
81	107500E-04	.[illegible]9080E-03	.218500E-03	.482000E-05	.231411E+00	.555700E-04	.768000E+00
82	740000E-06	.[illegible]700E-04	.110700E-04	.359000E-06	.231962E+00	.561000E-05	.768000E+00
83	.400000E-07	.[illegible]000E-06	.430000E-06	.203000E-07	.231998E+00	.350000E-06	.768000E+00
84	.110000E-09	.[illegible]00E-07	.100000E-07	.110000E-09	.232000E+00	.200000E-07	.768000E+00
85	.110000E-09	.[illegible]000E-09	.110000E-09	.110000E-09	.232000E+00	.110000E-09	.768000E+00
86	.110000E-09	.[illegible]000E-09	.110000E-09	.110000E-09	.232000E+00	.110000E-09	.768000E+00
87	.110000E-09	.[illegible]000E-09	.110000E-09	.110000E-09	.232000E+00	.110000E-09	.768000E+00
88	110000E-09	.[illegible]000E-09	.110000E-09	.110000E-09	.232000E+00	.110000E-09	.768000E+00
89	110000E-09	.[illegible]00E-09	.110000E-09	.110000E-09	.232000E+00	.110000E-09	.768000E+00
90	.110000E-09	.[illegible]00E-09	.110000E-09	.110000E-09	.232000E+00	.110000E-09	.768000E+00
91	.110000E-09	.[illegible]00E-09	.110000E-09	.110000E-09	.232000E+00	.110000E-09	.768000E+00
92	110000E-09	.[illegible]00E-09	.110000E-09	.110000E-09	.232000E+00	.110000E-09	.768000E+00

Scramjet Geometry

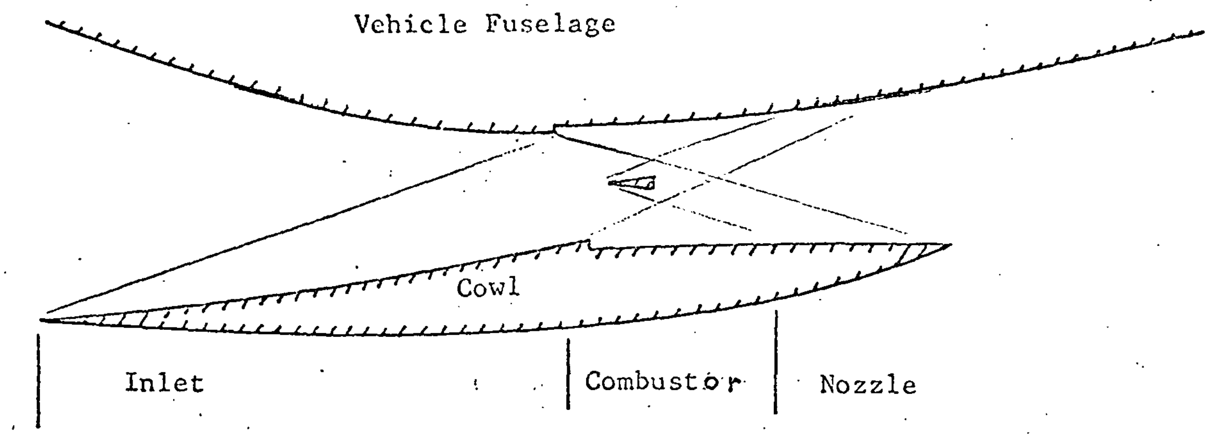


Figure 1a

Combustor Geometry

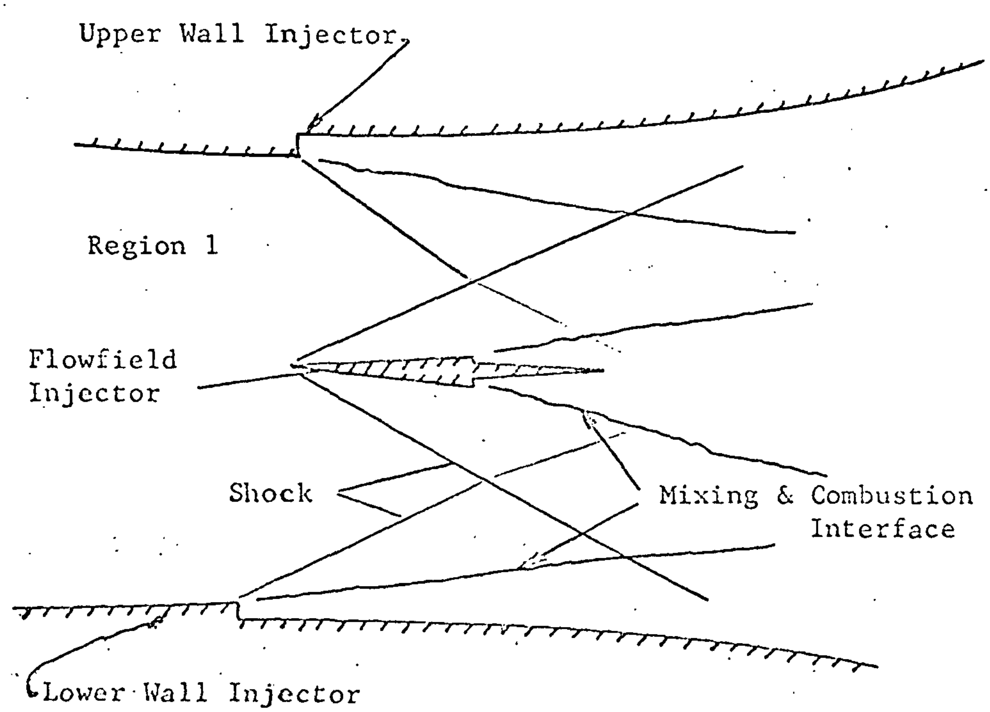
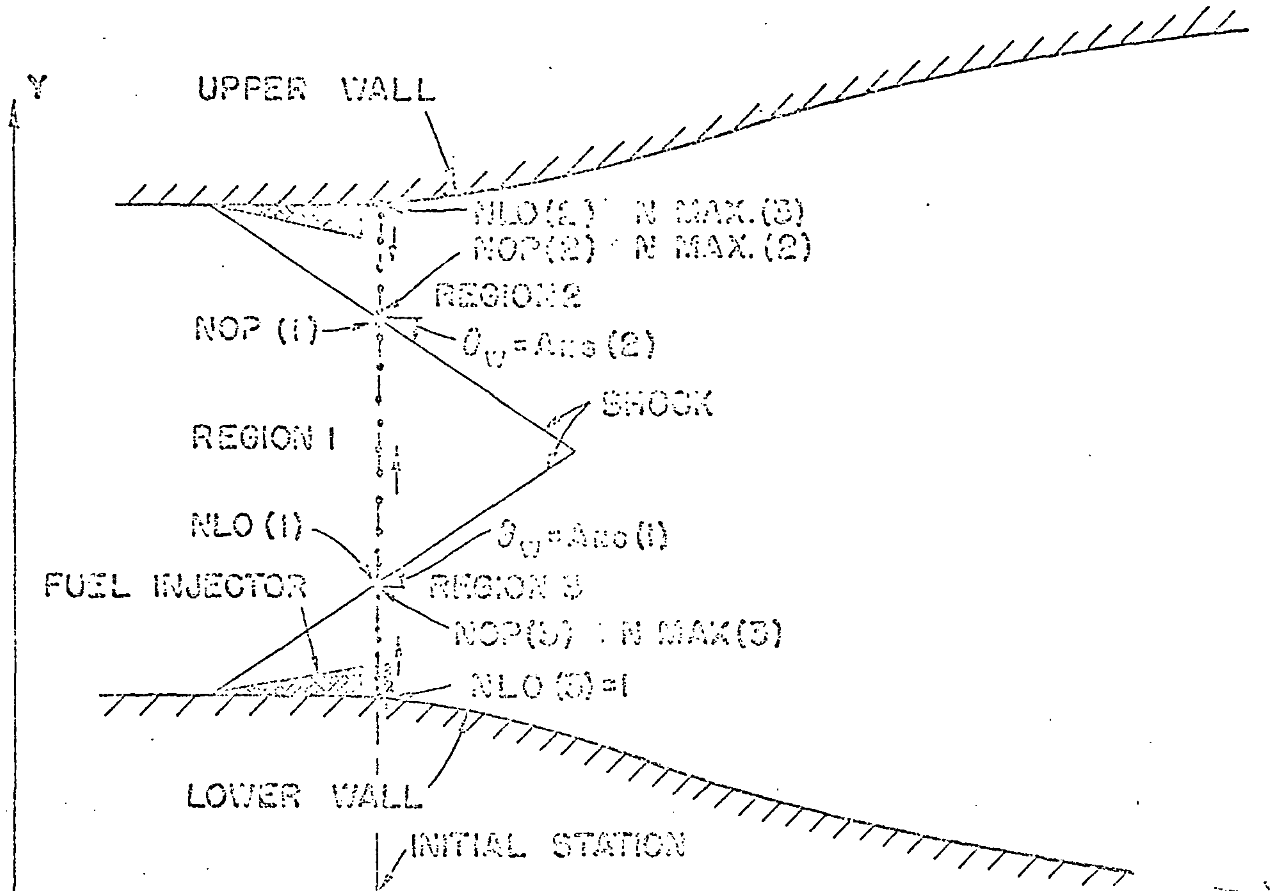
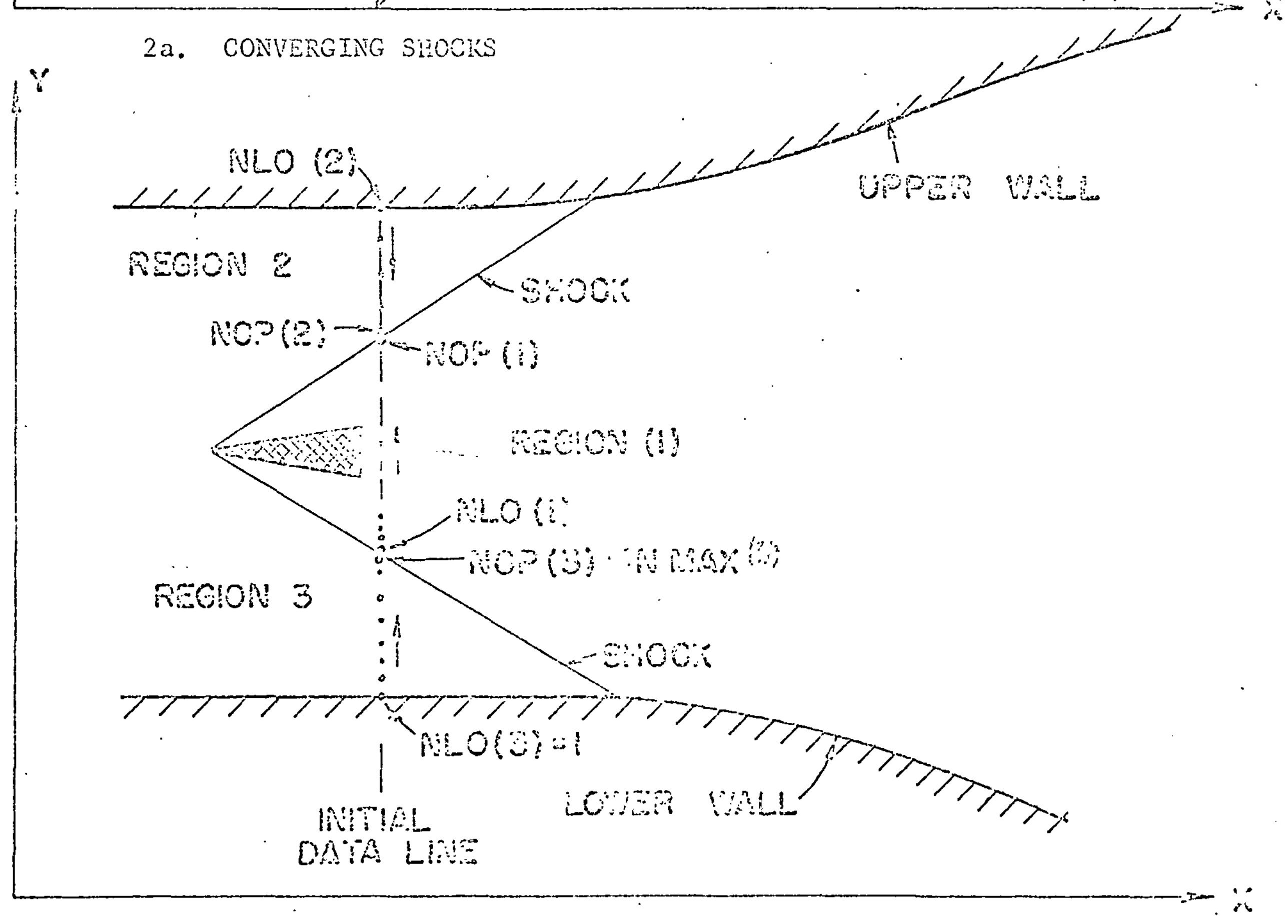


Figure 1b

Fig. 1 Simplified scramjet fuel injector arrangement



2a. CONVERGING SHOCKS



2b. DIVERGING SHOCKS

Fig. 2 Simplified Combustor Flow Field & Nomenclature

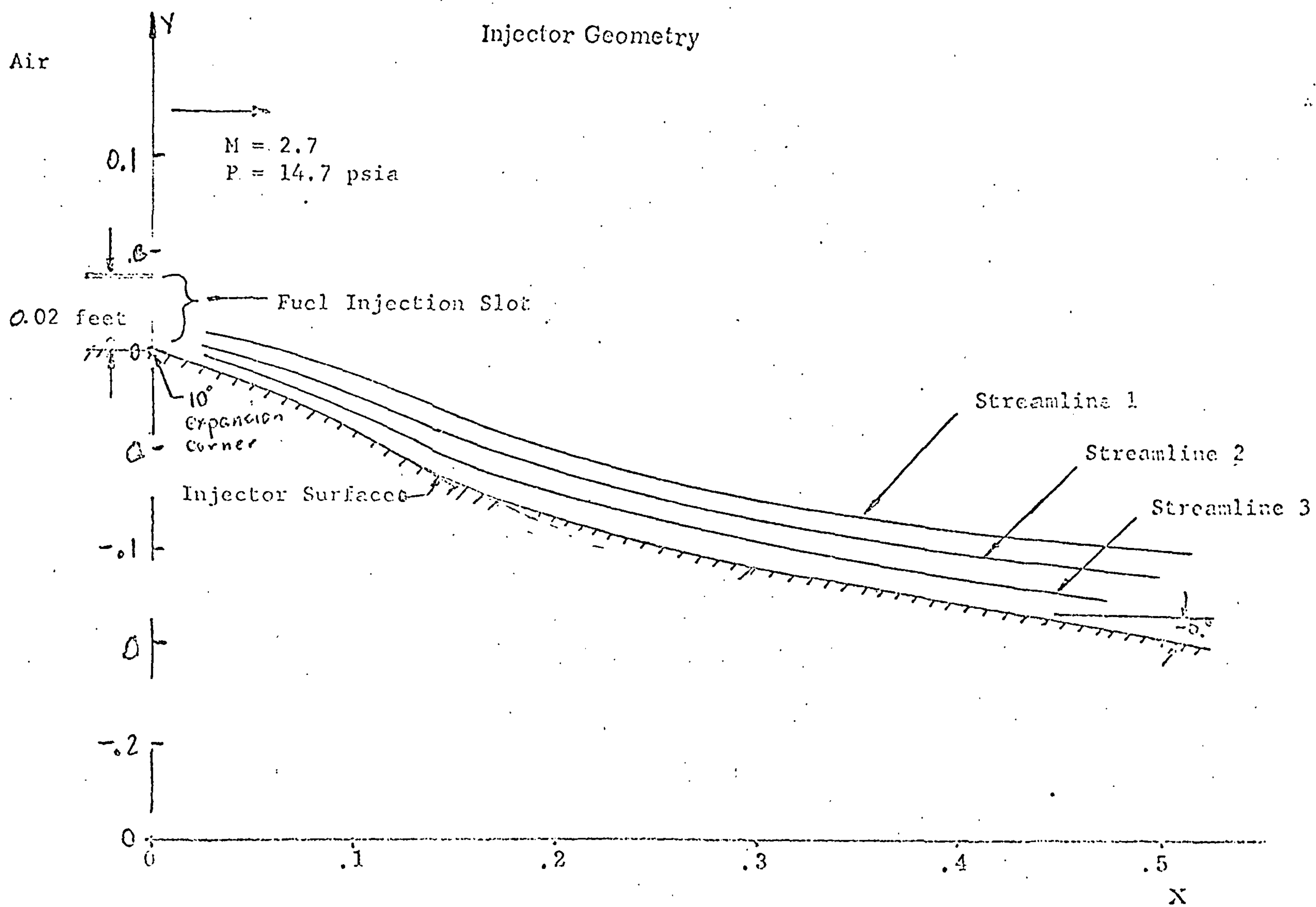


Figure 3a Fuel injector geometry

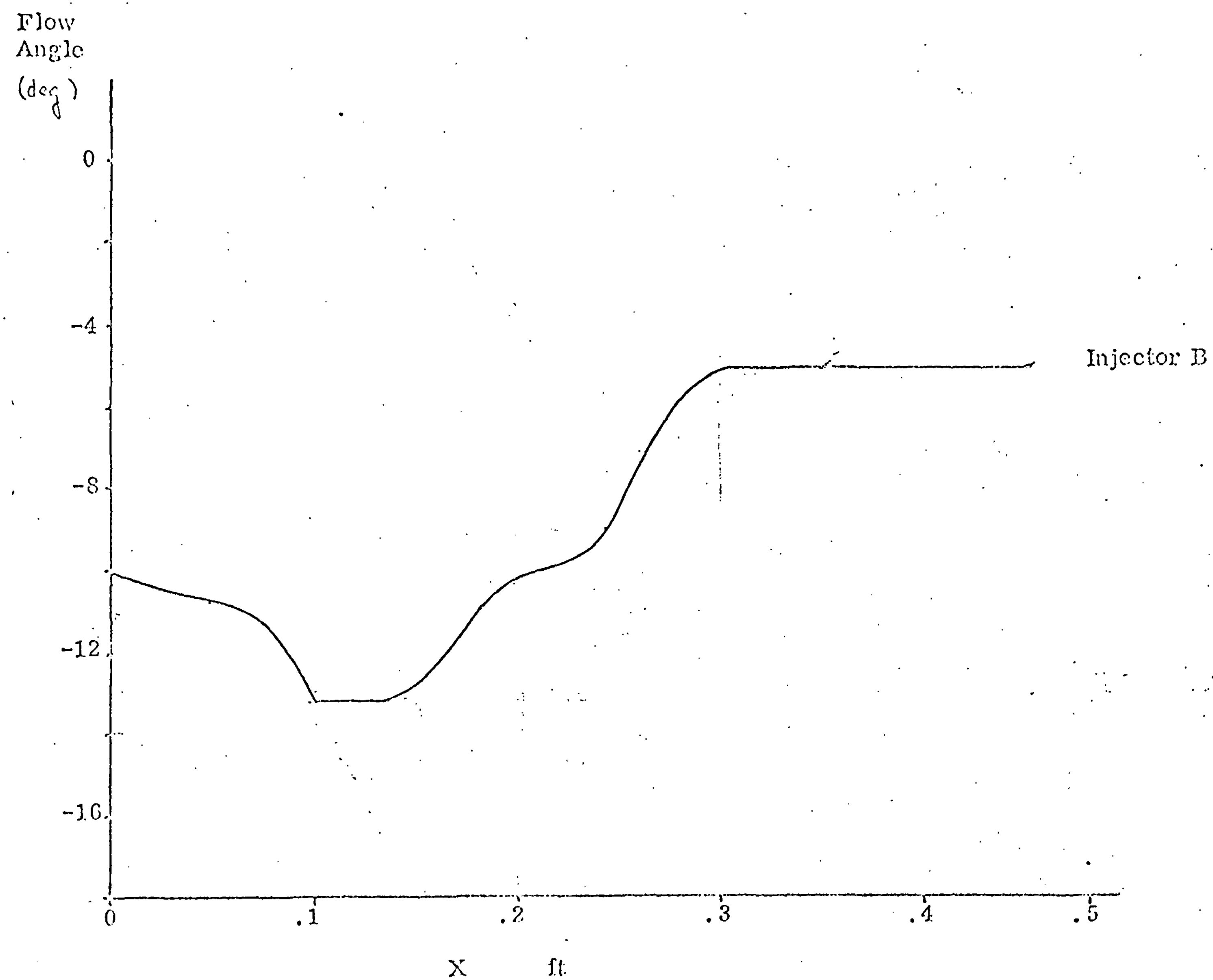


Figure 3b Local injector wall angle

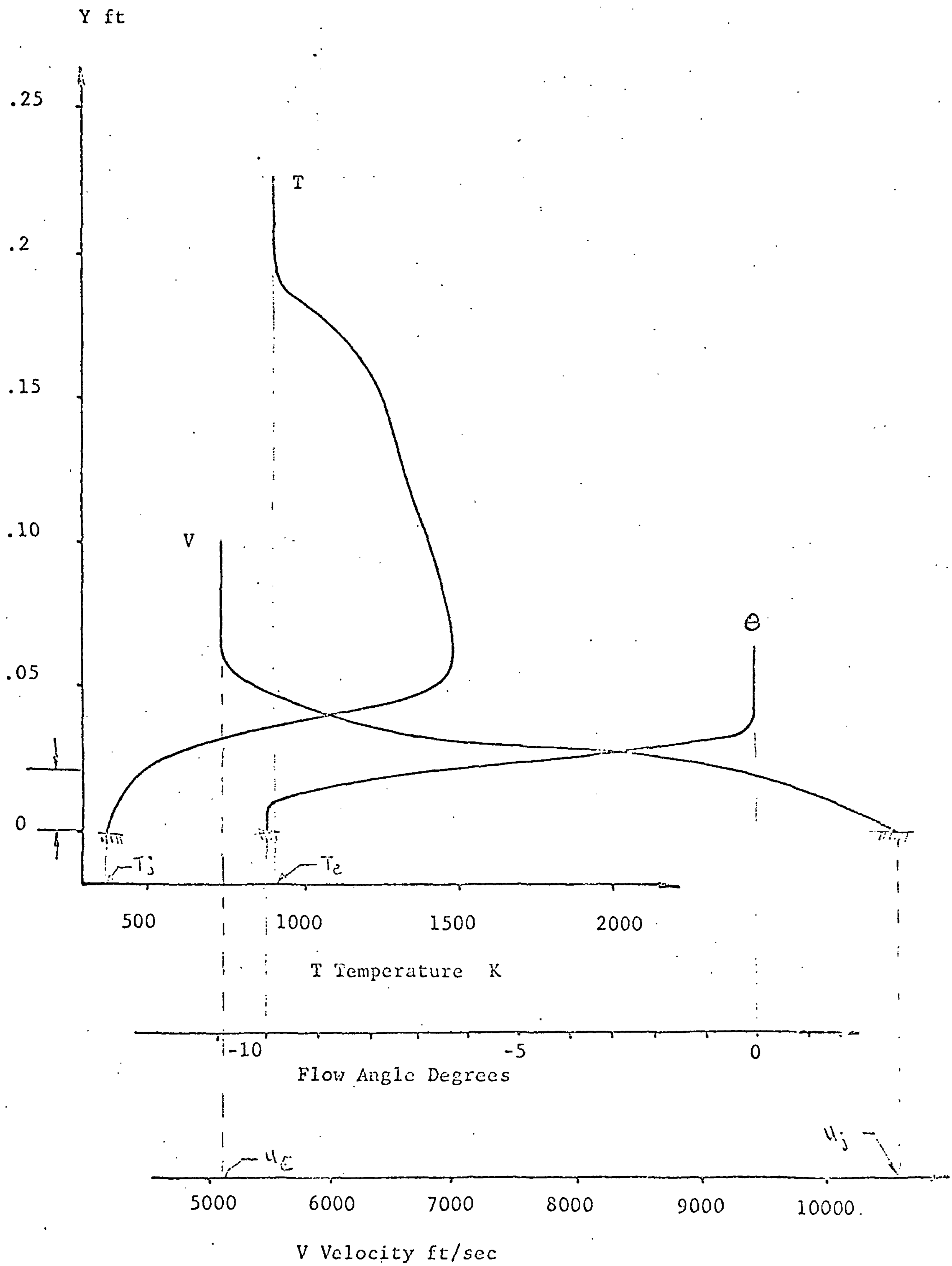


Figure 4 Initial flow profiles

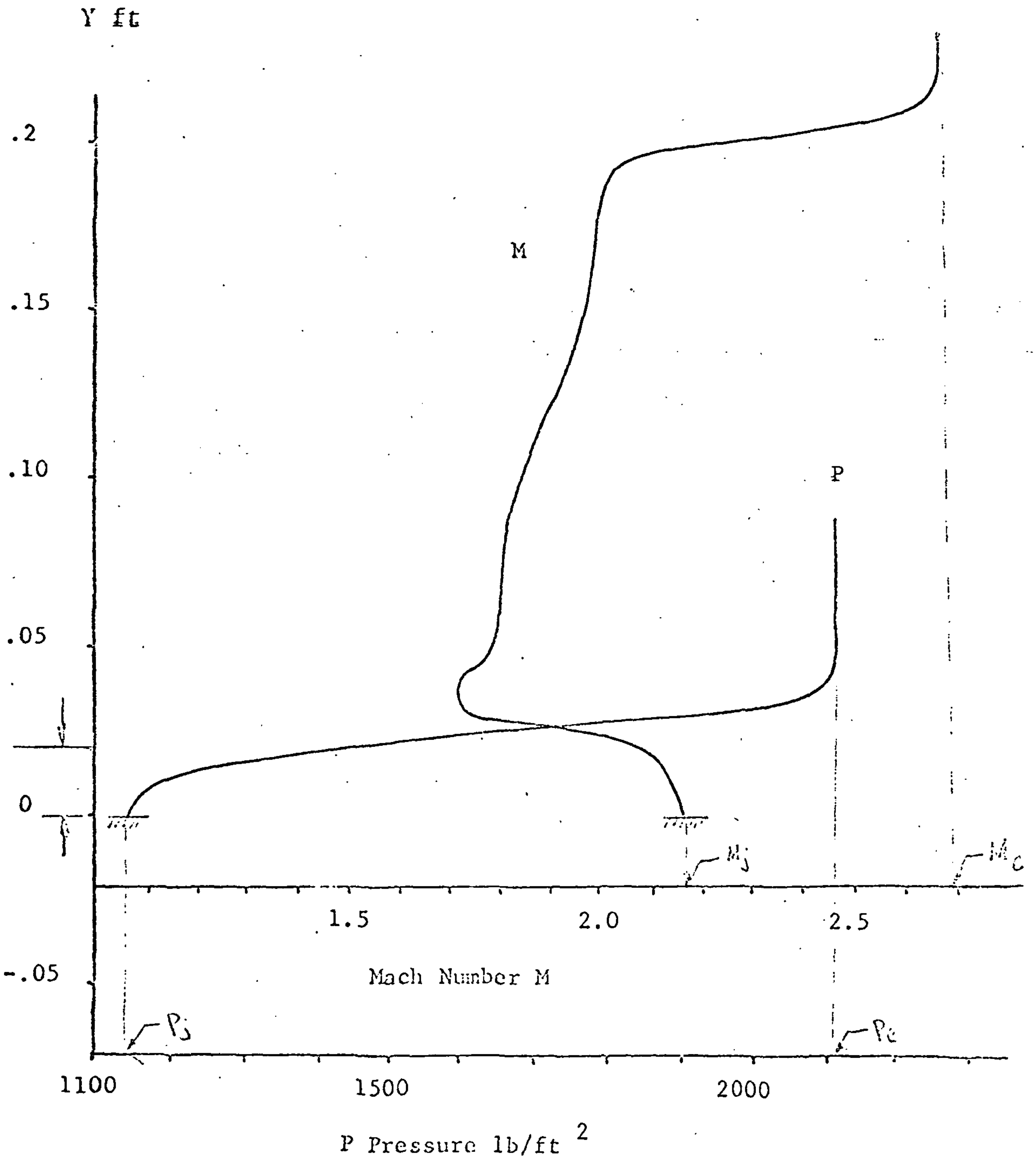


Figure 4 continued

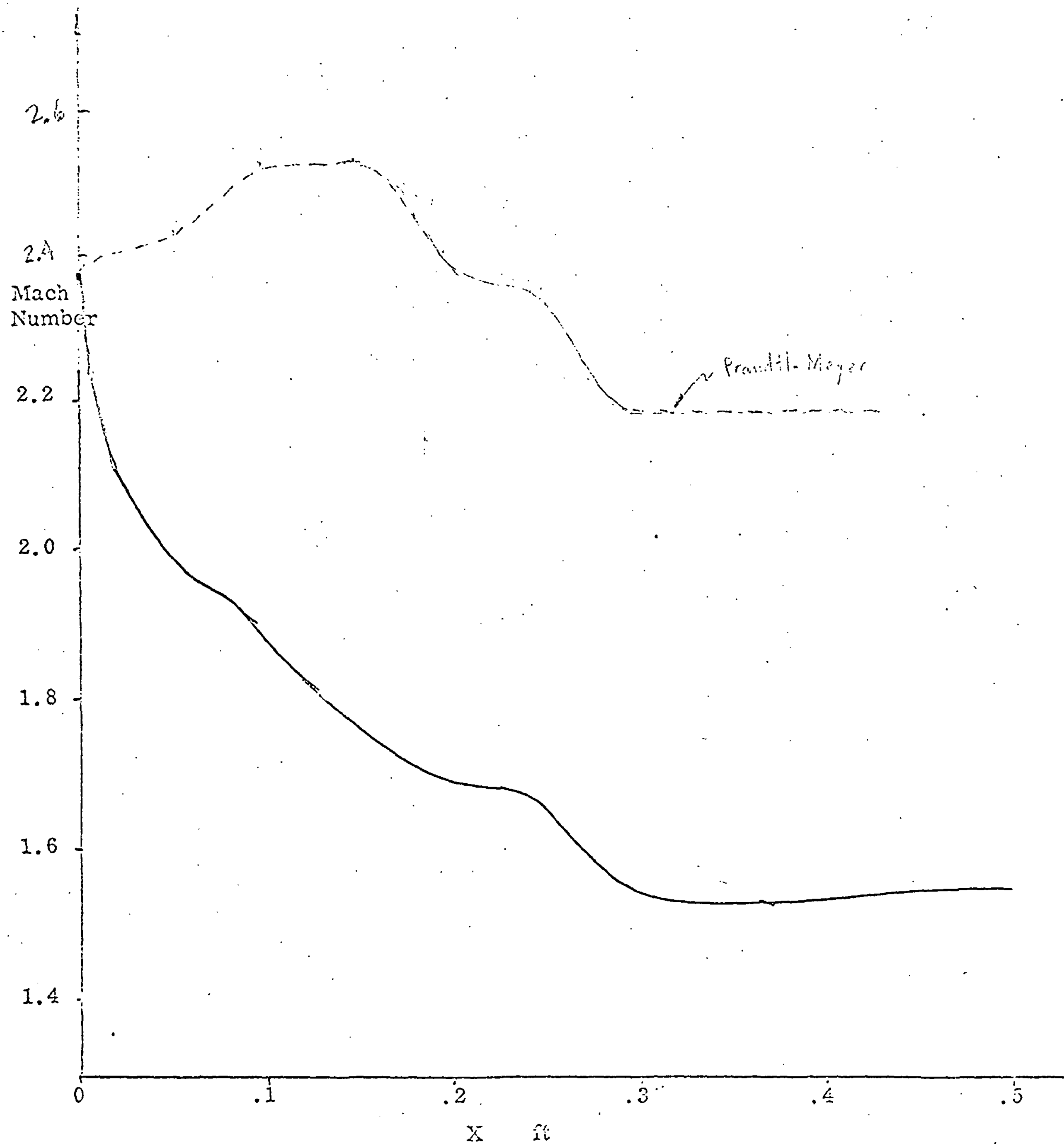


Figure 5a Flow properties along injector wall

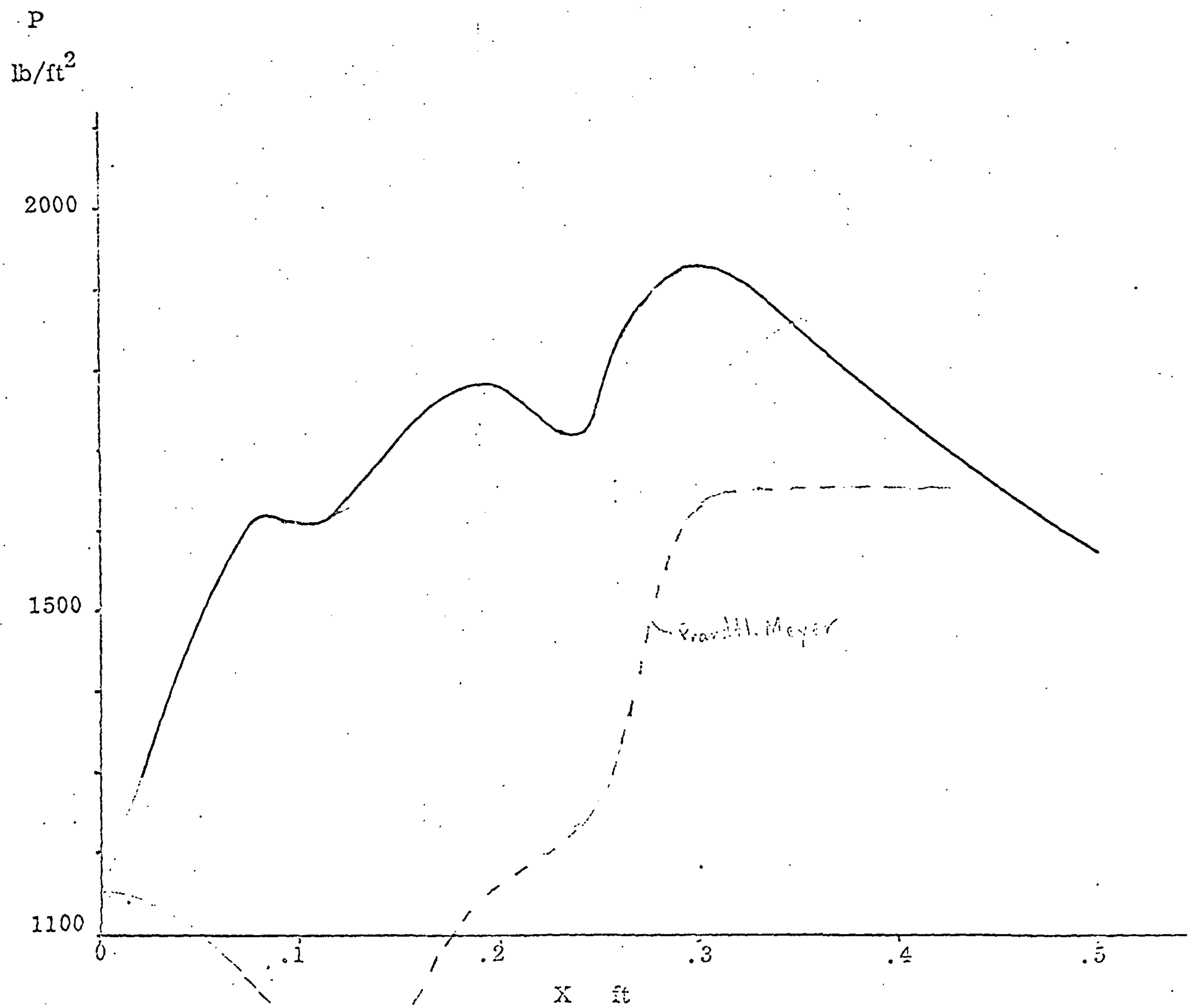


Figure 5b continued

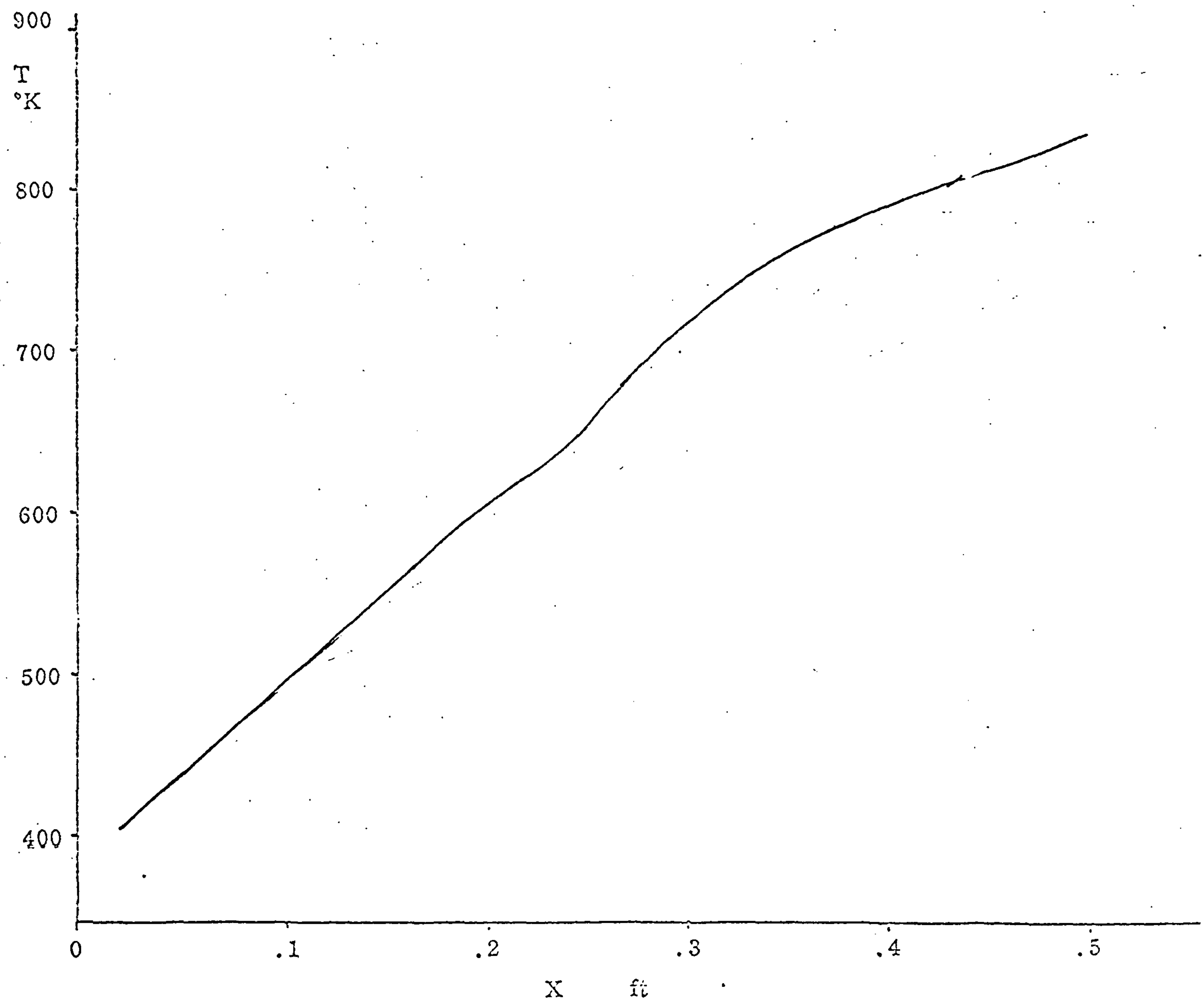


Figure 5c continued

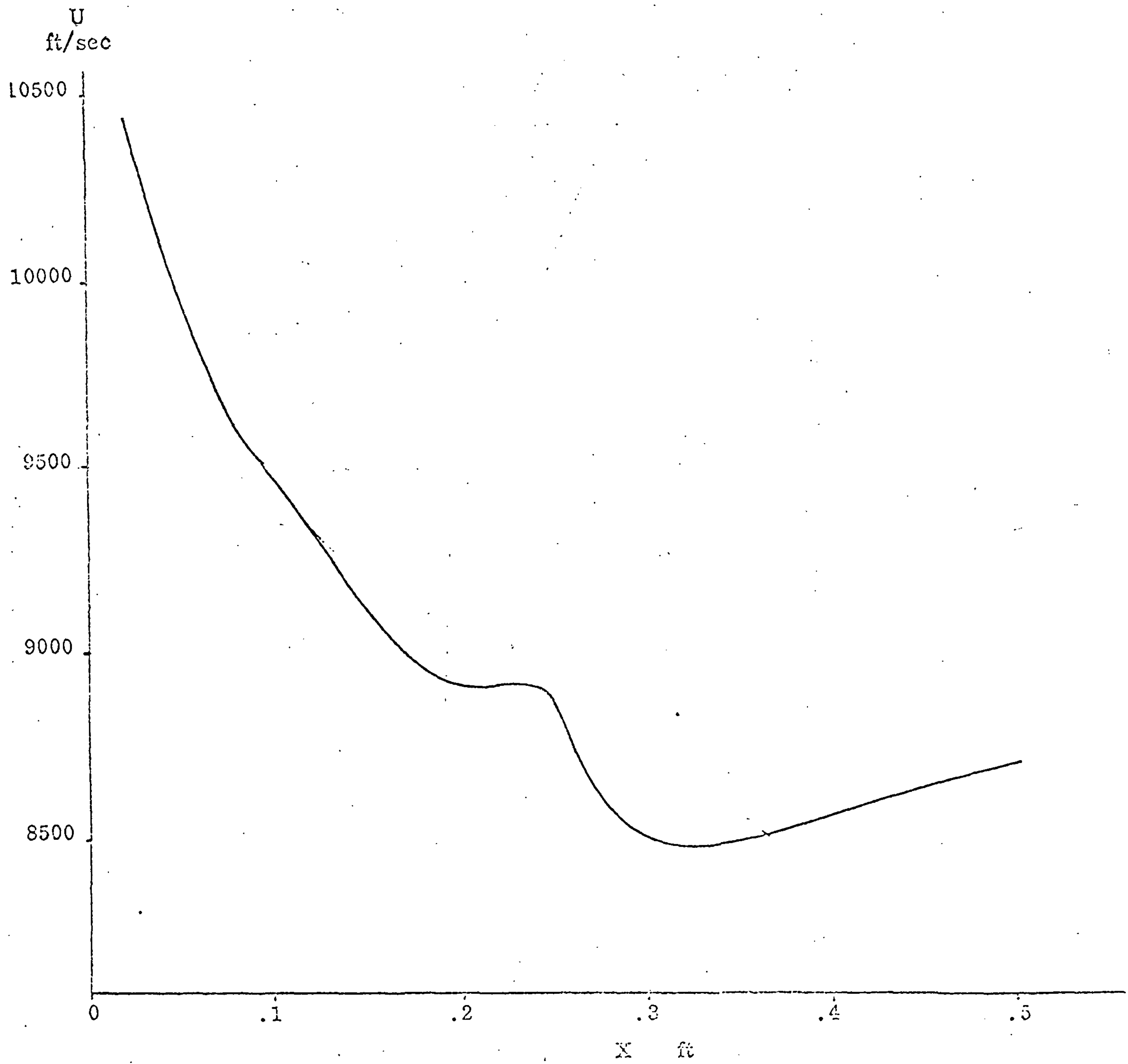


Figure 5d continued

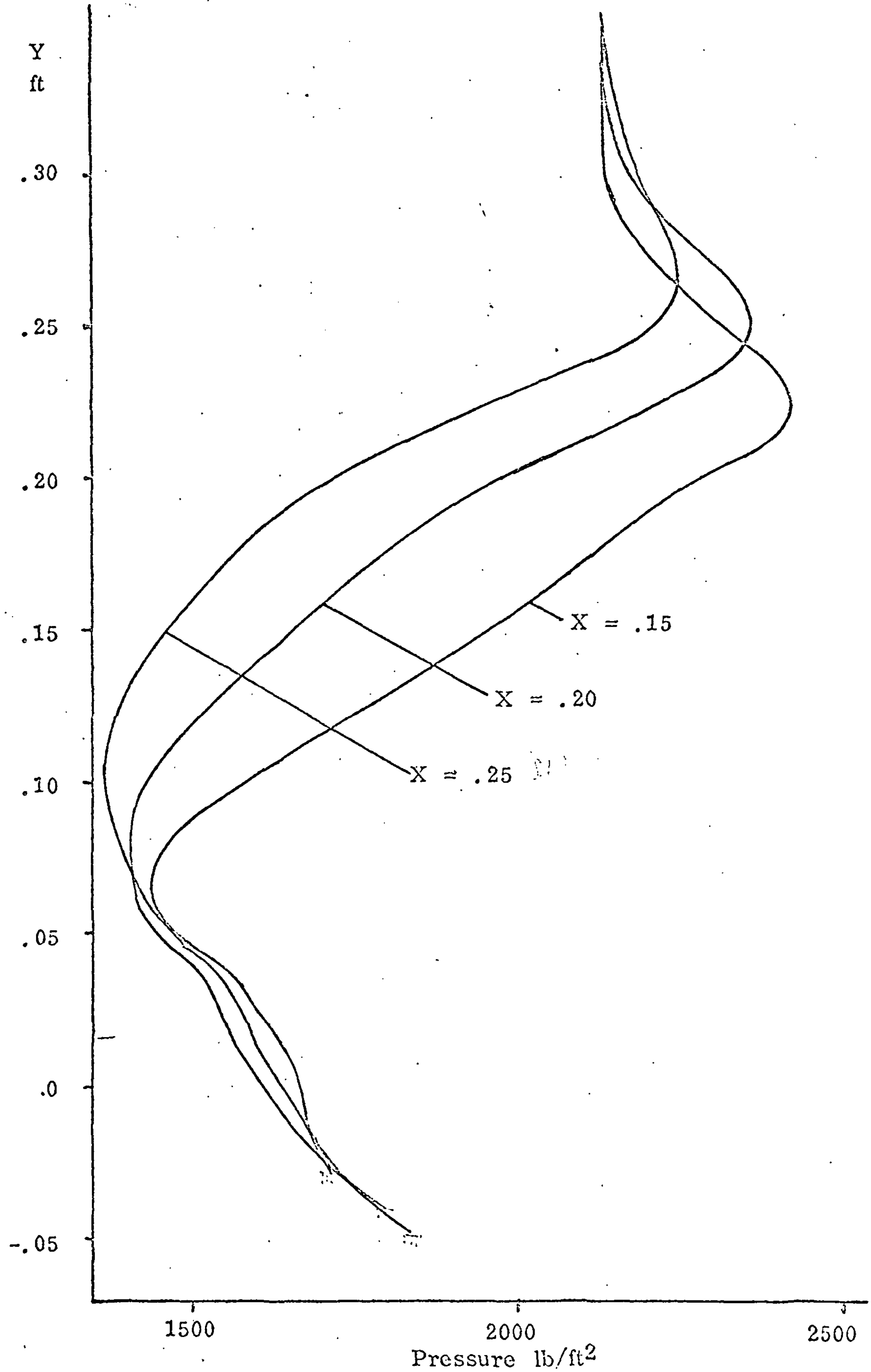
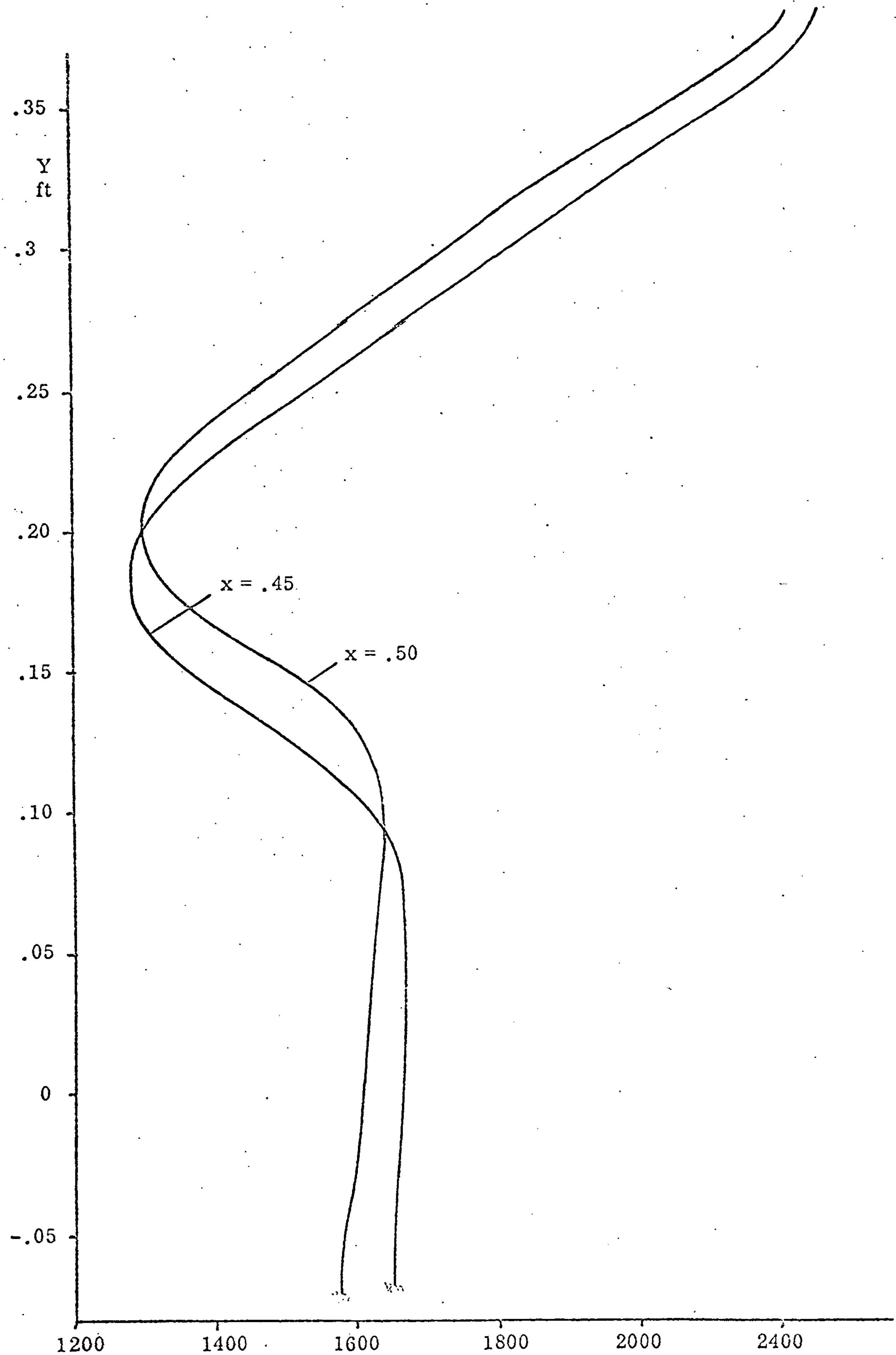


Figure 6a Flow profiles at various axial stations



Pressure lb/ft^2

Figure 6a (Cont'd)

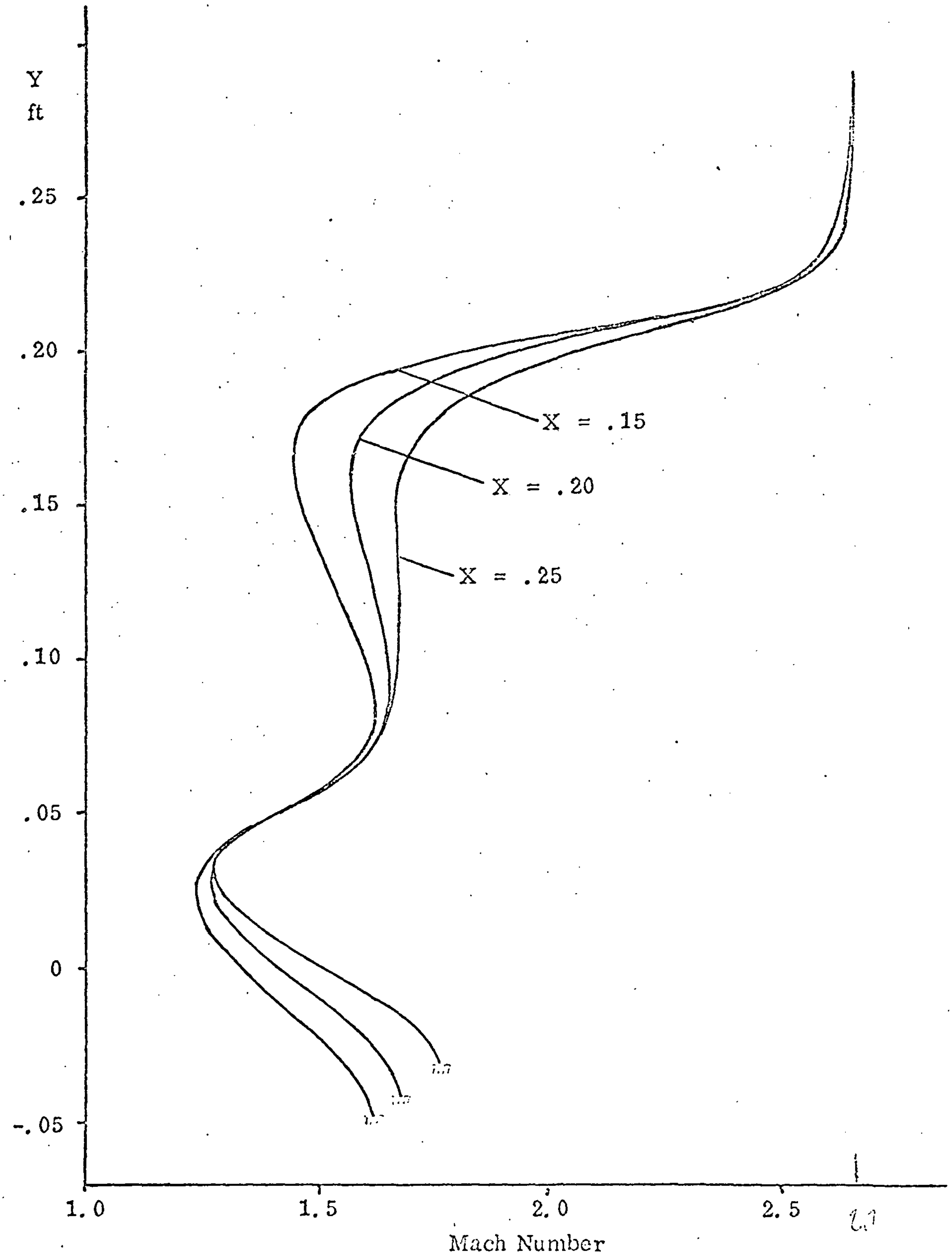


Figure 6b continued

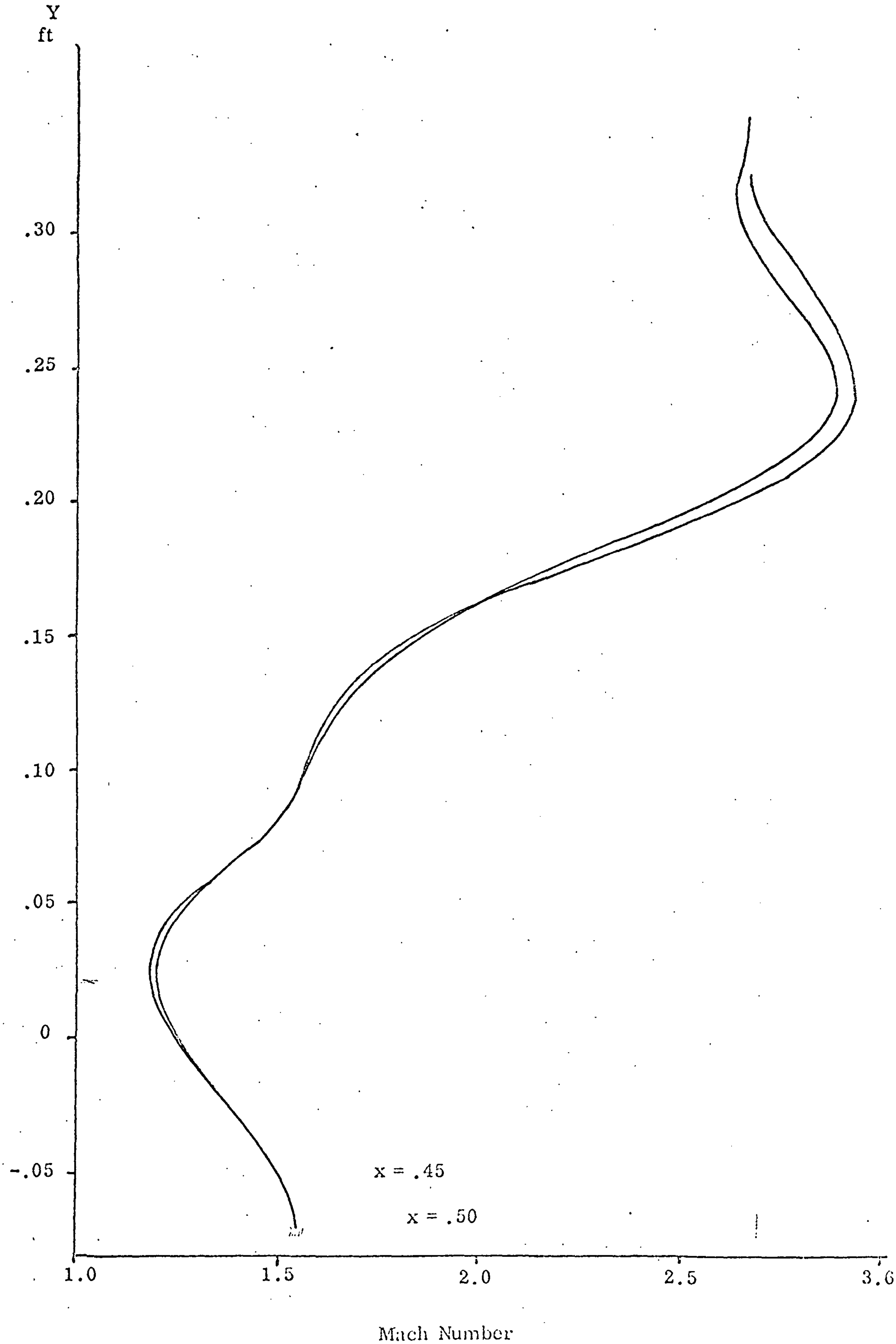


Figure 6b (Cont'd)

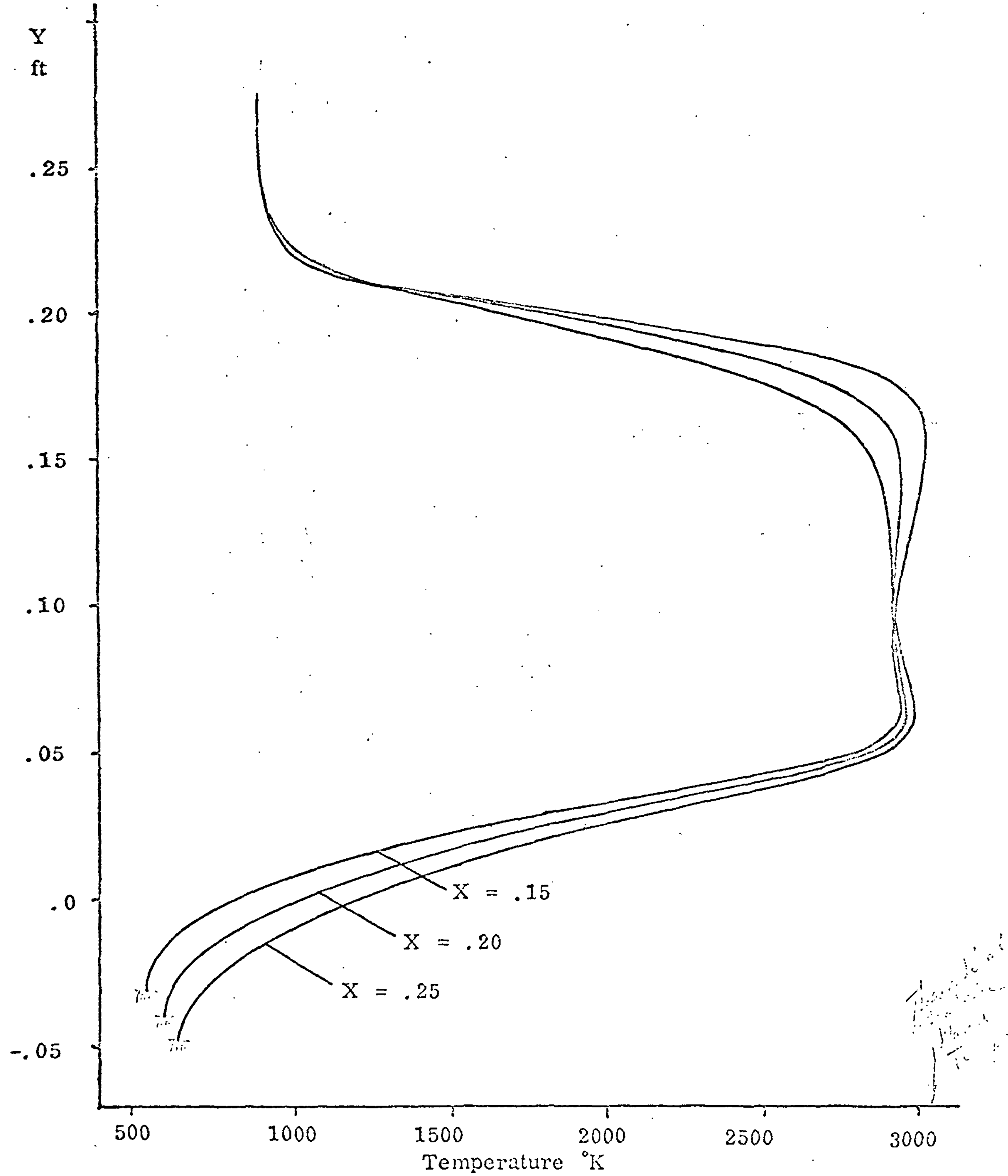


Figure 6c continued

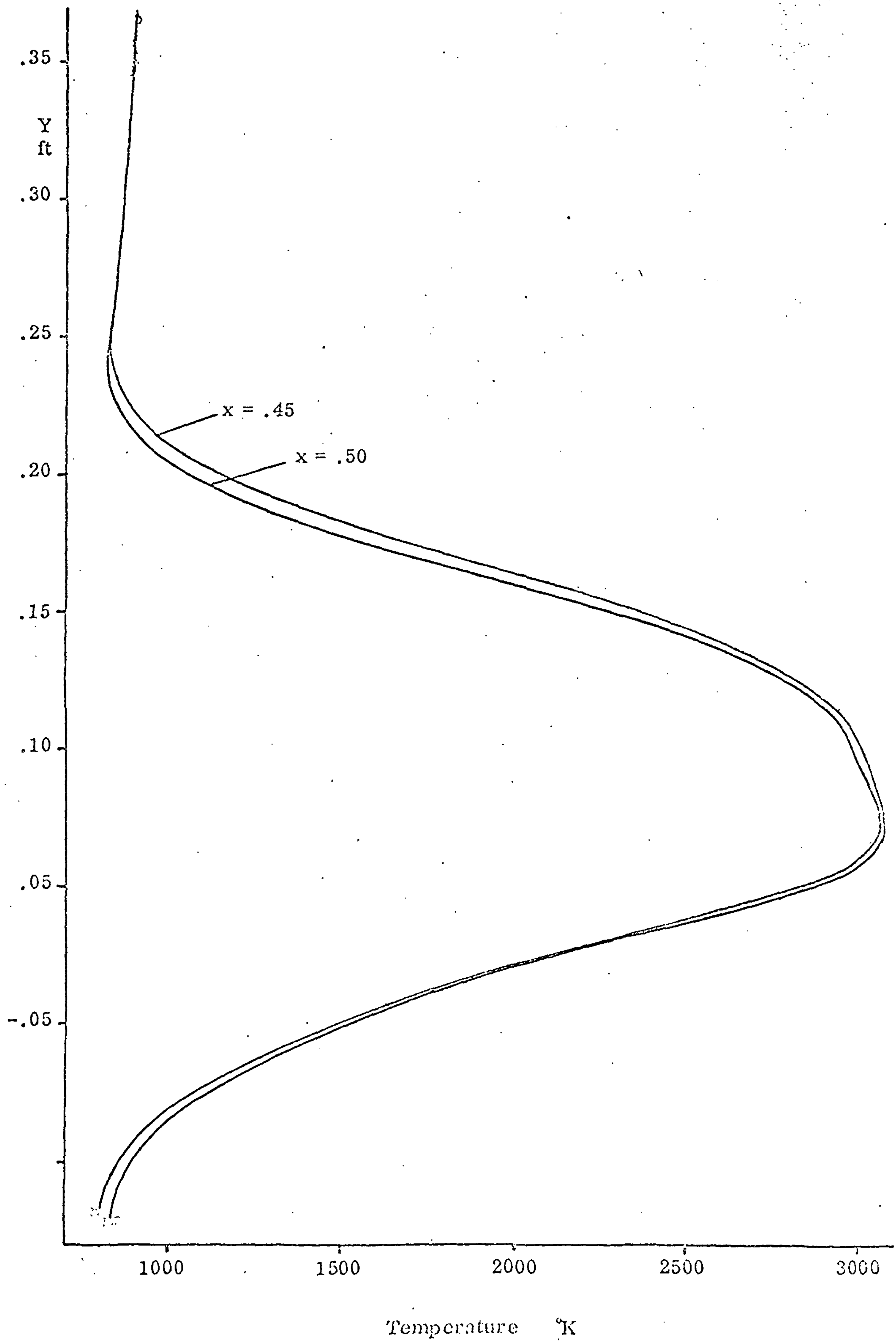


Figure 6c (Cont'd)

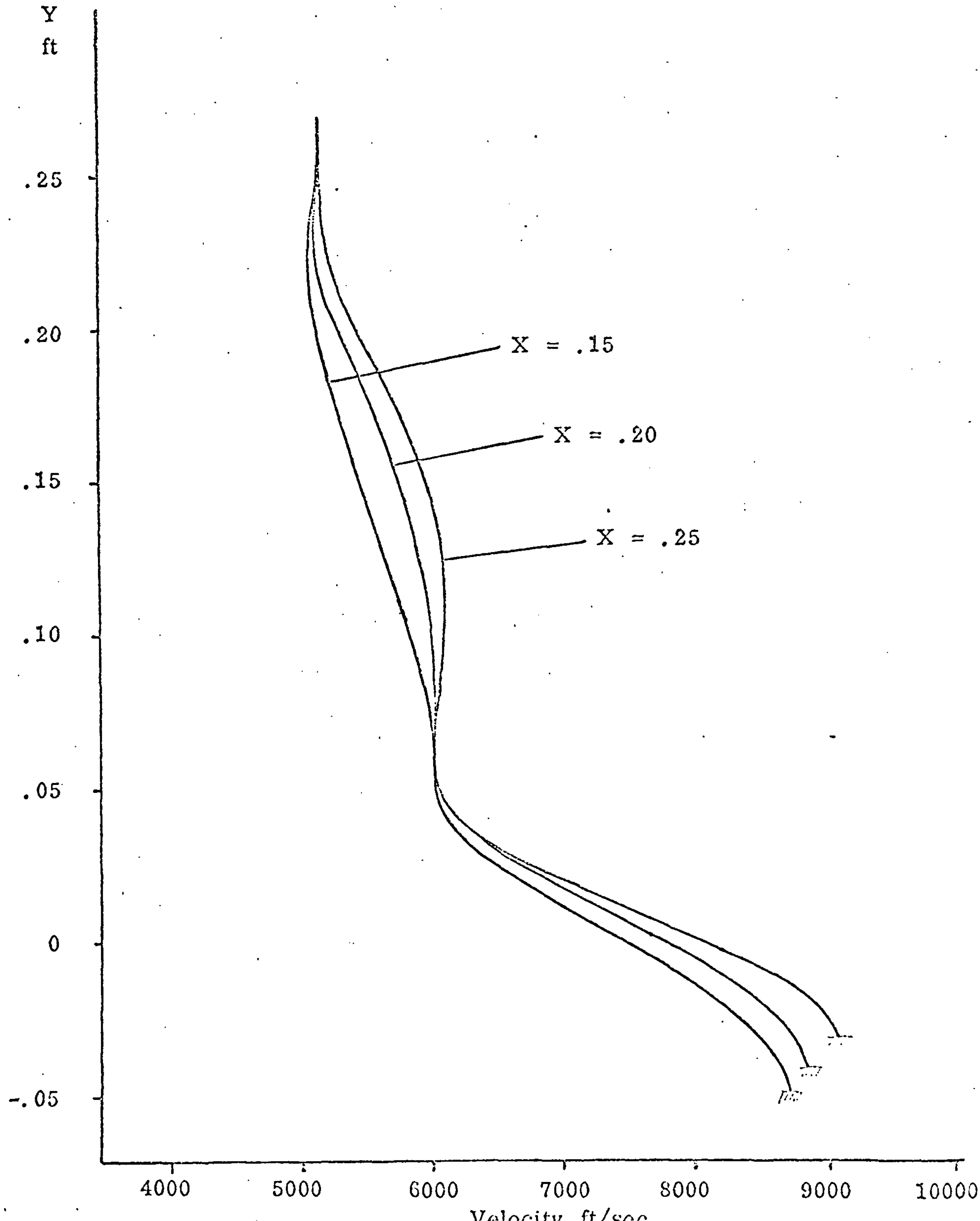


Figure 6d continued

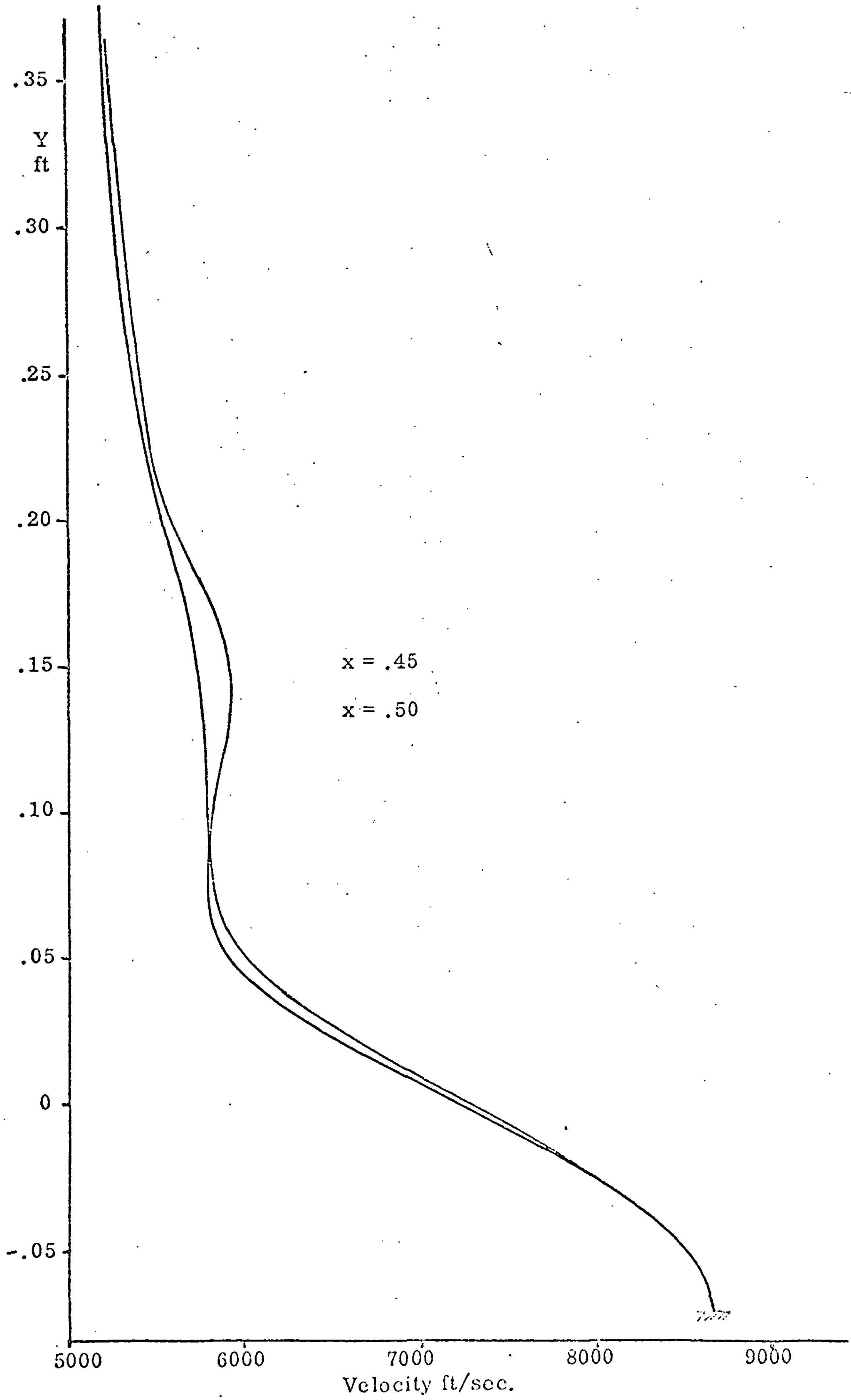


Figure 6d(Cont'd)

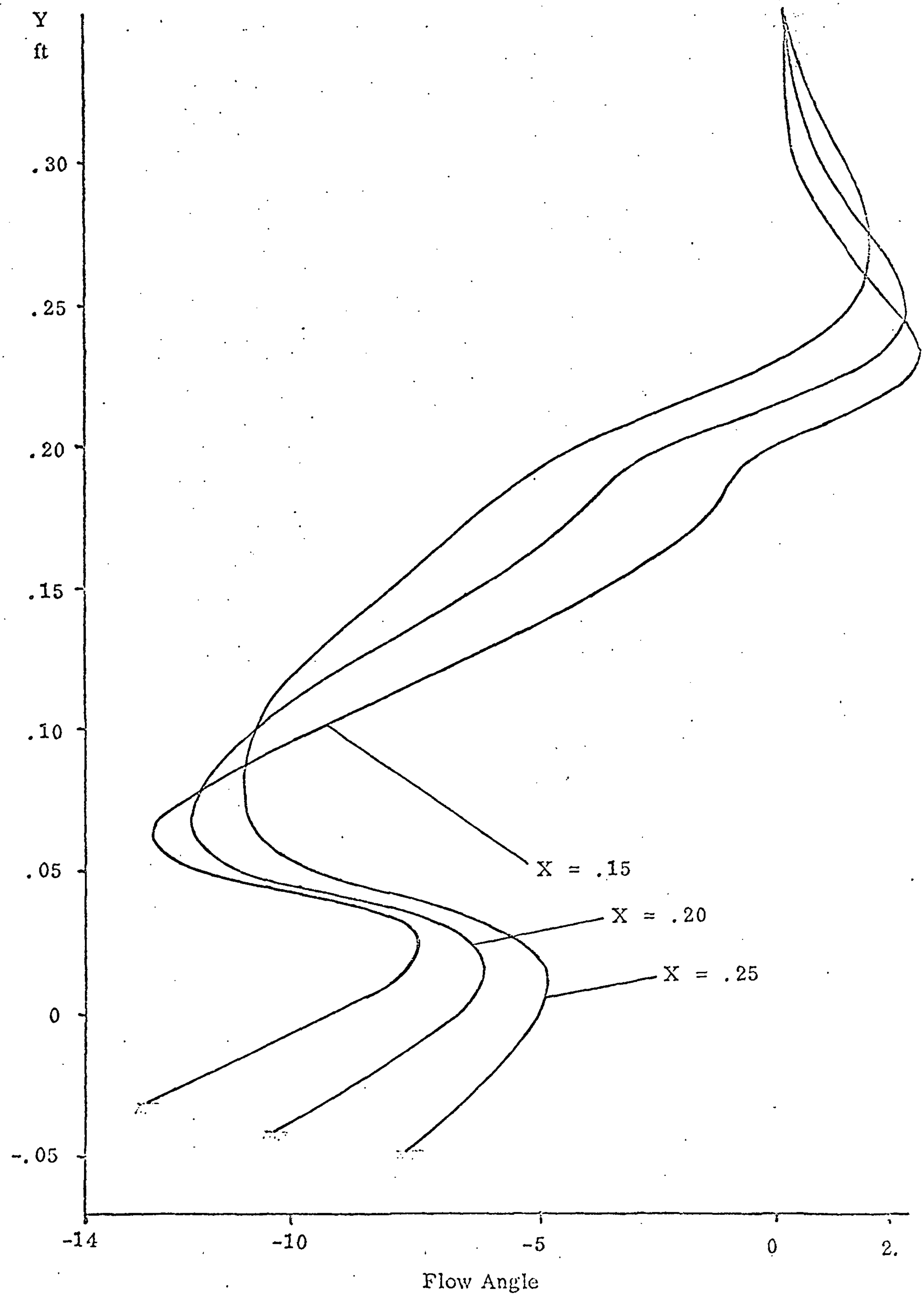
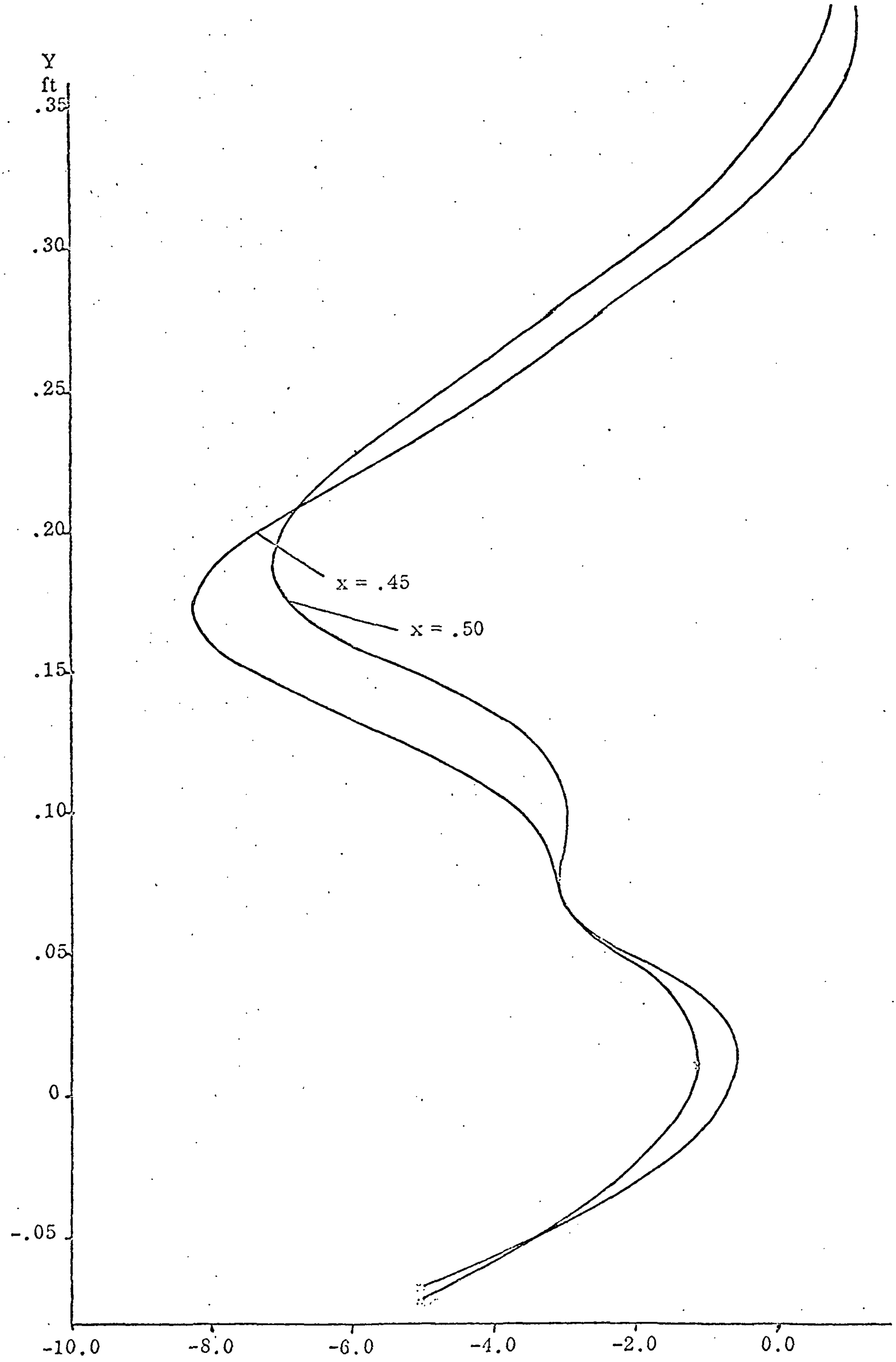


Figure 6e continued



Flow Angle
Figure 6e (Cont'd)

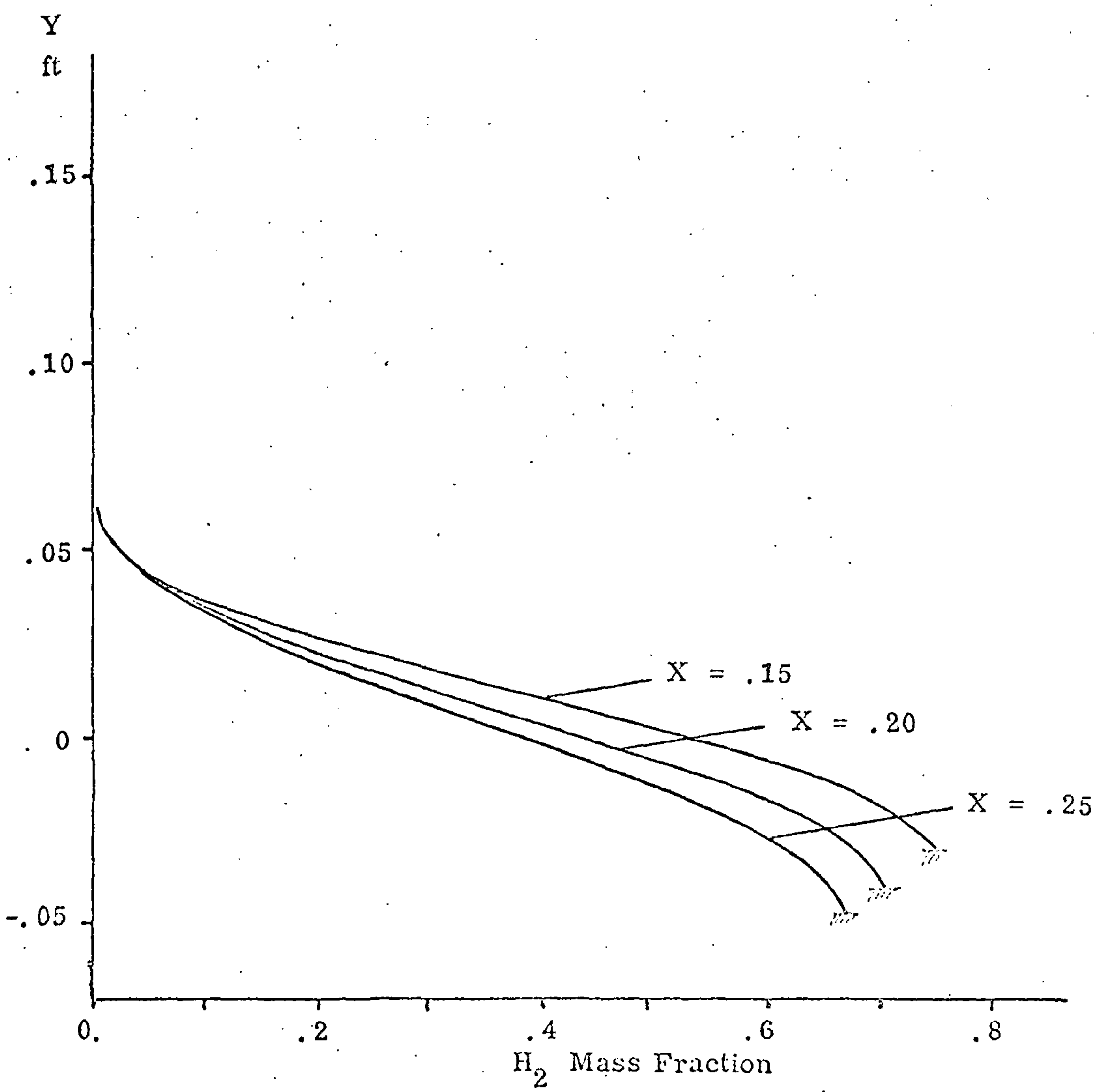
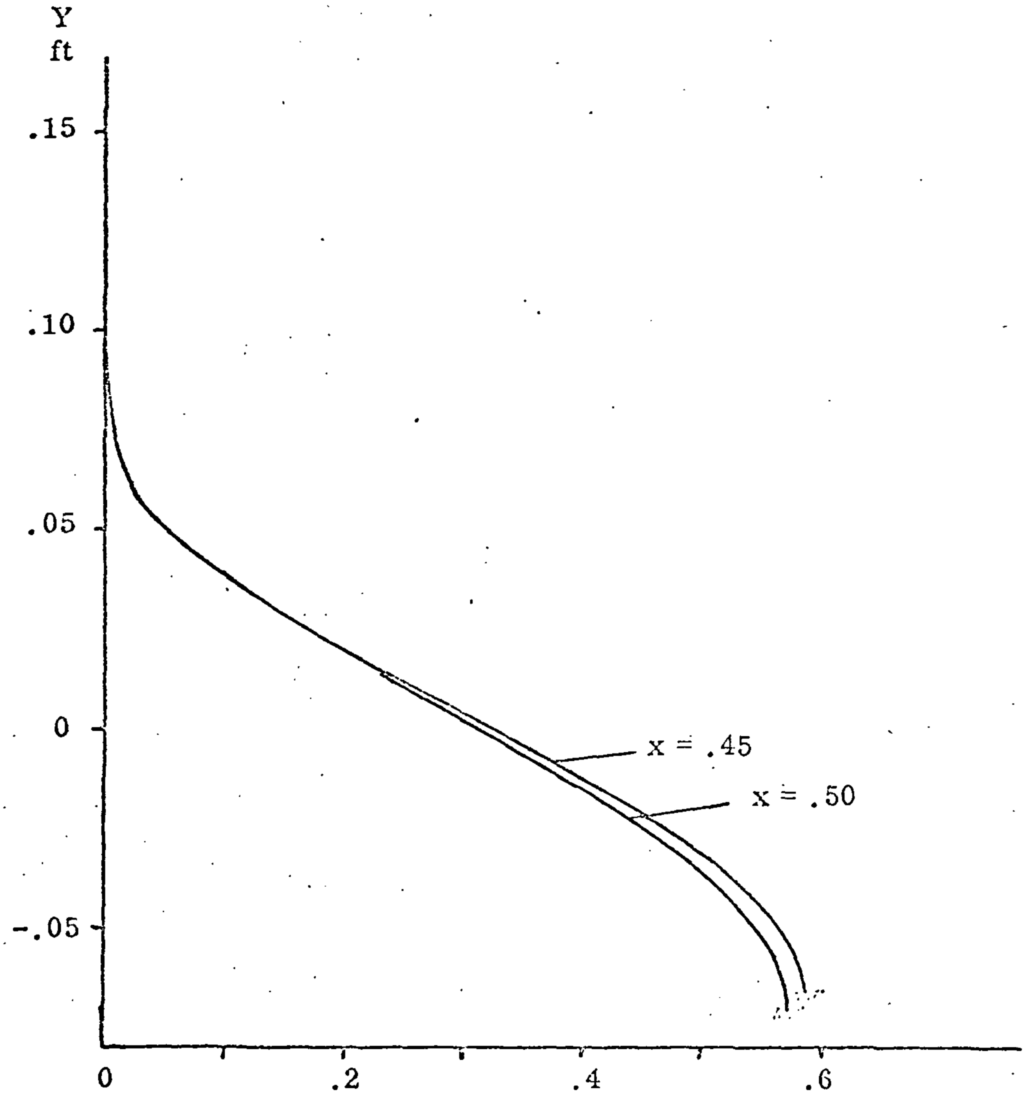


Figure 6f continued



H_2 Mass Fraction

Figure 6f (Contd')

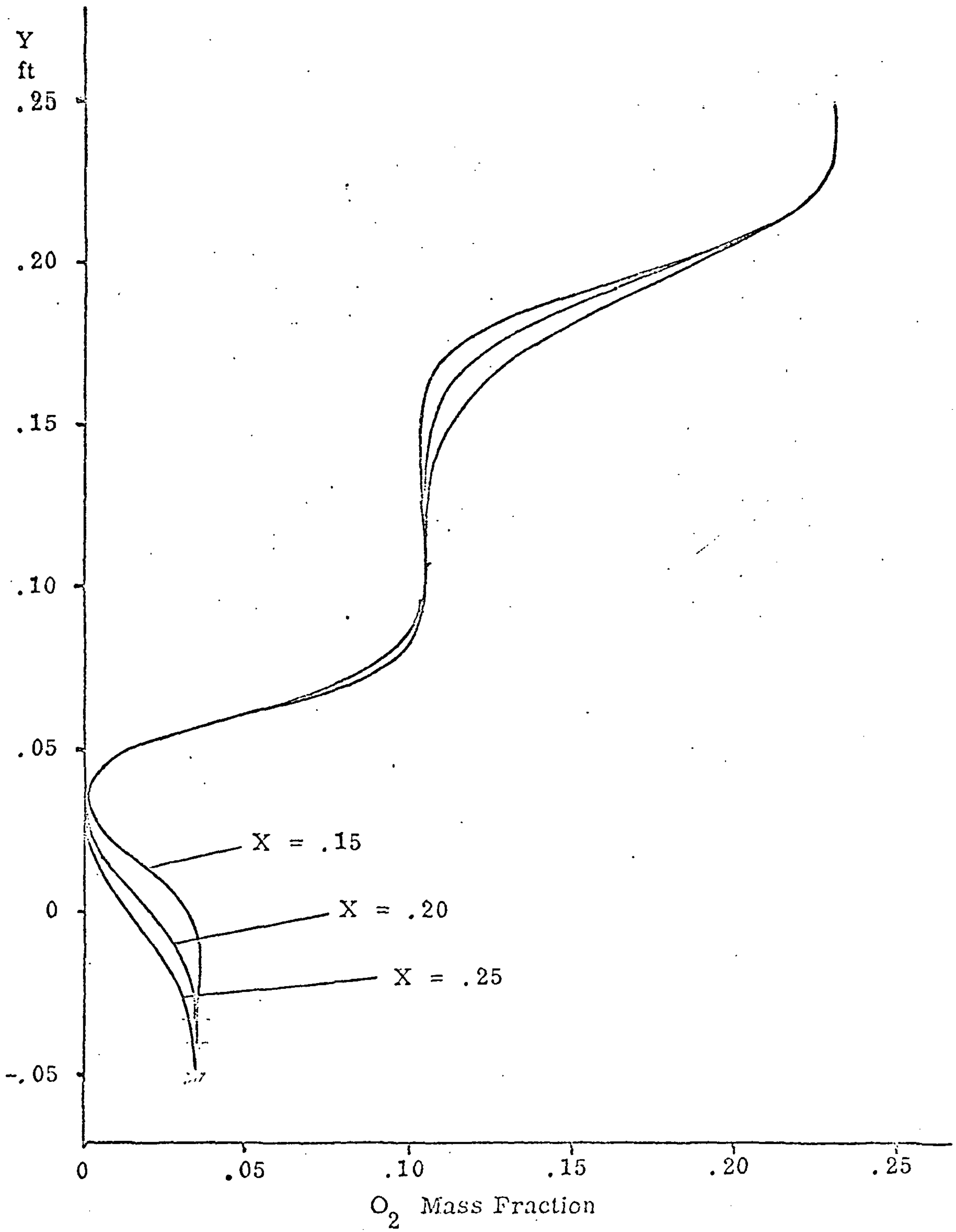


Figure 6g continued

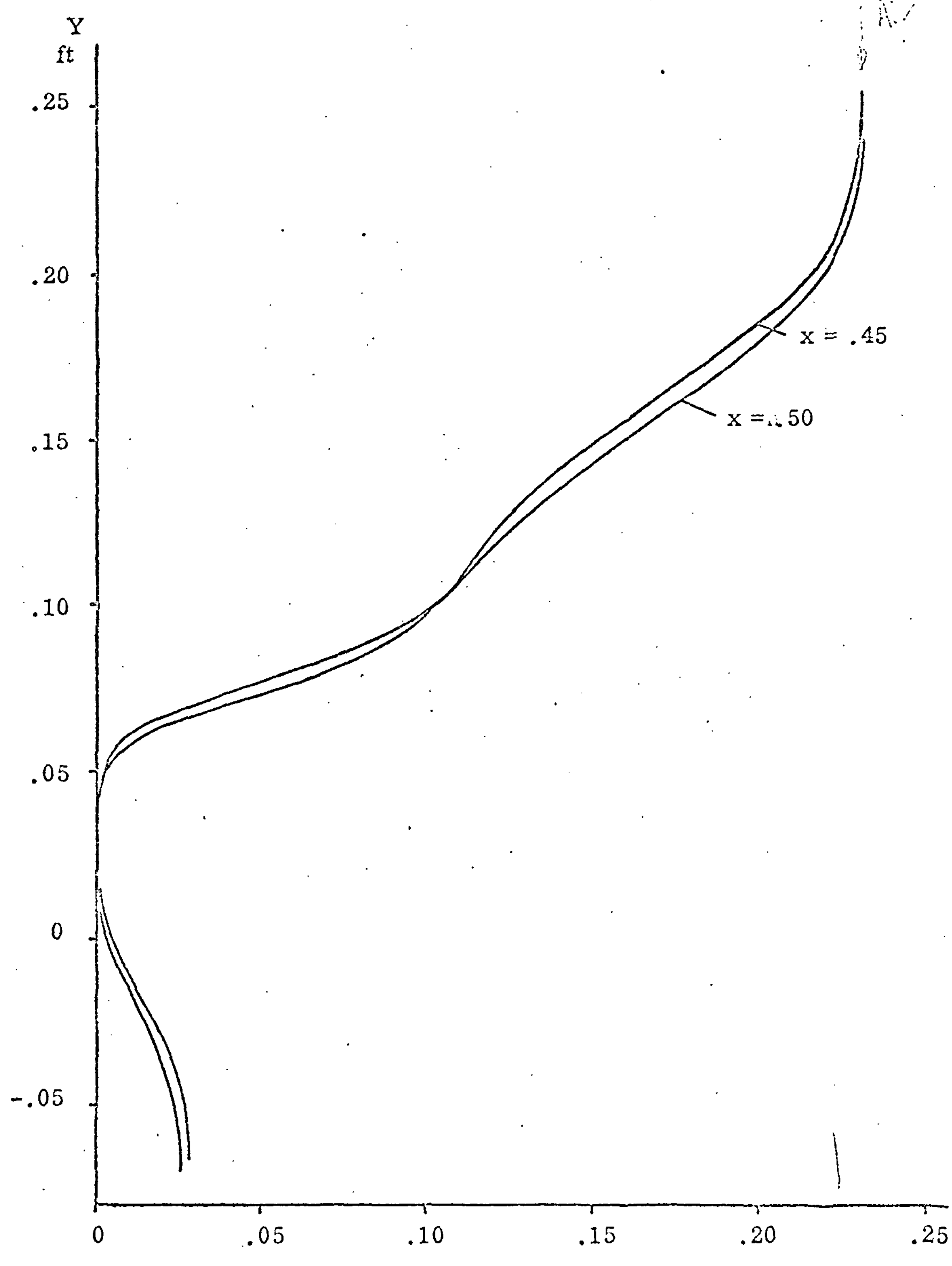


Figure 6g (Cont'd)

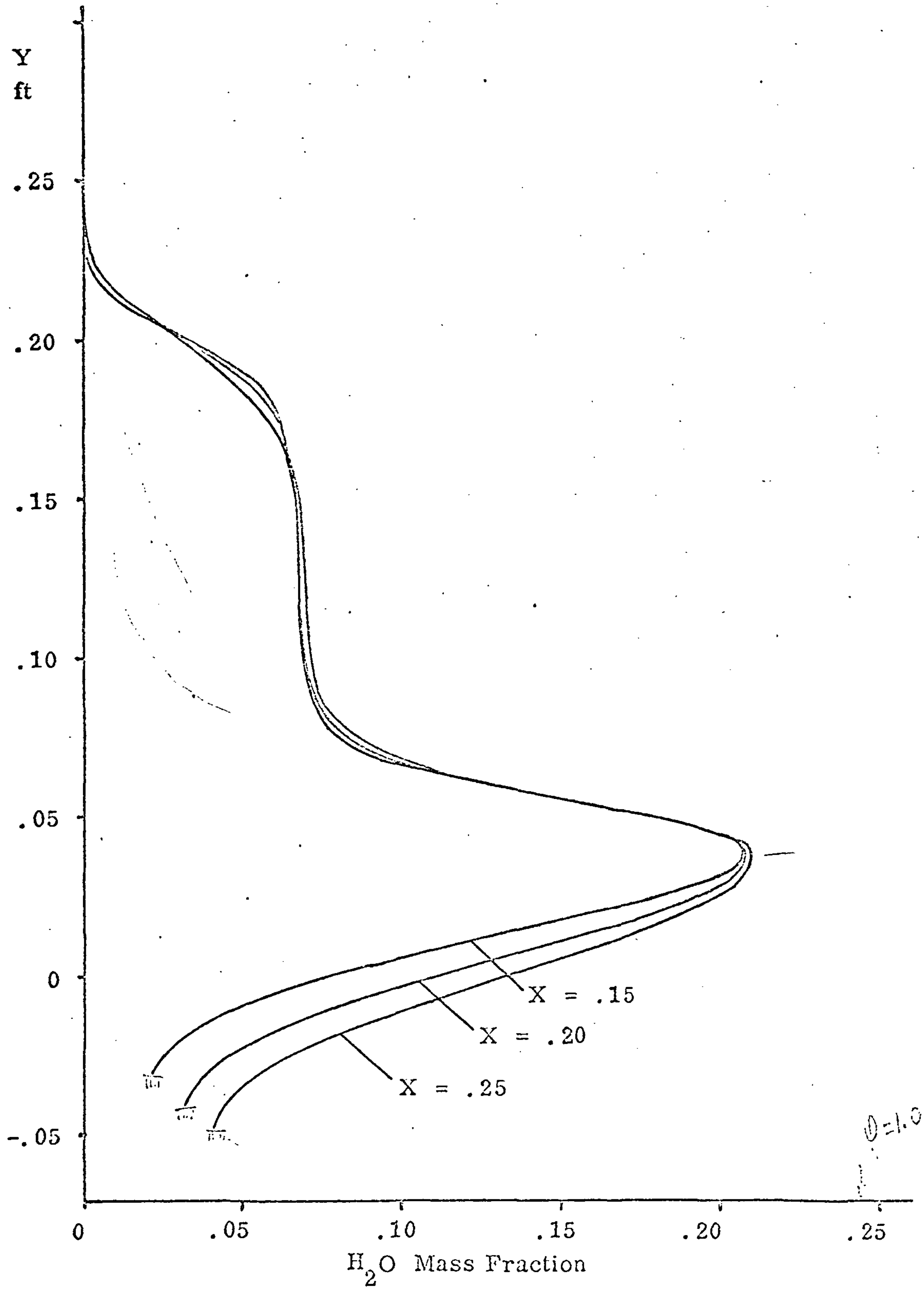
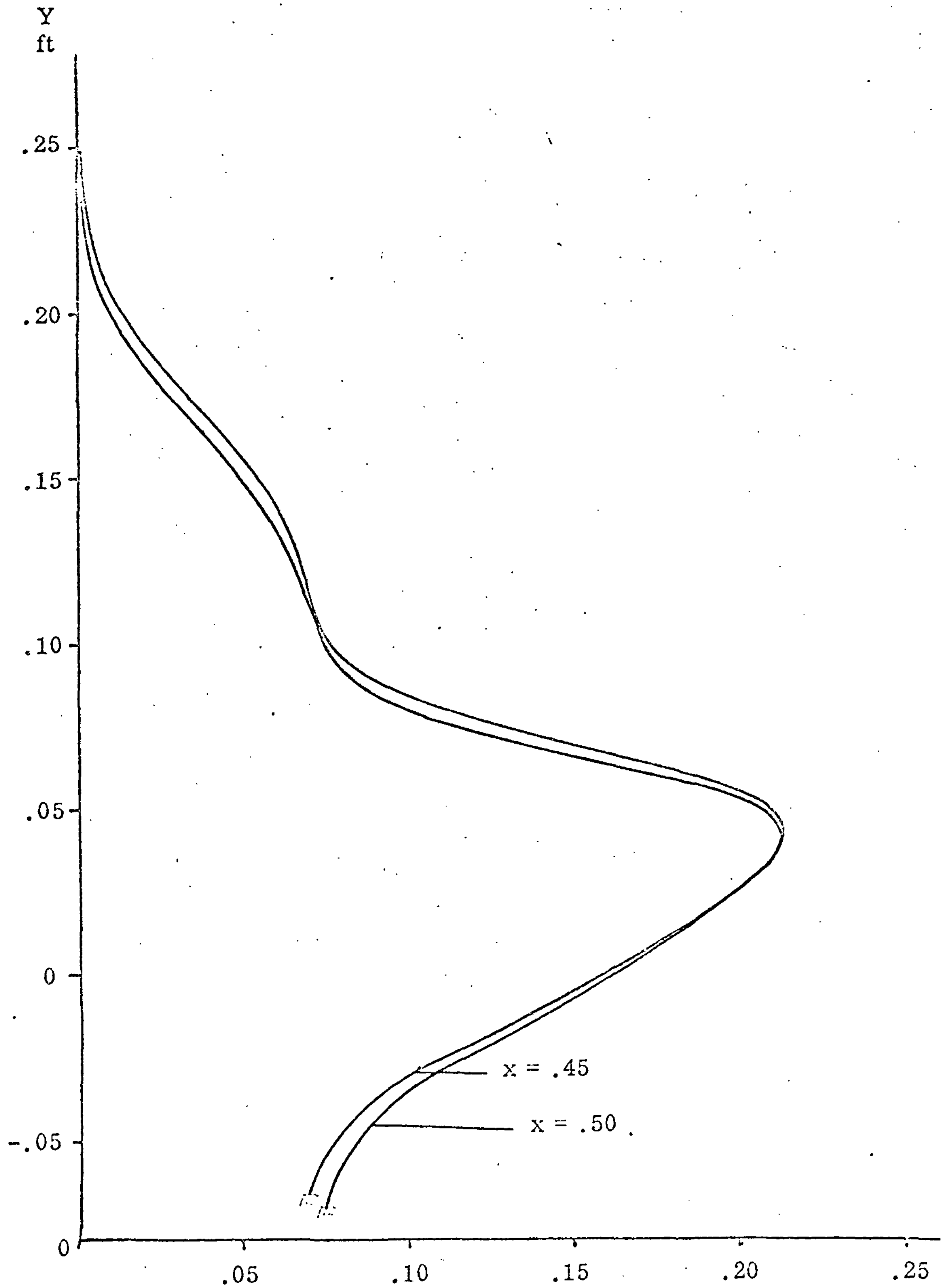
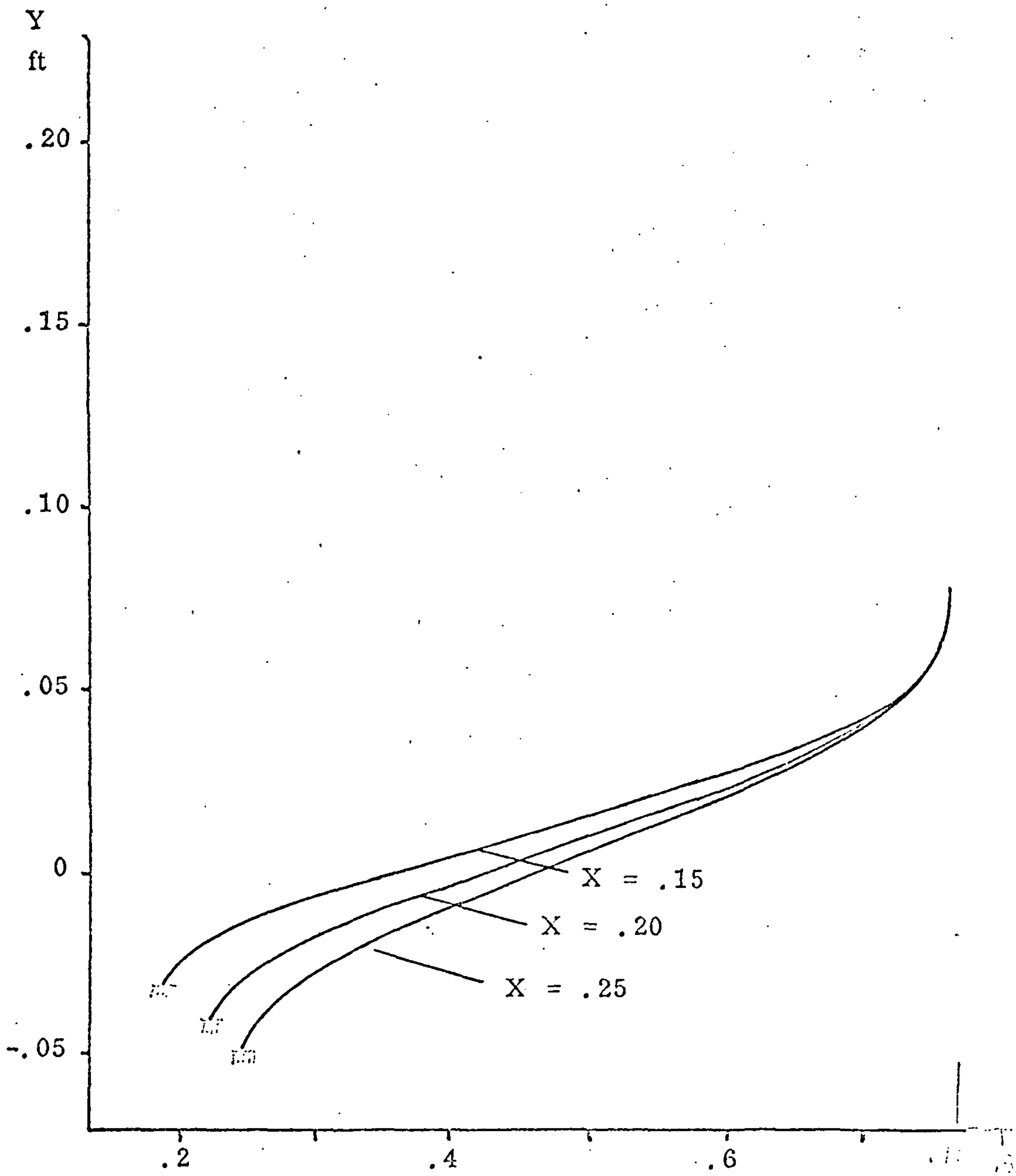


Figure 6h (Cont'd)



H_2O Mass Fraction

Figure 6h (Cont'd)



N_2 Mass Fraction

Figure 6i continued

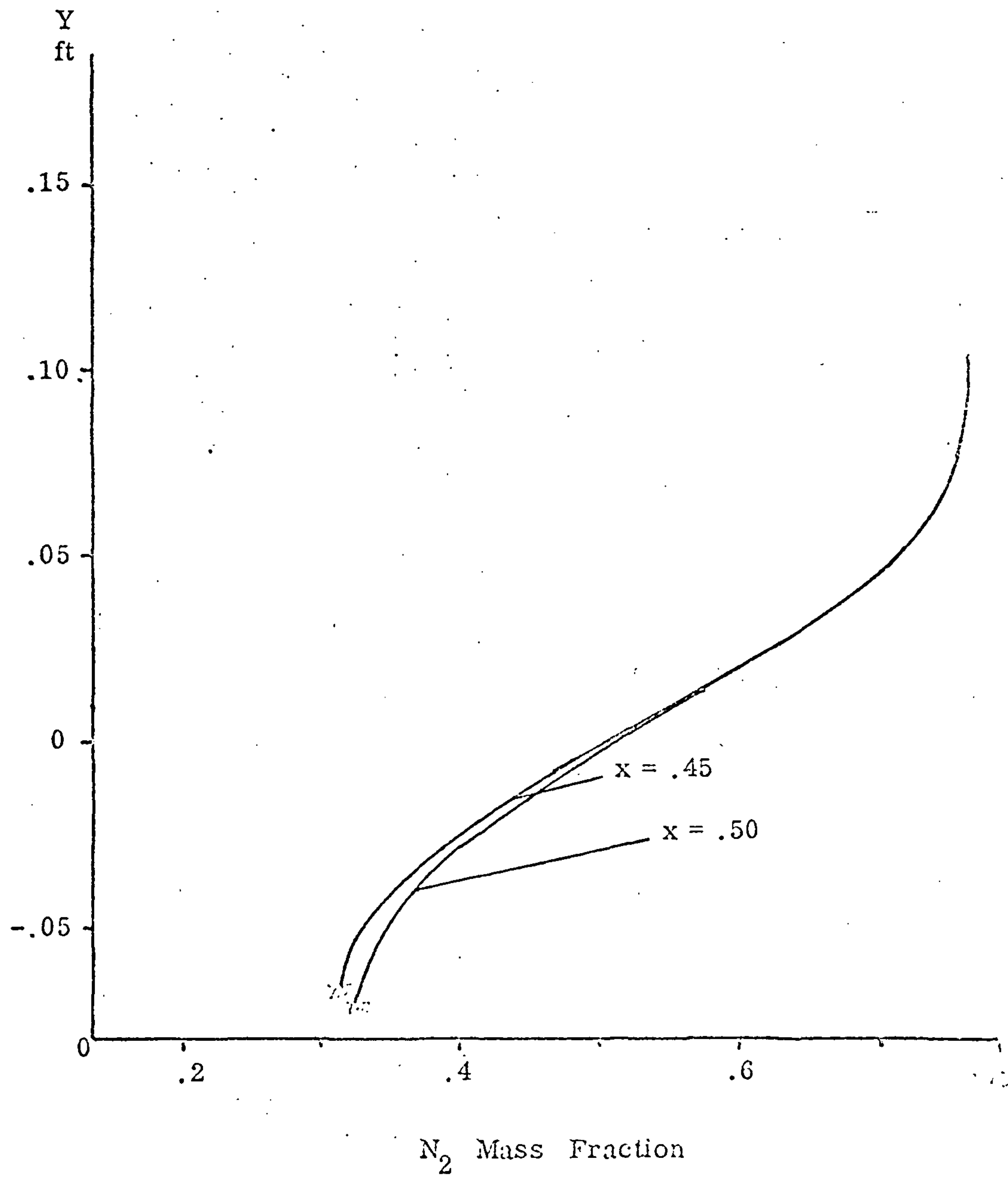


Figure 6i (Contd')

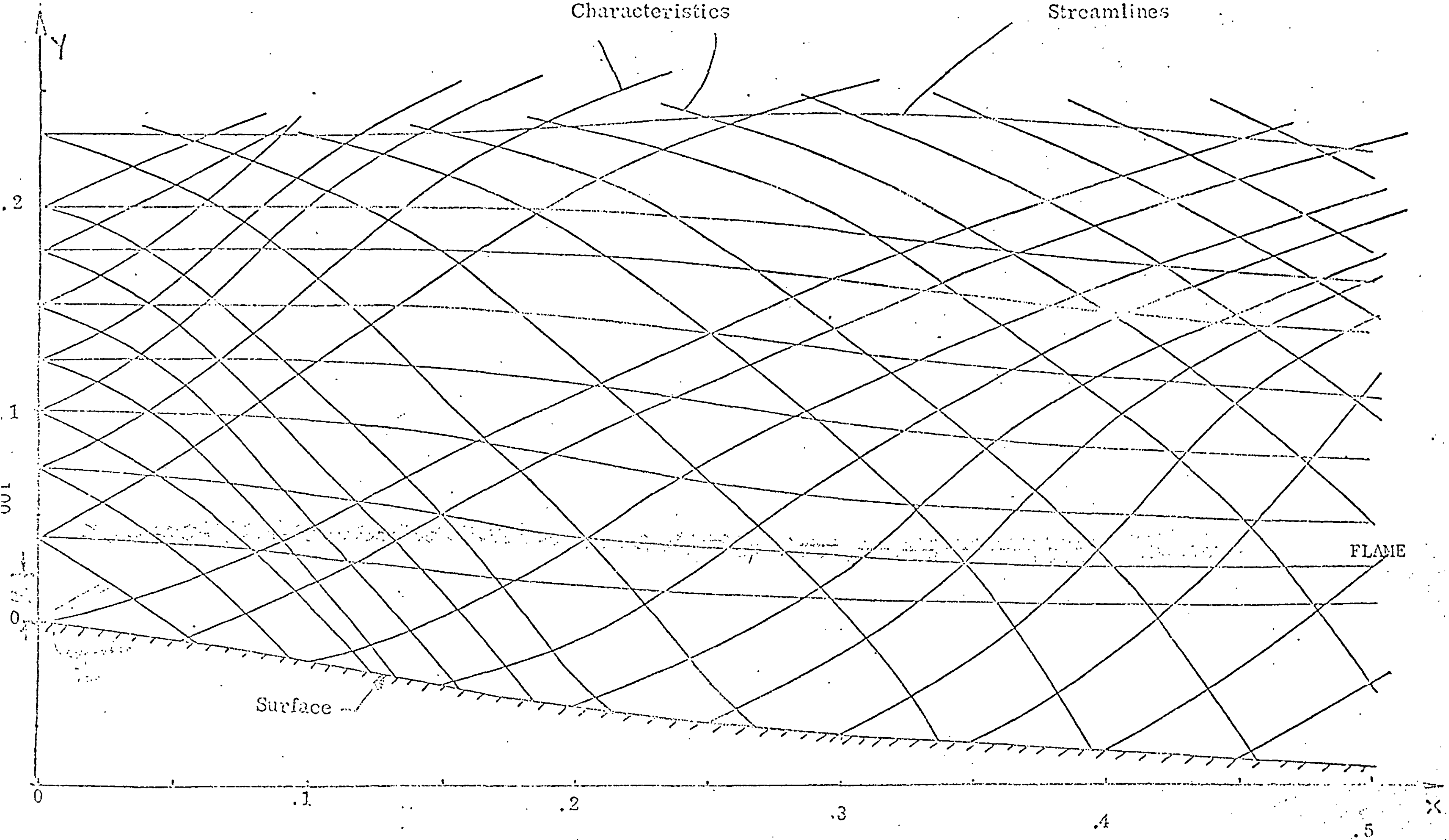


Figure 7 Characteristic mesh