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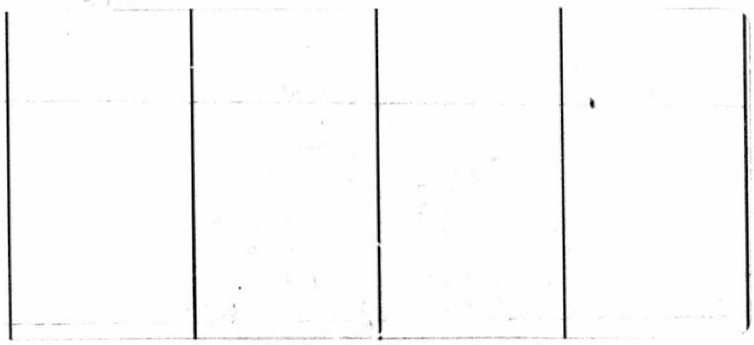

Advanced Technology Laboratories inc.

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MANUAL FOR IMPROVED SOURCE FLOW CHARACTERISTICS PROGRAM

By

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SECTION I
INTRODUCTION

The FØRTRAN IV program described herein analyzes the nozzle for a hypersonic scramjet by a two dimensional second order characteristic procedure described in ATL TR 213, "A Source Flow Characteristic Technique for the Analysis of Scramjet Exhaust Flow Fields", Reference (1).

The program starts from the initial profile and marches along down-running characteristics until the final X station is reached. This process can be interrupted by "Change of Origin Profiles" in source flow cases. This is done by interpolating the characteristic data at the required axial station and setting up "F arrays" i.e., XF, YF, ... Then the program continues on down-running characteristics using the "F arrays" as an initial profile. These "F arrays" are computed for all flows at an X station that coincides with the cowl tip if there is a cowl in the flow field. If the flow is overexpanded at the cowl the program will invert the problem as described in Reference (1). When the shock reflects off the lower wall "F arrays" are again calculated and the computation continues with the problem inverted until the final axial (X) station is attained.

SECTION II

DESCRIPTION OF INPUT

A. Input Format

Card Number	Columns	Format	Description
1	1-5	I5	J1, type of flow (0-two dimensional, 1-axisymmetric
	6-10	I5	J2, coordinate exponent for line source system (0-two dimensional or axisymmetric, 1-line source)
	11-15	I5	NPTS, number of data points on initial profile
	16-20	I5	IEQ, chemistry indicator (0-frozen hydrogen-air chemistry, 1-equilibrium chemistry)
	21-25	I5	ICØWL, external data indicator (1-overexpansion or underexpansion interaction calculations is required, 0-internal flow only).
	26-30	I5	IØVER, overexpansion indicator (0-flow definitely underexpanded, 1-flow overexpanded or marginal)
	31-35	I5	MM, number of points in Prandtl-Meyer fan (MM=9, maximum)
	36-40	I5	IDEAL, indicator for ideal gas calculation, 1-for calculation, 0-non ideal gas
	1-5	I5	KSIDE-sidewall force and moment indicator, 0-no sidewall calculation, 1-for calculation
	6-10	I5	IVIS-viscous calculation indicator, 0-no calculation, 1-viscous forces and local heat transfer calculated

Card Number	Columns	Format	Description
2	11-15	I5	ITW-adiabatic wall indicator, 0-wall temperature must be specified if IWIS=1, (see card 17) 1-adiabatic wall calculation
3	1-10	E10.0	*XBP, ratio of axial coordinate of cowl at initial station to throat height
	11-20	E10.0	XBØD, ratio of axial coordinate of lower wall at initial station to throat height
	21-30	E10.0	XCØWL, ratio of axial coordinate of cowl trailing edge to throat height
	31-40	E10.0	RTH, throat height (ft.), scaling parameter L*
	41-50	E10.0	TEST, maximum allowable axial step size, used for computing upper boundary - typical value = .1
	51-60	E10.0	XFINAL, ratio of final axial coordinate of run to throat height
	6-170	E10.0	XTJ1, ratio of axial coordinate of beginning of Cartesian region to throat height
4	1-10	E10.0	XSHFT, ratio of axial coordinate of moment axis to throat height
	11-20	E10.0	YSHFT, ratio of radial coordinate of moment axis to throat height
	21-30	E10.0	XTHX, initial thrust (lbs/RTH^2)
	31-40	E10.0	YLFT, initial lift (lbs/RTH^2)
	41-50	E10.0	XMØM, initial pitching moment ($ft\text{-}lbs/RTH^3$)

*(All length variables are non-dimensionalized by RTH.)

Card Number	Columns	Format	Description
5	1-10	E10.0	XTHS, initial sidewall thrust (lbs/RTH^2)
	11-20	E10.0	XLFTS, initial sidewall lift (lbs/RTH^2)
	21-30	E10.0	XMØMS, initial sidewall moment ($ft\text{-}lbs/RTH^3$)
	31-40	E10.0	XVTHX, initial viscous thrust (lbs/RTH^2)
	41-50	E10.0	XVLFT, initial viscous lift (lbs/RTH^2)
	51-60	E10.0	SVMØM, initial viscous moment ($ft\text{-}lbs/RTH^3$)
6	1-5	I5	NXXJ1, number of locations in source flow where a new initial profile is desired, maximum is 4, minimum is 1 (i.e., changes of origin, cowl station, ...)
7	One of the following cards is necessary for each NXXJ1. If two-dimensional flow, card 7a may be blank.		
7a	1-10	E10.0	XXJ1, ratio of axial coordinate of new initial profile to throat height
	11-20	E10.0	AXX, coefficients of polynomial describing a segment of lateral extent of the nozzle
	21-30	E10.0	BXX, for the equation ($Z_L = AXX(X-X_1) + BXX$
	31-40	E10.0	XØR, ratio of axial coordinate of line source origin
7b	1-5	I5	IFENCE, fence indicator (0-no fence; 1-supersonic fence exists)
	11-20	E10.0	AFENCE, coefficients of fence for the equation
	21-30	E10.0	BFENCE, Y=AFENCE (X-XBP) + BFENCE

Card Number	Columns	Format	Description
7b	31-40	E10.0	XFENCE, ratio of axial coordinate of fence on lower surface to throat radius
8	1-5	I5	NUWSEG, number of polynomial segments describing the cowl (maximum is 5)
	6-10	I5	NLWSEG, number of polynomial segments describing the lower wall (maximum is 5)
9	One of the following cards is necessary for each cowl segment.		
9a	1-10	E10.0	XXU(L), ratio of axial coordinate of beginning of "L^{th}" segment of cowl to throat height
	11-20	E10.0	A, coefficients of the "L^{th}" segment
	21-30	E10.0	B, of polynomial describing cowl for the equation
	31-40	E10.0	C, $Y=AX^2+BC+C$; Y=Y/RTH & X=X/RTH
10	One of the following cards is necessary for each lower wall segment.		
10a	1-10	E10.0	XXL(L), ratio of axial coordinate of beginning of the "L^{th}" segment of lower wall to throat height
	11-20	E10.0	A, coefficients of the "L^{th}" segment
	21-30	E10.0	B, of polynomial describing lower wall for the equation
	31-40	E10.0	C, $Y=AX^2+BX+C$: Y=Y/RTH & X=X/RTH
11	1-10	E10.0	EMINF, free stream of reference Mach number

Card Number	Columns	Format	Description
11	11-20	E10.0	TIN, free stream or reference temperature (^{o}K)
	21-30	E10.0	WINF, free stream or reference molecular weight (lbs/lb-mole)
	31-40	E10.0	PINF, free stream or reference pressure (lbs/ft^2)
12	Read this card if IDEAL = 1.		
12a	1-10	E10.0	GAMEY, ideal gas ratio of specific heats (γ)
	11-20	E10.0	XMWT, molecular weight
13	Initial Profile - One of the following cards are required for each data point as described below. The program reads data points beginning at the lower wall (point #1) and proceeds to the cowl (point #NPTS).		
13a	1-10	E10.0	X(1), ratio of axial coordinate of data point to throat height
	11-20	E10.0	Y(1), ratio of radial coordinate of data point to throat height
	21-30	E10.0	P(1), ratio of pressure at data point to free stream pressure
	31-40	E10.0	Q(1), ratio of velocity at data point to free stream velocity
	41-50	E10.0	T(1), ratio of temperature at data point to free stream temperature
	51-60	E10.0	TH(1), flow inclination at data point (in radians)
	61-70	E10.0	W(1), fuel to air equivalence ratio (only necessary if IEQ=1)

Card Number	Columns	Format	Description
14	Initial Mass Fractions - Same as card 13 above except for mass fractions at each data point. These cards are necessary only if IEQ=0.		
14a	1-10	E10.0	mass fraction of H
	11-20	E10.0	mass fraction of O
	21-30	E10.0	mass fraction of H_2O
	31-40	E10.0	mass fraction of H_2
	41-50	E10.0	mass fraction of O_2
	51-60	E10.0	mass fraction of OH
	61-70	E10.0	mass fraction of N_2
15	This card is ncessary only if ICØWL =1.		
15a	1-10	E10.0	*XM, axial location of cowl end
	11-20	E10.0	YM, vertical location of cowl end
	21-30	E10.0	PM, ratio of pressure external to the cowl to free stream or reference pressure
	31-40	E10.0	QM, ratio of velocity external to the cowl to free stream or reference velocity
	41-50	E10.0	TM, ratio of temperature equal the cowl to free stream or reference temperature
	51-60	E10.0	THM, flow inclination external to the cowl (in radians)
	61-70	E10.0	WM, external flow molecular weight assumed the same WINF

*(All length variables are non-dimensionalized by RTH.)

Card Number	Columns	Format	Description
16	This card necessary only if IVIS = 1.		
16a	1-10	E10.0	XSTR, boundary layer virtual origin
	11-20	E10.0	Pr, Prandtl number
	21-30	E10.0	Rec, boundary layer recovery factor (turbulent flow)
	31-40	E10.0	REIN, free stream Reynolds number per foot
	41-50	E10.0	SH, constant for turbulent Reynolds analogy ($ST = SH \cdot C_f/2$)
17	Wall temperature distributions-necessary only.		
	If ITW = 0, L = 1 Cowl surface; L = 2		
	Vehicle surface; L = 3 sidewall		
17a,b,c	1-10	E10.0	AH(L) coefficients in equations
	11-20	E10.0	BH(L) $T_{WALL} = AH(L) \cdot (X-XBP)^2 + BH(L) \cdot$
	21-30	E10.0	CH(L) $(X-XBP) + CH(L)$

B. Figures for Input

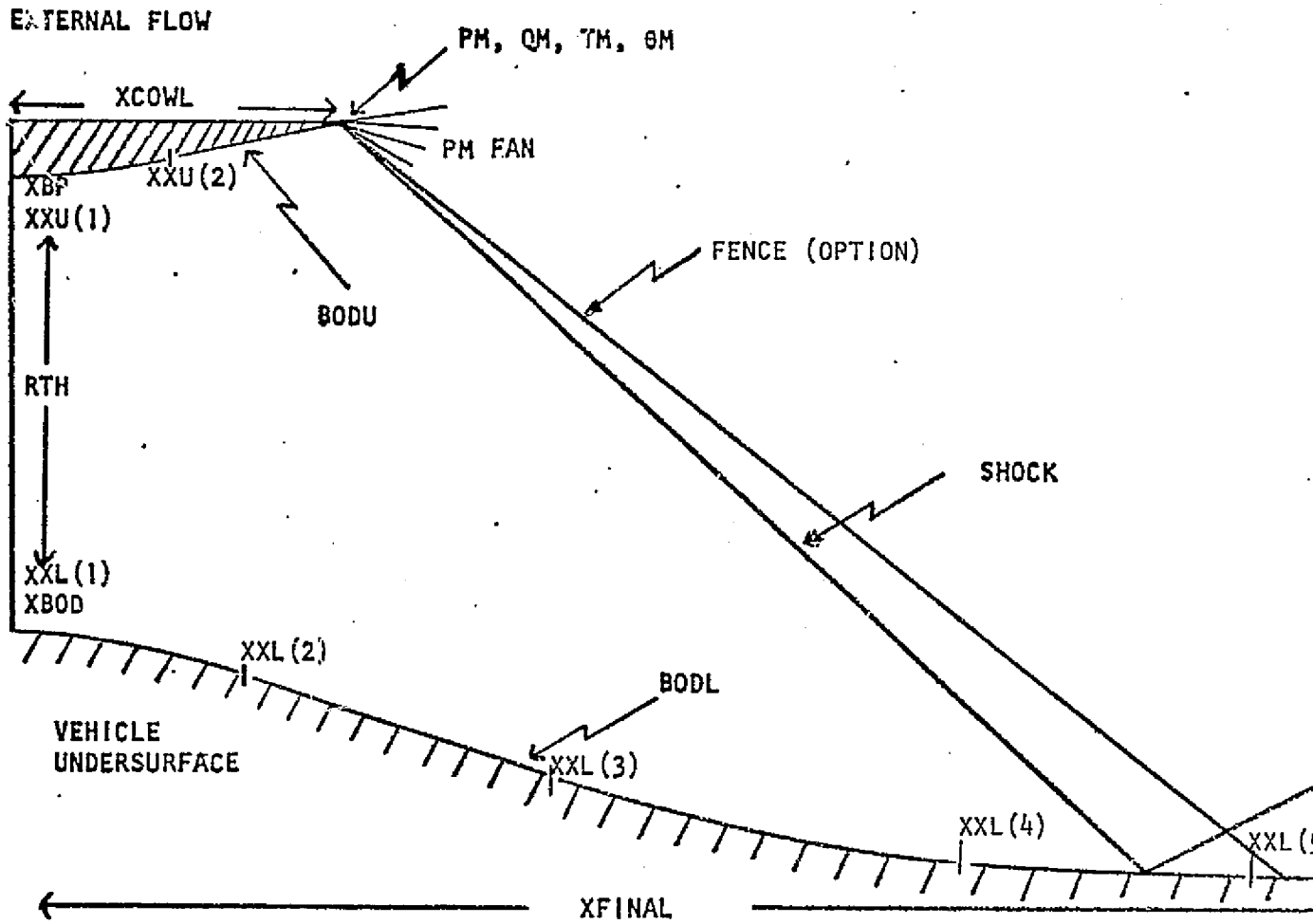

FIGURE #1. Definition of Physical Input Variables

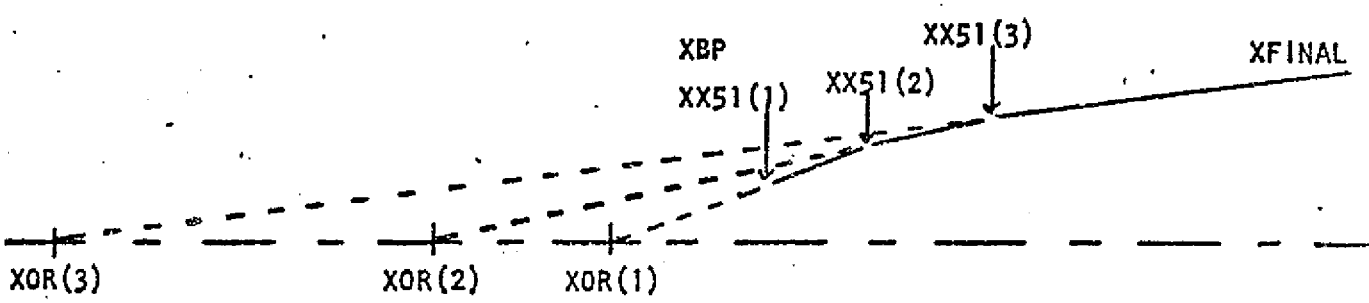

FIGURE #2. Definition of Change of Origin Variables

SECTION III

DESCRIPTION OF OUTPUT

A. Output Format - The heading page contains program constants, line source coordinates and origin changes, upper and lower wall coordinates, free stream data at the cowl and infinity conditions. The program then prints the "initial profile," the data at selected points along down-running characteristics in the flow field and the running lift, thrust and pitching moment. The process continues until the input value for the final axial location is reached.

The above flow can be interrupted by "change of origin profiles" and a profile at the trailing edge of the cowl. If the flow is over-expanded at the cowl the output will switch to up-running characteristics from the lower wall to the contact surface and additional output covering the shock angle and external Mach number will be printed. When the shock reflects off the lower wall another profile will be printed and the run will proceed to the final axial location through down-running characteristics.

B. Identification of Output Variables

X - axial distance/throat height
Y - radial distance/throat height
Q - velocity/free stream velocity
T - temperature/free stream temperature
P - pressure/free stream pressure
TH - flow angle (radians)
EM - Mach number

ALP(1) = mass fraction of H
ALP(2) = mass fraction of O
ALP(3) = mass fraction of H_2O
ALP(4) = mass fraction of H_2
ALP(5) = mass fraction of O_2
ALP(6) = mass fraction of OH
ALP(7) = mass fraction of N_2

Frozen flow extra output is:

CPX - specific heat/free stream specific heat

W - molecular weight of mixture/free stream molecular weight

Equilibrium flow extra output is:

GAM - equilibrium isentropic exponent

PHI - fuel to air ratio

Vehicle Forces (thrust, lift, pitching moment):

Vehicle force data are given at every output Station and ave delineated as follows

(a) Cowl and undersurface forces

(b) Sidewall forces

(c) Viscous forces

SECTION IV

SUBROUTINES AND FUNCTIONS

A. Subroutines

	Name	Description
1.	INDATA	reads and prints initial data and computes infinity conditions
2.	COEFF	sets thermodynamic coefficients as functions of temperature
3.	ERROR	prints program statement number nearest selected errors and terminates computer run
4.	BODL	locates axial and radial coordinates along lower vehicle surface
5.	BODU	locates axial and radial coordinates along upper cowl surface
6.	COWL	calculates shock jump relations and Prandtl-Meyer fan at cowl trailing edge for under-expanded flow
7.	COWLO	computes contact points, shock paints and shock angle at cowl trailing edge for over-expanded flow
8.	DPØINT	computes location and properties of streamline intersection with characteristic ($C_{\pm}$)
9.	SHOCK	calculates shock jump conditions
10.	SHOCPT	computes shock angle by matching pressure from shock jump relations and pressure from characteristic relation on downstream side of shock
11.	PRM	computes isentropic ideal gas expansion
12.	DRTEST	tests for dropping data points on free stream side of shock
13.	ALL	calculates density, ratio of specific heats, Mach number, Mach angle, frozen flow specific heat, molecular weight and gas constant
14.	THERMO	computes frozen flow specific heat, derivative of specific heat and enthalpy of each species from polynomial fits in temperature
15.	XMASSS	computes mass flow correction factor
16.	FM	computes mass function
17.	PMI	computes flow properties for given Prandtl-Meyer turning
18.	GEM	computes intersection of two straight lines

Name		Description
19.	SL	computes streamline properties of newly calculated data point
20.	INT	interpolation routine
21.	ERR	finds roots of a given function
22.	FUZZY	detects crossing of down-running characteristics
23.	WUZZY	detects crossing of up-running characteristics
24.	LTHM	computes incremental lift, thrust, pitching moment and side force
25.	VIS	computes viscosity coefficient
26.	SNARF	computes surface area unit normal and area centroid for elemental surface quadrilaterals
27.	GNURE	computes flat plate skin friction and heat transfer coefficients
28.	BØDL	calculates body height and slope for vehicle surface given the axial location
29.	BØDU	calculates body height and slope for cowl surface given the axial location

B. Functions

Name		Description
1.	FT	calculates temperature at any data point in flow field
2.	FH	computes static enthalpy at any point in flow field
3.	FGAM	makes isentropic exponent and associated thermodynamic data at any point in flow field
4.	RHEQ	computes equilibrium density
5.	XM1	calculates tan $(\theta+\mu)$ along up-running characteristic
6.	XM2	calculates tan $(\theta+\mu)$ along down-running characteristic
7.	XM3	calculates tan (θ) along streamline

Name		Description
8.	F1	*A_1 or B_1 coefficient along up-running and down-running characteristics respectively
9.	F2	*A_2 or B_2 coefficient along up-running and down-running characteristics respectively

---

*Note: p - θ relationship along up-running characteristic:

$$A_1(p_C-p_A) + \theta_C-\theta_A+A_2(X_C-X_A) = 0$$

p - θ relationship along down-running characteristic:

$$B(p_C-p_B) - \theta_C+\theta_B+B_2(X_C-X_B) = 0$$

SECTION V

MACHINE CONTROL CONSIDERATIONS

1. Machine - program designed for CDC 6600.

2. Estimates for run.

   a. Field length:

      (1) compile - 65,000 octal locations

      (2) load - 120,000 octal locations

      (3) run - 100,000 octal locations

   b. CP time: variable depending on number of points in initial profile and type of flow

   c. IO: less than 100 octal seconds

   d. Tapes or disks used:

      (1) Tape 5 - card input

      (2) Tape 6 - printed output

      (3) no other tapes or disk files used

   e. Printed output: as in CP time it is variable depending on case submitted.

SECTION VI

SAMPLE INPUT FOR SOURCE FLOW

```
C
        0    1   21     1    1    0    9    0
        1    0    0
C
0.              0.          3.          1.          .1          21.         22.
0.              .5          0.          0.          0.
0.              0.          0.          0.          0.          0.
C       2
0.              .0875       1.          -7.
3.              .0875       1.          -7.
C           1   -.59        3.064       16.
            2   3
0.              .1314       0.          1.
.4              0.          .1051       .979
0.              -.5565      0.          0.
.4              0.          -.4452      .08905
8.              .01019      -.6082      .741
10.             232.3       28.96       23.09
0.              0.          36.65       .929        10.1        0.          1.
0.              .05         36.65       .929        10.1        0.          1.
0.              .1          36.65       .929        10.1        0.          1.
0.              .15         36.65       .929        10.1        0.          1.
0.              .2          36.65       .929        10.1        0.          1.
0.              .25         36.65       .929        10.1        0.          1.
0.              .3          36.65       .929        10.1        0.          1.
0.              .35         36.65       .929        10.1        0.          1.
0.              .4          36.65       .929        10.1        0.          1.
0.              .45         36.65       .929        10.1        0.          1.
0.              .5          36.65       .929        10.1        0.          1.
0.              .55         36.65       .929        10.1        0.          1.
0.              .6          36.65       .929        10.1        0.          1.
0.              .65         36.65       .929        10.1        0.          1.
0.              .7          36.65       .929        10.1        0.          1.
0.              .75         36.65       .929        10.1        0.          1.
0.              .8          36.65       .929        10.1        0.          1.
0.              .85         36.65       .929        10.1        0.          1.
0.              .9          36.65       .929        10.1        0.          1.
0.              .95         36.65       .929        10.1        0.          1.
0.              1.          36.65       .929        10.1        0.          1.
3.              1.3943      1.          1.          1.          0.          0.
```

APPENDIX

PROGRAM LISTING

The following is a listing of the Fortran IV program for Source Flow Characteristic

```
      PROGRAM NOZ BOD (INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,
     1  TAPE7=PUNCH)
      COMMON/COWL/ICOWL,MM,XM(9),YM(9),PM (9),WM(9),RHM(9),THM(9),QM(9),
     1RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)
      COMMON/IPP/IPP
      COMMON/SHAPE/AA1(5,2),AA2(5,2),AA3(5,2),XXU(5),XXL(5),XINTU,XINTL
      COMMON/LTM/XSHFT,YSHFT,XTHX,YLFT,XMOM,XTHS,YLFTS,XMOMS,KSIDE
      COMMON/HOT/AH(3),BH(3),CH(3),XSTR,PR,REC,REIN,RT,SH,ITW,IVIS
      COMMON/VISF/XVTHX,YVLFT,XVMOM
      COMMON/XXJ/NXXJ1,XXJ1(6),AXX(6),BXX(6),XOR(6)
      COMMON/XFINAL/XFINAL
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/VAR/RHO(200),
     1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
     2             XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
     3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
     4XMASSN(200),ALPN(10,200),SI(10),HI(10),TEMP(20)
     5,ALPDUM(10)
      COMMON /SP/ NSP
      COMMON/FVAR/
     1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
     2XMASSF(200),               HF(200),SF(200),ALPD(10),
     3THETA(20)
      COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
      COMMON /I/ IOPUT
      COMMON/A/ TIN,CPIN,RO
      COMMON/B/ WTMOLE
      COMMON/D/ GAMINF,EMINF,RINF,WINF
      COMMON/F/A9,B9,IBOD,XWF,NBOD,YEND
      COMMON/ETX/XJ,XJ1,NPTS,IO,IREFL,ICHEM,IPUNCH,IDESGN,IR,NXX,XBP,
     1YBP,THBP,RAD,XBOD,YBOD,THBOD,RADB,XEND,THEND,RTH,YEXIT,THST,TEST,
     1IRFL,Y0,RADB2,RRAD(20),    NSTAR,YNOZ,EIN,     PEN,H16,H17
      COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
     110,200)
      COMMON/XCOWL/XCOWL
      COMMON/C1/ EMC1,TC1,QC1
      COMMON /IOVER/ IOVER
      COMMON/XTJ1/XTJ1
      COMMON/FENCE/IFENCE,AFENCE,BFENCE,XFENCE
      COMMON/ICMPLT/ICMPLT
      COMMON/ICU/EMC2
      COMMON/PFF/PFINF
      DIMENSION STS(200)
      DIMENSION WTMOLE(10)
      COMMON/DD/XD,YD,THD,PD,QD,RHD,RD,WD,EMD,GAMD,XMUD,TD
      DIMENSION TYPE2(2)
      DIMENSION TYPE3(2)
      DIMENSION TYPE9(2),PHIPR(2)
      DATA PHIPR/3H   ,3HPHI/
      DATA TYPE9/3HCPX,3HPHI/
      DATA TYPE3/3H W ,3HGAM/
      DATA TYPE2 /10H  NOZZLE   ,10HCENTERBODY/
      DATA XXP/1.E+06/
      DATA ISHOC/-10000/
      IDELG=0
      WRITE(6,400)
  400 FORMAT(1H1)
```

```
C       J=0 TWO DIMENSIONAL
C       J=1 AXISYMMETRIC
C       SPECIES 1 IS H
C       SPECIES 2 IS O
C       SPECIES 3 IS H2O
C       SPECIES 4 IS H2
C       SPECIES 5 IS O2
C       SPECIES 6 IS OH
C       SPECIES 7 IS N2
C       SPECIES 8 IS CO2
C       SPECIES 9 IS CO
C       SPECIES 10 IS C3H8
        IPTP=0
        NXXJ=2
        IFLIP=0
        IHALT=0
        ICMPLT=0
        NSTAR=0
        IOPUT=32
        IUNDR=0
        IAA=1
        CALL INDATA
        XCOWLH=XCOWL
        IEQ5=IEQ+1
        YNOZ=YBP
        PEN=       PIN
        XJ1SV=XJ1
        PFINF=PINF*2116./PIN
        IFENC1=0
 7211   IPP=0
        LSTT=0
        WRITE(6,400)
        IF(IFENC1.EQ.1) WRITE(6,3100)
 3100   FORMAT(30X*FENCE INITIAL PROFILE*)
        IF(IFENC1.EQ.1) GO TO 3101
        IF(IPTP.EQ.0 ) WRITE(6,9191) XOR(1)
 9191   FORMAT(20X*INITIAL PROFILE*
       1*  -  ORIGIN OF SYSTEM =*E13.5)
        IF(IFLIP.EQ.0.AND.IPTP.EQ.1.AND.XF(1).NE.XCOWLH) WRITE(6,9192)
       1 XOR(NXXJ-1)
 9192   FORMAT(16X*CHANGE OF ORIGIN PROFILE*
       1*  -  ORIGIN OF SYSTEM =*E13.5)
        IF(IFLIP.EQ.0.AND.IPTP.EQ.1.AND.XF(1).EQ.XCOWLH) WRITE(6,3132)
       1 XOR(NXXJ-1)
 3132   FORMAT( 8X*PROFILE FOR UNDEREXPANDED SHOCK AT COWL*
       1*  -  ORIGIN OF SYSTEM =*E13.5)
        IF(IFLIP.EQ.1) WRITE(6,600)  XOR(NXXJ-1)
  600   FORMAT( 8X*PROFILE FOR OVEREXPANDED SHOCK AT COWL*
       1*  -  ORIGIN OF SYSTEM =*E13.5)
        IF(IFLIP.EQ.2) WRITE(6,621)   XOR(NXXJ-1)
  621   FORMAT( 6X*PROFILE WHEN SHOCK REFLECTS OFF LOWER WALL*
       1*  -  ORIGIN OF SYSTEM =*E13.5)
 3101   CONTINUE
        IEQ1=IEQ+1
        WRITE(6,6896) PHIPR(IEQ1)
 6896   FORMAT(                                                  //5X,*PT.*,8
       1X,*X*,11X,*Y*,11X,*Q*,11X,*T*,11X,*P*,10X,*TH*10XA3)
```

```
      IF(ICHEM.EQ.0.AND.IEQ.EQ.0) WRITE(6,7701)
7701  FORMAT(13X*ALP(1)=H*4X*ALP(2)=O*3X*ALP(3)=H2O*2X*ALP(4)=H2*
     13X*ALP(5)=O2*3X*ALP(6)=OH*3X*ALP(7)=N2*)
3160  CONTINUE
      DO 3163 I=1,NPTS
      C=PF(I)/PIN
      YFPR=YF(I)
      THFPR=THF(I)
      IF(IFLIP.EQ.1) YFPR=-YF(I)
      IF(IFLIP.EQ.1) THFPR=-THF(I)
      IF(IEQ.EQ.1) GO TO 9806
      WRITE(6,16) I,XF(I) ,YFPR  ,QF (I),TF (I),C      ,THFPR
                  WRITE(6,1602) (ALPF (J,I),J=1,NSP)
      GO TO 3163
9806  WRITE(6,16) I,XF(I) ,YFPR  ,QF (I),TF (I),C      ,THFPR,WF(I)
3163  CONTINUE
1800  FORMAT(* UNDERSURFACE AND COWL THRUST =*E13.5,7X*LIFT =*E13.5,7X*M
     1OMENT =*E13.5)
      IPTP=1
      XJ1SV=XJ1
      WRITE(6,3130)
3130  FORMAT(/)
      IF(KSIDE.EQ.0) GO TO 3104
      WRITE(6,1800) XTHX,YLFT,XMOM
      WRITE(6,3107)XTHS,YLFTS,XMOMS
3107  FORMAT(5X*SIDEWALL THRUST=*E12.4,5X*SIDEWALL LIFT=*E12.4,5X*SIDEW
     1ALL MOMENT=*E12.4//)
      IF(IVIS.EQ.1)WRITE(6,3153)XVTHX,YVLFT,XVMOM
3153  FORMAT(5X*VISCOUS THRUST =*E12.4,5X*VISCOUS LIFT =*E12.4,5X*VISCOU
     1S MOMENT =*E12.4//)
3104  CONTINUE
      N=2
      LMAX=1
      KMAX=2*(N-1)-1
      IF(IOVER.NE.2) GO TO 7423
      N=3
      IPP=1
      LMAX=2
      KMAX=2
7423  NN1=N-1
      DO 7424 I=1,NN1
      II=NN1-I+1
      DO 1500 J=1,NSP
      ALP(J,I)=ALPF(J,II)
1500  ALPDUM(J)=ALP(J,I)
      D=0.
      CALL INT(0.,XF(II),YF(II),THF(II),PF(II),QF(II),RHOF(II),RF(II),
     1WF(II),GAMF(II),EMF(II),XMUF(II),TF(II),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,X(I),Y(I),TH(I),P(I),Q(I),RHO(I),R(I),W(I),GAM(I),
     1EM(I),XMU(I),T(I),ALPDUM,1,IEQ)
7424  CONTINUE
 500  CONTINUE
      IF(KMAX.GE.191) GO TO 9123
6060  IPP=IPP+1
6883  WRITE(6,7633) IPP
7633  FORMAT(5X,*LINE NO. = *,I4)
```

```
      IF(IOVER.EQ.2.AND.KMAX.GE.10) GO TO 670
      JJ=1+KMAX/10
      JJ1=KMAX-1
      IF(IO.EQ.1) JJ=1
      WRITE(6,6885)TYPE3(IEQ5),TYPE9(IEQ5)
   16 FORMAT(3X,I4,3X,10E12.4)
 6885 FORMAT(5X,*PT,*,8X,*X*,11X,*Y*,11X,*P*,10X,*TH*,11X,*Q*,11X,*T*,
     110X,*EM*,10X,A3 , 9X,A3)
      DO 7637 I=1,JJ1,JJ
      C=P(I)/PIN
      YFPR=Y (I)
      THFPR=TH (I)
      DUPR=W(I)
      IF(IEQ5.EQ.2) DUPR=GAM(I)
      CPR=CPX(I)
      IF(IEQ.EQ.1)CPR=W(I)
      IF(IFLIP.EQ.1) YFPR=-Y (I)
      IF(IFLIP.EQ.1) THFPR=-TH (I)
      WRITE(6,7632) I,X(I),YFPR,C    ,THFPR,Q(I),T(I),EM(I),DUPR,CPR
 7632 FORMAT(3X,I4,3X,10E12.4)
 7637 CONTINUE
 1602 FORMAT(10X,10E12.4)
      IF(IPP.EQ.1) GO TO 7759
      I=KMAX
      C=P(I)/PIN
      YFPR=Y (I)
      THFPR=TH (I)
      DUPR=W(I)
      IF(IEQ5.EQ.2) DUPR=GAM(I)
      CPR=CPX(I)
      IF(IEQ.EQ.1)CPR=W(I)
      IF(IFLIP.EQ.1) YFPR=-Y (I)
      IF(IFLIP.EQ.1) THFPR=-TH (I)
      WRITE(6,7632) I,X(I),YFPR,C    ,THFPR,Q(I),T(I),EM(I),DUPR,CPR
      GO TO 7759
  670 JJ=1+KMAX/10
      JJ2=1
      ISH=ISHOC
      JJ1=ISH-1
      WRITE(6,6885)TYPE3(IEQ5)
  672 DO 671 I=JJ2,JJ1,JJ
      C=P(I)/PIN
      YFPR=Y (I)
      THFPR=TH (I)
      DUPR=W(I)
      IF(IEQ5.EQ.2) DUPR=GAM(I)
      CPR=CPX(I)
      IF(IEQ.EQ.1)CPR=W(I)
      IF(IFLIP.EQ.1) YFPR=-Y (I)
      IF(IFLIP.EQ.1) THFPR=-TH (I)
      WRITE(6,7632) I,X(I),YFPR,C    ,THFPR,Q(I),T(I),EM(I),DUPR,CPR
  671 CONTINUE
      I=JJ1+1
      C=P(I)/PIN
      YFPR=Y (I)
      THFPR=TH (I)
      DUPR=W(I)
```

```
      IF(IEQS.EQ.2) DUPR=GAM(I)
      CPR=CPX(I)
      IF(IEQ.EQ.1)CPR=W(I)
      IF(IFLIP.EQ.1) YFPR=-Y (I)
      IF(IFLIP.EQ.1) THFPR=-TH (I)
      WRITE(6,7632) I,X(I),YFPR,C    ,THFPR,Q(I),T(I),EM(I),DUPR,CPR
      IF(JJ1.EQ.KMAX-1) GO TO 7759
      JJ2=ISH+1
      JJ1=KMAX-1
      GO TO 672
 7759 BETPR=BET
      WRITE(6,1800) XTHX,YLFT,XMOM
      IF(KSIDE.EQ.1)
     1WRITE(6,3107)XTHS,YLFTS,XMOMS
      IF(IVIS.EQ.1)WRITE(6,3153)XVTHX,YVLFT,XVMOM
      IF(IFLIP.EQ.1) BETPR=-BET
      IF(IOVER.EQ.2) WRITE(6,653) BETPR,EMC1
  653 FORMAT(5X*SHOCK ANGLE =*E12.4,5X*EXTERNAL MACH NO. =*E12.4)
      IF(IUNDR.EQ.1)WRITE(6,596)EMC1
  596 FORMAT(5X* EXTERNAL MACH NO. = *E12.4)
      WRITE(6,1603)
 1603 FORMAT(///)
 6884 ICMP=ICMPLT+1
      IF(IOVER.NE.2) GO TO 2658
      ISHOC=ISHOC+1
      IF(NSTAR.EQ.1) ISHOC=ISHOC-2
 2658 CONTINUE
      IF(IHALT.EQ.1) STOP
      IF(IFLIP.EQ.2.AND.N.GT.NPTS) STOP
      GO TO (4300,4301,4302,4303),ICMP
 4301 IF(ICOWL.EQ.0) STOP
      ICMPLT=2
      IUNDR=1
      CALL COWL(-1.)
      IPM=1
 4302 IPM=IPM+1
      IF(IPM.GT.MM-3)ICMPLT=0
      IF(IPM.GT.MM-3)GO TO 8104
      LMAX=KMAX+1
      DO 4306 J=1,NSP
      ALPN(J,1)=ALPM(J,IPM)
 4306 ALPDUM(J)=ALPM(J,IPM)
      D=0.
      CALL INT(0.,XM(IPM),YM(IPM),THM(IPM),PM(IPM),QM(IPM),RHM(IPM),
     1RM(IPM),WM(IPM),GM(IPM),EMM(IPM),XMUM(IPM),TM(IPM),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,XN(1),YN(1),THN(1),PN(1),QN(1),RHON(1),RN(1),WN(1),GAMN(1),
     1EMN(1),XMUN(1),TN(1),ALPDUM,0,IEQ)
      GO TO 8060
 4303 ICMPLT=3
      STOP
 4300 IF(X(1).EQ.XCOWLH.AND.IPP.EQ.NPTS.AND.IOVER.NE.2) GO TO 4301
      IF(N.GT.NPTS) GO TO 8104
      LMAX=LMAX+2
      L=1
      K=1
      D=0.
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      DO 510 J=1,NSP
      ALPN(J,L)=ALPF(J,N)
  510 ALPDUM(J)=ALPF(J,N)
      CALL INT (0.,XF(N),YF(N),THF(N),PF(N),QF(N),RHOF(N),RF(N),
     1WF(N),GAMF(N),EMF(N),XMUF(N),TF(N),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,XN(L),YN(L),THN(L),PN(L),QN(L),RHON(L),RN(L),WN(L),GAMN(L),
     1EMN(L),XMUN(L),TN(L),ALPDUM,1,IEQ)
      IFENC1=1
      IF(IFENCE.EQ.1.AND.XN(L).EQ.XCOWLH.AND.N.EQ.NPTS) GO TO 2601
      IFENC1=0
      GO TO 8060
 8104 ASL=TAN(TH(1))
      ACH=TAN(TH(2)+XMU(2))
      THSL=TH(1)
      CALL GEM(X(2),Y(2),ACH,X(1),Y(1),ASL,XN(1),YDUM)
      DELTH=XN(1)-X(1)
      IF((DELTH/TEST).GT.1.) GO TO 9061
      IT=1
      IER=0
      IF(IUNDR.GT.0)GO TO 9060
      CALL BODU(X(1),Y(1),TH(1),X(2),Y(2),ACH,XN(1),YDUM ,THN(1))
      THSL=THN(1)
      IF(IOVER.NE.2) GO TO 694
      YN(1)=-YN(1)
      THN(1)=-THN(1)
  694 CONTINUE
      DELTH=ABS(THN(1)-TH(1))
      IF(DELTH.GT.THST)GO TO 9061
      DELTH=XN(1)-X(1)
      IF((DELTH/TEST).LT.1.) GO TO 9060
 9061 LMAX=KMAX+1
      DO 9000 M1=2,KMAX
      L=KMAX-M1+2
      I=L+1
      D=0.
      DO 9001 J=1,NSP
      ALP(J,I)=ALP(J,L)
 9001 ALPDUM(J)=ALP(J,L)
      CALL INT(0.,X(L),Y(L),TH(L),P(L),Q(L),RHO(L),R(L),W(L),GAM(L),
     1EM(L),XMU(L),T(L),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,X(I),Y(I),TH(I),P(I),Q(I),RHO(I),R(I),W(I),GAM(I),EM(I),
     1XMU(I),T(I),ALPDUM,0,IEQ)
 9000 CONTINUE
      ISHOC=ISHOC+1
      KMAX=KMAX+1
      RAT=.5
      DO 9003 J=1,NSP
      ALP(J,2)=ALP(J,1)+RAT*(ALP(J,3)-ALP(J,1))
 9003 ALPDUM(J)=ALP(J,2)
      CALL INT(RAT,X(1),Y(1),TH(1),P(1),Q(1),RHO(1),R(1),W(1),GAM(1),
     1EM(1),XMU(1),T(1),X(3),Y(3),TH(3),P(3),Q(3),RHO(3),R(3),W(3),
     1GAM(3),EM(3),XMU(3),T(3),X(2),Y(2),TH(2),P(2),Q(2),RHO(2),R(2),
     1W(2),GAM(2),EM(2),XMU(2),T(2),ALPDUM,1,IEQ)
      GO TO 8104
 9060 LMAX=KMAX
```

```
      A=1.
      B=0.
      IF(ISHOC.EQ.1) BETN=BET
 8000 CONTINUE
      IT=1
      IER=0
      IF(B.EQ.0) THN(1)=THSL
 8030 EMSL=XM3(.5,.5,TH(1),THN(1))
      EM1=XM1(A,B,TH(2),XMU(2),THN(1),XMUN(1))
      IF(ISHOC.EQ.1) EM1=.5*(TAN(BET)+TAN(BETN))
      CALL GEM(X(2),Y(2),EM1,X(1),Y(1),EMSL,XN(1),YN(1))
      IF(IUNDR.GT.0)GOT O 8020
      CALL BODU(X(1),Y(1),TH(1),X(2),Y(2),EM1,XN(1),YN(1),THN(1))
      THSL=THN(1)
      IF(IOVER.NE.2) GO TO 698
      YN(1)=-YN(1)
      THN(1)=-THN(1)
  698 CONTINUE
 8020 A1=F1(A,B,XMU(2),GAM(2),P(2),XMUN(1),GAMN(1),PN(1))
      XDUM2=X(2)-XOR(NXXJ-1)
      XDUMN=XN(1)-XOR(NXXJ-1)
      A2=F2(A,B,1.,XJ,XJ1,XDUM2,Y(2),TH(2),XMU(2),XDUMN,YN(1),THN(1),XMU
     1N(1))
      DUM1=A2*(XN(1)-X(2))
      IF(XJ1.GT.0.) DUM1=A2*ALOG(XDUMN/XDUM2)
      DUM=        (TH(2)-THN(1)-DUM1)/A1
      PN(1)=P(2)*EXP(DUM)
      IF(IUNDR.EQ.0)GO TO 1801
      P2=PN(1)/P(1)
      CALL PRM(P2,TH(1),EMC1,TH2T,EMC2,-1)
      ER4=TH2T-THN(1)
      IF(ABS(ER4).LT.1.E-04)GO TO 1801
      CALL ERR(IER,IT,THN(1),ER4,1.01,THN1,ER1)
      IF(IER.EQ.0)GO TO 73
      WRITE(6,17)
   17 FORMAT(1X,*  TOO MANY ITERATIONS IN BODU CONTACT  *)
      STOP
   73 IT=IT+1
      GO TO 8030
 1801 CONTINUE
      DO 8050 J=1,NSP
      ALPN(J,1)=ALP(J,1)
 8050 ALPDUM(J)=ALPN(J,1)
      CALL SL(P(1),Q(1),RHO(1),R(1),W(1),GAM(1),EM(1),XMU(1),T(1),
     1PN(1),QN(1),RHON(1),RN(1),WN(1),GAMN(1),EMN(1),XMUN(1),TN(1),
     1ALPDUM,IEQ,A,B)
      IF(B.EQ.0..OR.IUNDR.EQ.1)GO TO 1798
      IF(XN( 1).GT.XCOWL-1.E-04) GO TO 1798
      IF(XN( 1).GT.XXJ1(NXXJ)-1.E-04) GO TO 1798
C *****COMPUTE  COWL AND SIDEWALL FORCES  **********C
      Z1=AXX(NXXJ-1)*(X (1)-XBP)+BXX(NXXJ-1)
      Z2=AXX(NXXJ-1)*(XN(1)-XBP)+BXX(NXXJ-1)
      CALL LTHM( X(1),Y(1),Z1,X(1),Y(1),-Z1,XN(1),YN(1),-Z2,XN(1),
     1YN(1),Z2,P(1),P(1),PN(1),PN(1),Q(1),Q(1),QN(1),QN(1),RHO(1),
     2RHO(1),RHON(1),RHON(1),R(1),R(1),RN(1),RN(1),W(1),W(1),WN(1),
     3WN(1),TH(1),TH(1),THN(1),THN(1),ALPDUM,.25,.25,.25,.25,
     4XTHX,YLFT,XMOM,CF,ST,1)
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```
      STU=ST
      IF(KSIDE.EQ.0)GO TO 1798
      Z4=AXX(NXXJ-1)*(X(2)-XBP)+BXX(NXXJ-1)
      DO 2031 J=1,NSP
 2031 ALPDUM(J)=(ALP(J,1)+ALP(J,2))/2.
      CALL LTHM(X(1),Y(1),Z1,XN(1),YN(1),Z2,XN(1),YN(1),Z2,X(2),Y(2),
     1Z4,P(1),PN(1),PN(1),P(2),Q(1),QN(1),QN(1),Q(2),RHO(1),RHON(1),
     2RHON(1),RHO(2),R(1),RN(1),RN(1),R(2),W(1),WN(1),WN(1),W(2),
     3TH(1),THN(1),THN(1),TH(2),ALPDUM,.33333,.33333,0.,.33333,
     4XTHS,YLFTS,XMOMS,CF,ST,3)
      STS(1)=ST
 1798 IF(B.GT.0.) GO TO 8049
      A=.5
      B=.5
      GO TO 8000
 8049 IF(ISHOC.NE.1) GO TO 2600
      CALL SHOCPT(ISHOC,3,BET,BETN,A,B)
      BET=THN(2)-(BETN-THN(1))
      IGG=1
 2625 CALL SHOCK(BET,QN(2),THN(2),GAMN(2),EMN(2),RHON(2),PN(2),WN(2),
     1RN(2),QN(1),TH2,GAMN(1),EMN(1),RHON(1),PN(1),WN(1),RN(1),TN(1),
     1XMUN(1),-1.)
      ER4=THN(1)-TH2
      IF(ABS(ER4).LT.1.E-04) GO TO 2601
      IGG=IGG+1
      IF(IGG.GT.15) GO TO 2627
      IF(IGG.GT.2) GO TO 2628
      ER1=ER4
      BETP=BET
      BET=BET+.02
      GO TO 2625
 2627 WRITE(6,2629)
 2629 FORMAT(* ERROR IN BETA LOOP IN MAIN*)
      STOP
 2628 DUMM=BETP-ER1*(BET-BETP)/(ER4-ER1)
      ER1=ER4
      BETP=BET
      BET=DUMM
      GO TO 2625
 2600 CONTINUE
      IF(IFLIP.EQ.1.AND.XN(1).GT.XFINAL) IHALT=1
      IF(XN(1).LE.XCOWL-1.E-04.AND.XN(1).LE.XXJ1(NXXJ)-1.E-04) GOTO 8060
      XNN=XCOWL
      IF(XN(1).GT.XXJ1(NXXJ)-1.E-04) XNN=XXJ1(NXXJ)
      RAT=(XNN  -X(1))/(XN(1)-X(1))
      DO 3519 J=1,NSP
      ALPN(J,1)=ALP(J,1)
 3519 ALPDUM(J)=ALP(J,1)
      CALL INT(RAT,X(1),Y(1),TH(1),P(1),Q(1),RHO(1),R(1),W(1),GAM(1),
     1 EM(1),XMU(1),T(1),
     1XN(1),YN(1),THN(1),PN(1),QN(1),RHON(1),RN(1),WN(1),GAMN(1),
     1EMN(1),XMUN(1),TN(1),
     1XN(1),YN(1),THN(1),PN(1),QN(1),RHON(1),RN(1),WN(1),GAMN(1),
     1EMN(1),XMUN(1),TN(1), ALPDUM,1,IEQ)
      XN(1)=XNN
      XZ=XN(1)-XINTU
      L6=5
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      IF(XZ.LT.XXU(5))L6=4
      IF(XZ.LT.XXU(4))L6=3
      IF(XZ.LT.XXU(3))L6=2
      IF(XZ.LT.XXU(2))L6=1
      YN(1)=AA1(L6,1)*XZ*XZ+AA2(L6,1)*XZ+AA3(L6,1)
      THN(1)=ATAN(2.*AA1(L6,1)*XZ+AA2(L6,1))
C *****COMPUTE  COWL AND SIDEWALL FORCES  **********C
      Z1=AXX(NXXJ-1)*(X (1)-XBP)+BXX(NXXJ-1)
      Z2=AXX(NXXJ-1)*(XN(1)-XBP)+BXX(NXXJ-1)
      CALL LTHM( X(1),Y(1),Z1,X(1),Y(1),-Z1,XN(1),YN(1),-Z2,XN(1),
     1YN(1),Z2,P(1),P(1),PN(1),PN(1),Q(1),Q(1),QN(1),QN(1),RHO(1),
     2RHO(1),RHON(1),RHON(1),R(1),R(1),RN(1),RN(1),W(1),W(1),WN(1),
     3WN(1),TH(1),TH(1),THN(1),THN(1),ALPDUM,.25,.25,.25,.25,
     4XTHX,YLFT,XMOM,CF,ST,1)
      STU=ST
      IF(KSIDE.EQ.0)GO TO 2601
      Z4=AXX(NXXJ-1)*(X(2)-XBP)+BXX(NXXJ-1)
      DO 2033 J=1,NSP
 2033 ALPDUM(J)=(ALP(J,1)+ALP(J,2))/2.
      CALL LTHM(X(1),Y(1),Z1,XN(1),YN(1),Z2,XN(1),YN(1),Z2,X(2),Y(2),
     1Z4,P(1),PN(1),PN(1),P(2),Q(1),QN(1),QN(1),Q(2),RHO(1),RHON(1),
     2RHON(1),RHO(2),R(1),RN(1),RN(1),R(2),W(1),WN(1),WN(1),W(2),
     3TH(1),THN(1),THN(1),TH(2),ALPDUM,.33333,.33333,0.,.33333,
     4XTHS,YLFTS,XMOMS, CF,ST,3)
      STS(1)=ST
 2601 CONTINUE
      ICMPLT=1
      IF(XN(1).EQ.XCOWL)XCOWL=1.E+06
      IF(IDELG.EQ.1)  GO TO 2622
      IF(XJ1.EQ.0..AND.IOVER.EQ.0) GO TO 8060
 2622 CONTINUE
      IX=1
      IF(IFLIP.EQ.1) IX=2
 2655 IAA=IAA+1
      D=0.
      DO 3470 J=1,NSP
      ALPDUM(J)=ALPN(J,IX)
 3470 ALPF(J,IAA)=ALPN(J,IX)
      CALL INT(0.,XN(IX),YN(IX),THN(IX),PN(IX),QN(IX),RHON(IX),
     1RN(IX),WN(IX),GAMN(IX),EMN(IX),XMUN(IX),TN(IX),
     1D,D,D,D,D,D,D,D,D,D,D,D ,
     1XF(IAA),YF(IAA),THF(IAA),PF(IAA),QF(IAA),RHOF(IAA),RF(IAA),
     1WF(IAA),GAMF(IAA),EMF(IAA),XMUF(IAA),TF(IAA),ALPDUM,0,IEQ)
      IF(IX.EQ.1) GO TO 2656
      IX=1
      GO TO 2655
 2656 IF(IFLIP.EQ.1) IAA=IAA-1
      ICMPLT=0
      NSTAR=0
      IF(XN(1)+.0001.GE.XTJ1) XJ1=0.
      IF(IFLIP.NE.1                    ) NXXJ=NXXJ+1
      IF(IFENC1.EQ.1) IFENCE=0
      IF(NXXJ.GT.NXXJ1) NXXJ=NXXJ1+1
      IF(IFLIP.GT.0) GO TO 2602
      IF(ICOWL.EQ.0) GO TO 7593
      RP=PM (MM)/PF(IAA)*PIN
      IF(RP.GT.1.) GO TO 5989
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 7593 NPTS=IAA
      IOVER=0
      IAA=1
      GO TO 7211
 5989 CONTINUE
      EMEXT=EMINF*QM(MM)/SQRT(TM(MM))
      CALL COWLO(IAA,THM(MM),EMEXT,BET,PM (MM))
      XINTU=XINTL
      DO 691 I13=1,5
      XXU(I13)=XXL(I13)
      AA1(I13,1)=AA1(I13,2)
      AA2(I13,1)=AA2(I13,2)
  691 AA3(I13,1)=AA3(I13,2)
 2602 CONTINUE
      NPTS=IAA+1
      IFLIP=IFLIP+1
      IF(IFLIP.GT.1) XXP=XFINAL
      IAA=1
      LSTT=0
      IOVER=2
      CALL INDATA
      BET=-BET
      ISHOC=1
      GO TO 7211
 8060 CONTINUE
      LM=LMAX-1
      IF(IDELG.EQ.1 .AND. IAA.GT.1)  LM=1000
      IF(XJ1.GT.0..AND.IAA.GT.1) LM=1000
      IF(IOVER.EQ.2.AND.LSTT.EQ.1) LM=1000
      LST=0
      LTH=1
      IF(NSTAR.EQ.0)LTH=0
      L=1
      M=0
      IDPT=0
      LWUZ=1000
      XXP=XFINAL
      IF(NSTAR.EQ.1) M=2
      IF(ICMPLT.EQ.2) M=1
C *******  COMPUTE SIDEWALL FORCES    ******************  C
 5520 IF(KSIDE.EQ.0.OR.L.EQ.1)GO TO 5521
      NM=M-1
      LTH=LTH+1
      IF(M.EQ.1)NM=1
      Z1=AXX(NXXJ-1)*(X (NM)-XBP)+BXX(NXXJ-1)
      Z2=AXX(NXXJ-1)*(XN(K )-XBP)+BXX(NXXJ-1)
      Z3=AXX(NXXJ-1)*(XN(L )-XBP)+BXX(NXXJ-1)
      Z4=AXX(NXXJ-1)*(X (M )-XBP)+BXX(NXXJ-1)
      XK1=.25 $XK2=.25 $XK3=.25 $XK4=.25
      IF(M.GT.1)GO TO 683
      XK1=.33333 $XK2=.33333 $XK3=.33333 $XK4=0.
  683 CONTINUE
      DO 687 J=1,NSP
  687 ALPDUM(J)=XK1*ALP(J,NM)+ALPN(J,K)*XK2+XK3*ALPN(J,L)+XK4*ALP(J,M)
      CALL LTHM(X(NM),Y(NM),Z1,XN(K),YN(K),Z2,XN(L),YN(L),Z3,X(M),Y(M),
     1Z4,P(NM),PN(K),PN(L),P(M),Q(NM),QN(K),QN(L),Q(M),RHO(NM),RHON(K),
     2RHON(L),RHO(M),R(NM),RN(K),RN(L),R(M),W(NM),WN(K),WN(L),W(M),
```

```
     3TH(NM),THN(K),THN(L),TH(M),ALPDUM,XK1,XK2,XK3,XK4,
     4XTHS,YLFTS,XMOMS,CF,ST,3)
      STS(LTH)=ST
      IF(L.EQ.LMAX)GO TO 265
5521  L=L+1
      IF(L.GT.LM) GO TO 6520
      K=L-1
 678  M=M+1
      A=1.
      B=0.
      CALL FUZZY(K,L,M,N,LMAX,KMAX,NPTS,IPP,IFZ)
      IF(IFZ.GT.0)GO TO 265
 250  CONTINUE
      IF(L.EQ.ISHOC+1) CALL SHOCPT(ISHOC,M,BET,BETN,A,B)
      IF(L.NE.ISHOC+1.OR.B.EQ.0..OR.IFLIP.NE.1) GO TO 2603
      IPL=3
2684  POLYC=-AA3(IPL,1)-YN(L)+TAN(BETN)*(XN(L)-XINTU)
      POLYB=-AA2(IPL,1)-TAN(BETN)
      POLYA=-AA1(IPL,1)
      IF(POLYA.NE.0.)
     1XXP =(-POLYB-SQRT(POLYB*POLYB-4.*POLYA*POLYC))/(2.*POLYA)
      IF(POLYA.EQ.0.) XXP =-POLYC/POLYB
      XXP =XXP +XINTU
      IF(XXP .GE.XXU(IPL)) GO TO 2603
      IPL=IPL-1
      GO TO 2684
2603  CONTINUE
      IF(L.EQ.ISHOC+1) GO TO 3003
      EM1=XM1(A,B,TH(M),XMU(M),THN(L),XMUN(L))
      EM9=EM1
      IF(L.EQ.ISHOC) EM1=TAN(BET)
      IF(L.EQ.ISHOC.AND.M.GT.1)EM1=TAN(BET+THN(L-1)+XMUN(L-1)-TH(M-1)
     1-XMU(M-1))
      EM2=XM2(A,B,THN(K),XMUN(K),THN(L),XMUN(L))
      XN(L)=(YN(K)-Y(M)+EM1*X(M)-EM2*XN(K))/(EM1-EM2)
      YN(L)=Y(M)+EM1*(XN(L)-X(M))
      IF(B.GT.0.) GO TO 681
      IDROP=0
      BETT=BET
      IF(M.GT.1.AND.IOVER.EQ.2)BETT=BET+THN(L-1)+XMUN(L-1)-TH(M-1)-XMU(M
     1-1)
      IF(L.EQ.ISHOC-1) CALL DRTEST(XN(L),YN(L),EM1,BETT,IDROP,+1,M)
      IF(L.EQ.ISHOC+2) CALL DRTEST(XN(L),YN(L),EM1,BETN,IDROP,-1,M)
      IF(IDROP.EQ.0) GO TO 681
      LMAX=LMAX-1
      LM=LM-1
      IF(L.LT.ISHOC) ISHOC=ISHOC-1
      GO TO 678
 681  CONTINUE
      IF(L.NE.ISHOC) GO TO 601
      YSHOC=Y(M)
      XSHOC=X(M)
      IF(L.GT.2) GO TO 602
      YDUM=YN(L)-EM9*(XN(L)-X(M))
      XDUM=X(M)
      RAT=(YDUM-Y(M))/(YN( 1)-Y(M))
      D=0.
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      DO 644 J=1,NSP
      ALP(J,M)=ALP(J,M)+RAT*(ALPN(J,1)-ALP(J,M))
  644 ALPDUM(J)=ALP(J,M)
      CALL INT(RAT,D,D,TH(M),P(M),Q(M),RHO(M),R(M),W(M),GAM(M),
     1EM(M),XMU(M),T(M),D,D,THN(1),PN(1),QN(1),RHON(1),RN(1),WN(1),
     1GAMN(1),EMN(1),XMUN(1),TN(1),D,D,TH(M),P(M),Q(M),RHO(M),R(M),
     1W(M),GAM(M),EM(M),XMU(M),T(M),ALPDUM,1,IEQ)
      GO TO 601
  602 CONTINUE
      EM8=XM2(.5,.5,TH(M-1),XMU(M-1),TH(M),XMU(M))
      YDUM=(EM9*Y(M)-EM8*YN(L)+EM8*EM9*(XN(L)-X(M)))/(EM9-EM8)
      XDUM=XN(L)-(YN(L)-YDUM)/EM9
      RAT=(YDUM-Y(M))/(Y(M-1)-Y(M))
      D=0.
      DO 604 J=1,NSP
      ALP(J,M)=ALP(J,M)+RAT*(ALP(J,M-1)-ALP(J,M))
  604 ALPDUM(J)=ALP(J,M)
      CALL INT(RAT,D,D,TH(M),P(M),Q(M),RHO(M),R(M),W(M),GAM(M),
     1EM(M),XMU(M),T(M),D,D,TH(M-1),P(M-1),Q(M-1),RHO(M-1),R(M-1),
     1W(M-1),GAM(M-1),EM(M-1),XMU(M-1),T(M-1),D,D,TH(M),P(M),Q(M),
     1RHO(M),R(M),W(M),GAM(M),EM(M),XMU(M),T(M),ALPDUM,1,IEQ)
  601 CONTINUE
      A1=F1(A,B,XMU(M),GAM(M),P(M),XMUN(L),GAMN(L),PN(L))
      B1=F1(A,B,XMUN(K),GAMN(K),PN(K),XMUN(L),GAMN(L),PN(L))
      XDUMK=XN(K)-XOR(NXXJ-1)
      XDUMM=X(M)-XOR(NXXJ-1)
      XDUML=XN(L)-XOR(NXXJ-1)
      A2=F2(A,B,1.,XJ,XJ1,XDUMM,Y(M),TH(M),XMU(M),XDUML,YN(L),THN(L),XMU
     1N(L))
      B2=F2(A,B,-1.,XJ,XJ1,XDUMK,YN(K),THN(K),XMUN(K),XDUML,YN(L),THN(L)
     1,XMUN(L))
      DUM1=-(A2+B2)*XN(L)+A2*X(M)+B2*XN(K)
      IF(XJ1.GT.0.)DUM1=-(A2*ALOG(XDUML/XDUMM)+B2*ALOG(XDUML/XDUMK))
      DUM  =(A1*ALOG(P(M))+B1*ALOG(PN(K))+TH(M)-THN(K)+DUM1)/(A1+B1)
      PN(L)=EXP(DUM)
      DUM=ALOG(P(M)/PN(L))*A1
      DUM2=XN(L)-X(M)
      IF(XJ1.NE.0.) DUM2=ALOG(XDUML/XDUMM)
      THN(L)=DUM+TH(M)-A2*DUM2
  253 CONTINUE
      CALL DPOINT(K,L,M,N,NPTS,A,B)
      CALL SL(PD,QD,RHD,RD,WD,GAMD,EMD,XMUD,TD,PN(L),QN(L),RHON(L),
     1RN(L),WN(L),GAMN(L),EMN(L),XMUN(L),TN(L),ALPDUM,IEQ,A,B)
      DO 1502 J=1,NSP
 1502 ALPN(J,L)=ALPDUM(J)
 3003 CONTINUE
      IF(IDPT.EQ.0) GO TO 8400
      IF(B.GT.0.) GO TO 8401
      A=.5
      B=.5
      GO TO 253
 8400 CONTINUE
      IF(B.GT.0.) GO TO7520
      IF(L.NE.ISHOC) GO TO 606
      IF(L.GT.2) GO TO 650
      RAT=(YN( 1)-YSHOC)/(YN( 1)-Y(M))
      Y(M)=YSHOC
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      X(M)=XSHOC
      D=0.
      DO 655 J=1,NSP
      ALP(J,M)=ALP(J,M)+RAT*(ALPN(J,1)-ALP(J,M))
  655 ALPDUM(J)=ALP(J,M)
      CALL INT(RAT,D,D,TH(M),P(M),Q(M),RHO(M),R(M),W(M),GAM(M),
     1EM(M),XMU(M),T(M),D,D,THN(1),PN(1),QN(1),RHON(1),RN(1),WN(1),
     1GAMN(1),EMN(1),XMUN(1),TN(1),D,D,TH(M),P(M),Q(M),RHO(M),R(M),
     1W(M),GAM(M),EM(M),XMU(M),T(M),ALPDUM,1,IEQ)
      GO TO 606
  650 CONTINUE
      RAT=(Y(M-1)-YSHOC)/(Y(M-1)-Y(M))
      Y(M)=YSHOC
      X(M)=XSHOC
      D=0.
      DO 605 J=1,NSP
      ALP(J,M)=ALP(J,M)+RAT*(ALP(J,M-1)-ALP(J,M))
  605 ALPDUM(J)=ALP(J,M)
      CALL INT(RAT,D,D,TH(M),P(M),Q(M),RHO(M),R(M),W(M),GAM(M),
     1EM(M),XMU(M),T(M),D,D,TH(M-1),P(M-1),Q(M-1),RHO(M-1),R(M-1),
     1W(M-1),GAM(M-1),EM(M-1),XMU(M-1),T(M-1),D,D,TH(M),P(M),Q(M),
     1RHO(M),R(M),W(M),GAM(M),EM(M),XMU(M),T(M),ALPDUM,1,IEQ)
  606 CONTINUE
      A=.5
      B=.5
      GO TO 250
 7520 CONTINUE
      IF(IFENCE.EQ.0.OR.XN(1).NE.XCOWLH) GO TO 3108
      XXP=(YN(L)-BFENCE)/AFENCE+XBP
      IF(XN(L).LT.XXP) GO TO 520
      DUM=(YN(L)-YN(K))/(XN(L)-XN(K))
      XXP=(AFENCE*XBP-BFENCE-DUM*XN(K)+YN(K))/(AFENCE-DUM)
 3108 CONTINUE
      IF(IDELG.EQ.1)  GO TO 2623
      IF(XJ1.EQ.0..AND.IOVER.EQ.0) GO TO 520
 2623 CONTINUE
      IF(XN(L).LT.XXJ1(NXXJ).AND.XN(L).LT.XXP) GO TO 520
      IF(LST.GT.0) GO TO 520
      LST=1
      XNN=XXP
      IF(XN(L).GE.XXJ1(NXXJ)) XNN=XXJ1(NXXJ)
      RAT=(XNN-XN(K))/(XN(L)-XN(K))
      IAA=IAA+1
      IF(IPP.GT.NPTS.OR.IAA.LT.IPP)GO TO 3999
      WRITE(6,3998)
 3998 FORMAT(* INDEXING IN CHANGE OF ORIGIN OVERLAPS INITIAL DATA IAA EQ
     1UALS IPP*)
      STOP
 3999 XN(L  )=XNN
      YN(L  )=YN(K)+RAT*(YN(L)-YN(K))
      THN(L  )=THN(K)+RAT*(THN(L)-THN(K))
      DUM1=ALOG(PN(K))
      DUM2=ALOG(PN(L))
      DUM=DUM1+RAT*(DUM2-DUM1)
      PN(L  )=EXP(DUM)
      IDPT=1
      A=1.
```

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      B=0.
      GO TO 253
 8401 IDPT=0
      IF(IFENCE.EQ.0.OR.XN(1).NE.XCOWLH) GO TO 9804
      IF(IAA.LT.3.OR.XF(1).EQ.XFENCE) GO TO 9804
      WRITE(6,9805)
 9805 FORMAT(* FENCE MAY NOT BE ENTIRELY SUPERSONIC - CHECK FLOW FIELD*)
      STOP
 9804 CONTINUE
      DO 8402 J=1,NSP
      ALPDUM(J)=ALPN(J,L)
 8402 ALPF(J,IAA)=ALPN(J,L)
      D=0.
      CALL INT(0.,XN(L),YN(L),THN(L),PN(L),      QN(L),RHON(L),RN(L),
     1WN(L),GAMN(L),EMN(L),XMUN(L),TN(L),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,XF(IAA),YF(IAA),THF(IAA),PF(IAA),QF(IAA),RHOF(IAA),RF(IAA),
     1WF(IAA),GAMF(IAA),EMF(IAA),XMUF(IAA),TF(IAA),ALPDUM,0,IEQ)
      IF(IAA.EQ.2.AND.LSTT.EQ.0) GO TO 520
C  ******* COMPUTE SIDEWALL FORCES  ********** C
      IF(KSIDE.EQ.0)GO TO 521
      LT6=LTH+2
      MI=M
      I=M+1
      IF(I.GT.KMAX)GO TO 521
  519 Z1=AXX(NXXJ-1)*(X (MI)-XBP)+BXX(NXXJ-1)
      Z2=AXX(NXXJ-1)*(XN(L )-XBP)+BXX(NXXJ-1)
      Z3=AXX(NXXJ-1)*(X (I )-XBP)+BXX(NXXJ-1)
      Z4=Z3
      DO 5363 J=1,NSP
 5363 ALPDUM(J)=(ALP(J,MI)+ALPN(J,L)+ALP(J,I))/3.
      CALL LTHM(X(MI),Y(MI),Z1,XN(L),YN(L),Z2,X(I),Y(I),Z3,X(I),Y(I),
     1Z4,P(MI),PN(L),P(I),P(I),Q(MI),QN(L),Q(I),Q(I),RHO(MI),RHON(L),
     2RHO(I),RHO(I),R(MI),RN(L),R(I),R(I),W(MI),WN(L),W(I),W(I),
     3TH(MI),THN(L),TH(I),TH(I),ALPDUM,.33333,.33333,.33333,0.,
     4XTHS,YLFTS,XMOMS,CF,ST,3)
      STS(LT6)=ST
      IF(I.EQ.KMAX)GO TO 521
      I=I+1
      LT6=LT6+1
      MI=MI+1
      GO TO 519
  521 LMAX=L
      LWUZ=LMAX
      IF(KSIDE.EQ.0)GO TO 265
      GO TO 5520
  520 CONTINUE
      IF(XN(L).LT.XXJ1(NXXJ).AND.XN(L).LT.XXP) GO TO 5520
      IF(LSTT.EQ.0) GO TO 5520
      LMAX=L
      LWUZ=LMAX
      GO TO 265
 6520 CONTINUE
      A=1.
      B=0.
      L=LMAX
      KK=KMAX
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      K=LMAX-1
 5011 CONTINJE
      IF(B.EQ.0.) THN(L)=TH(KK)
      IB=1
      IER=0
  630 CONTINUE
      EMSL=XM3(.5,.5,TH(KK),THN(L))
      EM2=XM2(A,B,THN(K),XMUN(K),THN(L),XMUN(L))
      IF(IDESGN.EQ.0.AND.IFLIP.NE.1)
     1CALL BODL(X(KK),Y(KK),TH(KK),XN(K),YN(K),EM2,XN(L),YN(L),THN(L))
      IF(IFLIP.NE.1) GO TO 631
      CALL GEM(X(KK),Y(KK),EMSL,XN(K),YN(K),EM2,XN(L),YN(L))
  631 CONTINUE
      B1=F1(A,B,XMUN(K),GAMN(K),PN(K),XMUN(L),GAMN(L),PN(L))
      XDUMK=XN(K)-XOR(NXXJ-1)
      XDUML=XN(L)-XOR(NXXJ-1)
      B2=F2(A,B,-1.,XJ,XJ1,XDUMK,YN(K),THN(K),XMUN(K),XDUML,YN(L),THN(L)
     1,XMUN(L))
      DUM1=B2*(XN(L)-XN(K))
      IF(XJ1.GT.0.)DUM1=B2*ALOG(XDUML/XDUMK)
      DUM=          (THN(L)-THN(K)-DUM1)/B1
      PN(L)=PN(K)*EXP(DUM)
 1821 CONTINUE
      DO 1503 J=1,NSP
      ALPN(J,L)=ALP(J,KK)
 1503 ALPDUM(J)=ALPN(J,L)
      CALL SL(P(KK),Q(KK),RHO(KK),R(KK),
     1                                W(KK),GAM(KK),EM(KK),XMU(KK),T(KK),
     1PN(L),QN(L),RHON(L),RN(L),WN(L),GAMN(L),EMN(L),XMUN(L),TN(L),
     1ALPDUM,IEQ,A,B)
      IF(B.EQ.0..OR.IFLIP.EQ.1)GO TO 1523
      L1=LMAX
      IF(XN(L1).GT.XXJ1(NXXJ)-1.E-04) GO TO 1523
C ******* COMPUTE FORCES ON LOWER SURFACE AND SIDEWALL *******C
      Z1=AXX(NXXJ-1)*(X (KK)-XBP)+BXX(NXXJ-1)
      Z2=AXX(NXXJ-1)*(XN(L )-XBP)+BXX(NXXJ-1)
      Z3=-Z2
      Z4=-Z1
      CALL LTHM(X(KK),Y(KK),Z1,XN(L),YN(L),Z2,XN(L),YN(L),Z3,X(KK),Y(KK)
     1,Z4,P(KK),PN(L),PN(L),P(KK),Q(KK),QN(L),QN(L),Q(KK),RHO(KK),
     2RHON(L),RHON(L),RHO(KK),R(KK),RN(L),RN(L),R(KK),W(KK),WN(L),WN(L),
     3W(KK),TH(KK),THN(L),THN(L),TH(KK),ALPDUM,.25,.25,.25,.25,XTHX,YLFT
     4,XMOM,CF,ST,2)
      STL=ST
      IF(KSIDE.EQ.0)GO TO 1523
      LTH=LTH+1
      DO 1596 J=1,NSP
 1596 ALPDUM(J)=(ALP(J,KK)+ALPN(J,K))/2.
      Z1=AXX(NXXJ-1)*(X (KK)-XBP)+BXX(NXXJ-1)
      Z2=AXX(NXXJ-1)*(XN(K )-XBP)+BXX(NXXJ-1)
      Z3=AXX(NXXJ-1)*(XN(L )-XBP)+BXX(NXXJ-1)
      Z4=Z3
      CALLLTHM(X(KK),Y(KK),Z1,XN(K),YN(K),Z2,XN(L),YN(L),Z3,XN(L),YN(L),
     1Z4,P(KK),PN(K),PN(L),PN(L),Q(KK),QN(K),QN(L),QN(L),RHO(KK),RHON(K)
     2,RHON(L),RHON(L),R(KK),RN(K),RN(L),RN(L),W(KK),WN(K),WN(L),WN(L),
     3TH(KK),THN(K),THN(L),THN(L),ALPDUM,.33333,.33333,.33333,0.,
     4XTHS,YLFTS,XMOMS,CF,ST,3)
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      STS(LTH)=ST
 1523 IF(IFLIP.NE.1) GO TO 632
      P2=PN(L)/P(KK)
      CALL PRM(P2,TH(KK),EMC1   ,TH2T,EMC2,+1)
      ER4=TH2T-THN(L)
      IF(ABS(ER4).LT.1.E-04) GO TO 632
      CALL ERR(IER,IB,THN(L),ER4,1.01,THNL,ER1)
      IF(IER.EQ.0)GO TO 166
  633 WRITE(6,635)
  635 FORMAT(* ERROR IN PM LOOP AT CONTACT IN MAIN*)
      STOP
  166 IB=IB+1
      GO TO 630
  632 CONTINUE
      IF(B.GT.0.) GO TO1265
      A=.5
      B=.5
      GO TO 5011
 1265 IAAS=IAA
      IF(IFLIP.EQ.2.AND.XN(L).GE.XFINAL) IHALT=1
      IF(IHALT.EQ.1) GO TO 1802
      IF(XN(L).GE.XFINAL) GO TO 1802
      IF(IDELG.EQ.1)  GO TO 3109
      IF(XJ1.EQ.0..AND.IOVER.EQ.0) GO TO 265
      IF(IFENCE.EQ.0.OR.XN(1).NE.XCOWLH) GO TO 3109
      IF(XN(L).LT.XFENCE) GO TO 265
      XNN=XFENCE
      GO TO 3110
 3109 CONTINUE
      IF(XN(L).LT.XXJ1(NXXJ)) GO TO 265
 1802 CONTINUE
      XNN=XXJ1(NXXJ)
 3110 CONTINUE
      RAT=(XNN-X(KK))/(XN(L)-X(KK))
      IAA=1
      LSTT=1
      LWUZ=LMAX
      XF(IAA)=XNN
      IF(IFLIP.EQ.1) GO TO 2605
      XCH=XNN -XINTL
      LK=5
      IF(XCH.LT.XXL(5))LK=4
      IF(XCH.LT.XXL(4))LK=3
      IF(XCH.LT.XXL(3)) LK=2
      IF(XCH.LT.XXL(2)) LK=1
      YF(IAA)=AA1(LK,2)*XCH*XCH+AA2(LK,2)*XCH+AA3(LK,2)
      THF(IAA)=ATAN(2.*AA1(LK,2)*XCH+AA2(LK,2))
      GO TO 2606
 2605 YF(IAA)=Y(KK)+RAT*(YN(L)-Y(KK))
      THF(IAA)=ATAN(TAN(TH(KK))+RAT*(TAN(THN(L))-TAN(TH(KK))))
 2606 CONTINUE
      YN(L)=YF(IAA)
      THN(L)=THF(IAA)
      XN(L)=XF(IAA)
      PN(L)=P(KK)+RAT*(PN(L)-P(KK))
      QN(L)=Q(KK)+RAT*(QN(L)-Q(KK))
      TN(L)=T(KK)+RAT*(TN(L)-T(KK))
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      DO 3841 J=1,NSP
      ALPF(J,IAA)=ALP(J,KK)
      ALPN(J,L)=ALP(J,KK)
      ALPDUM(J)=ALPN(J,L)
 3841 CONTINUE
      CALL SL(P(KK),Q(KK),RHO(KK),R(KK),
     1                                W(KK),GAM(KK),EM(KK),XMU(KK),T(KK),
     1PN(L),QN(L),RHON(L),RN(L),WN(L),GAMN(L),EMN(L),XMUN(L),TN(L),
     1ALPDUM,IEQ,.5,.5)
      D=0.
      CALL INT(0.,XN(L),YN(L),THN(L),PN(L),      QN(L),RHON(L),RN(L),
     1WN(L),GAMN(L),EMN(L),XMUN(L),TN(L),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,DUM3   ,DUM1   ,DUM2    ,PF(IAA),QF(IAA),RHOF(IAA),RF(IAA),
     1WF(IAA),GAMF(IAA),EMF(IAA),XMUF(IAA),TF(IAA),ALPDUM,0,IEQ)
C ******* COMPUTE FORCES ON LOWER SURFACE AND SIDEWALL *******C
      Z1=AXX(NXXJ-1)*(X (KK)-XBP)+BXX(NXXJ-1)
      Z2=AXX(NXXJ-1)*(XN(L )-XBP)+BXX(NXXJ-1)
      Z3=-Z2
      Z4=-Z1
      CALL LTHM(X(KK),Y(KK),Z1,XN(L),YN(L),Z2,XN(L),YN(L),Z3,X(KK),Y(KK)
     1,Z4,P(KK),PN(L),PN(L),P(KK),Q(KK),QN(L),QN(L),Q(KK),RHO(KK),
     2RHON(L),RHON(L),RHO(KK),R(KK),RN(L),RN(L),R(KK),W(KK),WN(L),WN(L),
     3W(KK),TH(KK),THN(L),THN(L),TH(KK),ALPDUM,.25,.25,.25,.25,XTHX,YLFT
     4,XMOM,CF,ST,2)
      STL=ST
      IF(KSIDE.EQ.0)GO TO 264
      LTH=LTH+1
      DO 1597 J=1,NSP
 1597 ALPDUM(J)=(ALP(J,KK)+ALPN(J,K))/2.
      Z1=AXX(NXXJ-1)*(X (KK)-XBP)+BXX(NXXJ-1)
      Z2=AXX(NXXJ-1)*(XN(K )-XBP)+BXX(NXXJ-1)
      Z3=AXX(NXXJ-1)*(XN(L )-XBP)+BXX(NXXJ-1)
      Z4=Z3
      CALLLTHM(X(KK),Y(KK),Z1,XN(K),YN(K),Z2,XN(L),YN(L),Z3,XN(L),YN(L),
     1Z4,P(KK),PN(K),PN(L),PN(L),Q(KK),QN(K),QN(L),QN(L),RHO(KK),RHON(K)
     2,RHON(L),RHON(L),R(KK),RN(K),RN(L),RN(L),W(KK),WN(K),WN(L),WN(L),
     3TH(KK),THN(K),THN(L),THN(L),ALPDUM,.33333,.33333,.33333,0.,
     4XTHS,YLFTS,XMOMS,CF,ST,3)
      STS(LTH)=ST
  264 IAA=IAAS
  265 CONTINUE
C     IF(PN(LMAX).LE.PEN.AND.IDESGN.EQ.1) GO TO 7634
      CALL WUZZY(N,NPTS,KMAX,LMAX,IPP,IFZ,LWUZ)
      KMAX=LMAX
      BET=BETN
      EMC1=EMC2
      D=0.
      DO 270 K=1,KMAX
      DO 271 J=1,NSP
  271 ALP(J,K)=ALPN(J,K)
      DO 1504 J=1,NSP
 1504 ALPDUM(J)=ALP(J,K)
      CALL INT(0.,XN(K),YN(K),THN(K),PN(K),QN(K),RHON(K),RN(K),WN(K),
     1GAMN(K),EMN(K),XMUN(K),TN(K),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,X(K),Y(K),TH(K),P(K),Q(K),RHO(K),R(K),W(K),GAM(K),
```

```
     1EM(K),XMU(K),T(K),ALPDUM,0,IEQ)
  270 CONTINUE
      LMAX=KMAX
 7266 IF(N-NPTS) 7201,7202,500
 7201 N=N+1
      GO TO 500
 7202 CONTINUE
      NSTAR=1
      N=N+1
      GO TO 500
 9123 KTEST=KMAX/2
      KTEST1=(KMAX-1)/2
      KT3=KMAX-1
      IF(KTEST.EQ.KTEST1) KT3=KMAX
      I=0
      DO 6412 L=1,KT3,2
      I=I+1
      D=0.
      DO 6414 J=1,NSP
      ALPDUM(J)=ALP(J,L)
 6414 ALP(J,I)=ALP(J,L)
      CALL INT(0.,X(L),Y(L),TH(L),P(L),Q(L),RHO(L),R(L),W(L),GAM(L),
     1EM(L),XMU(L),T(L),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,X(I),Y(I),TH(I),P(I),Q(I),RHO(I),R(I),W(I),GAM(I),EM(I),
     1XMU(I),T(I),ALPDUM,0,IEQ)
 6412 CONTINUE
      IF(KTEST.EQ.KTEST1) GO TO 6413
      I=I+1
      L=KMAX
      D=0.
      DO 6415 J=1,NSP
      ALPDUM(J)=ALP(J,L)
 6415 ALP(J,I)=ALP(J,L)
      CALL INT(0.,X(L),Y(L),TH(L),P(L),Q(L),RHO(L),R(L),W(L),GAM(L),
     1EM(L),XMU(L),T(L),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,X(I),Y(I),TH(I),P(I),Q(I),RHO(I),R(I),W(I),GAM(I),EM(I),
     1XMU(I),T(I),ALPDUM,0,IEQ)
 6413 KMAX=KMAX/2+1
      LMAX=KMAX
      GO TO 6060
      END
```

```
      SUBROUTINE INDATA
      COMMON/HOT/AH(3),BH(3),CH(3),XSTR,PR,REC,REIN,RT,SH,ITW,IVIS
      COMMON/VISF/XVTHX,YVLFT,XVMOM
      COMMON/COWL/ICOWL,MM,XM(9),YM(9),PM(9),WM(9),RHM(9),THM(9),QM(9),
     1RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)
      COMMON/SHAPE/A1(5,2),A2(5,2),A3(5,2),XXU(5),XXL(5),XINTU,XINTL
      COMMON/LTM/XSHFT,YSHFT,XTHX,YLFT,XMOM,XTHS,YLFTS,XMOMS,KSIDE
      COMMON/XXJ/NXXJ1,XXJ1(6),AXX(6),BXX(6),XOR(6)
      COMMON/XFINAL/XFINAL
      COMMON /SP/ NSP
      COMMON/A/ TIN,CPIN,RO
      COMMON/B/ WTMOLE
      COMMON/D/ GAMINF,EMINF,RINF,WINF
      COMMON/F/A9,B9,IBOD,XWF,NBOD,YEND
      COMMON/ETX/XJ,XJ1,NPTS,IO,IREFL,ICHEM,IPUNCH,IDESGN,IR,NXX,XBP,
     1YBP,THBP,RAD,XBOD,YBOD,THBOD,RADB,XEND,THEND,RTH,YEXIT,THST,TEST,
     1IRFL,Y0,RADB2,RRAD(20),    NSTAR,YNOZ,EIN,    PEN,H16,H17
      COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
     110,200)
      COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
      COMMON/XCOWL/XCOWL
      COMMON/FVAR/
     1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
     2XMASSF(200),              HF(200),SF(200),ALPD(10),
     3THETA(20)
      COMMON/VAR/RHO(200),
     1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
     2            XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
     3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
     4XMASSN(200),ALPN(10,200),SI(10),HI(10),TEMP(20)
     5,ALPDUM(10)
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/IDEAL/IDEAL,GAMEY,XMWT ,CPI
      COMMON /IOVER/ IOVER
      COMMON/XTJ1/XTJ1
      COMMON/FENCE/IFENCE,AFENCE,BFENCE,XFENCE
      DIMENSION WTMOLE(10),TYPE(6),TYPE1(4),TYPE2(2),TYPE5(4),TYPE4(4)
      DATA TYPE2 /10H  NOZZLE  ,10HCENTERBODY/
      DATA TYPE1/10HHYDROGEN A,10HHYDROCARBO,2HIR,5HN AIR/
      DATA TYPE/10HTWO DIMENS,10HAXISYMMETR,10HLINE SOURC,5HIONAL,5HIC
     1 ,5HE    /
      DATA TYPE5/10HF L O W   ,10H    D E S ,9HF I E L D,9HI G N    /
      DATA TYPE4/10HFROZEN    ,10HEQUILIBRIU,1H ,1HM/
      DATA XXU/5*1.E+06/,XXL/5*1.E+06/,END/1.E+06/
      DATA IOVER/0/
      THST=.02
      IF(IOVER.EQ.2) GO TO 916
      IO=0
      IREFL=0
      IPUNCH=0
      IDESGN=0
      ICHEM=0
      READ(5,6895)J1,J2,NPTS,IEQ,ICOWL,IOVER,MM,IDEAL
      READ(5,6895)KSIDE,IVIS,ITW
5100  NSP=7
      READ(5,63) XBP,XBOD,XCOWL,RTH,TEST,XFINAL,XTJ1
6895  FORMAT(16I5)
```

```
      READ(5,63) XSHFT,YSHFT,XTHX,YLFT,XMOM
      READ(5,63)XTHS,YLFTS,XMOMS,XVTHX,YVLFT,XVMOM
      READ(5,6895) NXXJ1
      DO 9393 I=1,NXXJ1
 9393 READ(5,9463) XXJ1(I),AXX(I),BXX(I),XOR(I)
 9463 FORMAT(4E10.0)
      READ(5,4) IFENCE,AFENCE,BFENCE,XFENCE
    4 FORMAT(I5,5X3E10.0)
      XXJ1(NXXJ1+1)=XFINAL
      AXX(NXXJ1+1)=AXX(NXXJ1)
      BXX(NXXJ1+1)=BXX(NXXJ1)
      XOR (NXXJ1+1)=XOR (NXXJ1)
      IF(IFENCE.EQ.0) GO TO 321
      XXJ1(NXXJ1+2)=XFINAL
      AXX (NXXJ1+2)=AXX (NXXJ1)
      BXX (NXXJ1+2)=BXX (NXXJ1)
      XOR (NXXJ1+2)=XOR (NXXJ1)
  321 CONTINUE
      XINTU=XBP
      XINTL=XBOD
      READ(5,6895) NUWSEG,NLWSEG
      READ(5,6363) (XXU(L),A1(L,1),A2(L,1),A3(L,1),L=1,NUWSEG)
      READ(5,6363) (XXL(L),A1(L,2),A2(L,2),A3(L,2),L=1,NLWSEG)
 6363 FORMAT(4E10.0)
 3531 WRITE(6,7329) TYPE5(IDESGN+1),TYPE5(IDESGN+3)
 7329 FORMAT(    41X*N O Z Z L E   -   C E N T E R B O D Y *//50XA10,A9)
      JP1=J1+1+2*J2
      JP2=JP1+3
      WRITE(6,7330)                    TYPE(JP1 ),TYPE(JP2 ),TYPE1(ICHEM+1)
     1,TYPE1(ICHEM+3),NPTS,RTH
 7330 FORMAT(        /37X,*F O R   N O N U N I F O R M   G A S   F L O W
     2*///                          10X,*TYPE OF FLOW IS *,A10,A5,* FOR *,
     3A10,A5/10X,*NUMBER OF POINTS ON INITIAL DATA LINE IS *,I3/10X,
     4*THROAT RADIUS (RTH) = *,E13.5)
      WRITE(6,5001)   TYPE4(IEQ+1),TYPE4(IEQ+3)
 5001 FORMAT(
     110X*CHEMISTRY IS *A10,A1)
      WRITE(6,7500) XCOWL,XFINAL
 7500 FORMAT(10X*COWL TRAILING EDGE IS *E13.5/10X*AXIAL COORDINATE OF EN
     1D OF RUN IS *E13.5)
      IF(J2.EQ.0) GO TO 7510
      WRITE(6,7501) XTJ1
 7501 FORMAT(10X*AXIAL COORDINATE OF START OF CARTESIAN SYSTEM IS *E13.5
     1)
      WRITE(6,7502)
 7502 FORMAT(//25X*LINE SOURCE COORDINATES*)
      WRITE(6,7505)
      DO 7503 I=1,NXXJ1
 7503 WRITE(6,7504) XXJ1(I),XXJ1(I+1),AXX(I),BXX(I),XOR(I)
 7504 FORMAT(10X,4E11.3,5X,E11.3)
 7505 FORMAT(15X*X*4X*TO*4X*X*11X*COORDINATES*12X*ORIGIN X*)
 7510 CONTINUE
      WRITE(6,2020)
 2020 FORMAT(//25X*UPPER WALL COORDINATES*)
      WRITE(6,2071)
 2071 FORMAT(15X*X*4X*TO*4X*X*15X*COORDINATES*)
 2042 FORMAT(10X,5E11.3)
```

```
      DO 2050 I=1,NUWSEG
      IF(I.EQ.5)GO TO 2051
      WRITE(6,2042) XXU(I),XXU(I+1),A1(I,1),A2(I,1),A3(I,1)
      GO TO 2050
2051  WRITE(6,2042) XXU(I),END     ,A1(I,1),A2(I,1),A3(I,1)
2050  CONTINUE
      WRITE(6,2010)
2010  FORMAT(//25X*LOWER WALL COORDINATES*)
      WRITE(6,2071)
      DO 2040 I=1,NLWSEG
      IF(I.EQ.5)GO TO 2041
      WRITE(6,2042) XXL(I),XXL(I+1),A1(I,2),A2(I,2),A3(I,2)
      GO TO 2040
2041  WRITE(6,2042) XXL(I),END     ,A1(I,2),A2(I,2),A3(I,2)
2040  CONTINUE
      DO 7373 L=1,NUWSEG
7373  XXU(L)=XXU(L)-XINTU
      DO 7374 L=1,NLWSEG
7374  XXL(L)=XXL(L)-XINTL
      READ(5,63) EMINF,TIN,WINF,PINF
      IF(IDEAL.EQ.1)READ(5,63)GAMEY,XMWT
      IF(IDEAL.EQ.1)IEQ=1
      DO 5002 I=1,NPTS
      DO 5002 J=1,NSP
5002  ALPF(J,I)=0.
      READ(5,6364) (XF(I),YF(I),PF(I),QF(I),TF(I),THF(I),WF(I),I=1,NPTS)
      IF(IEQ.EQ.0)
     1READ(5,6364) ((ALPF(J,I),J=1,NSP),I=1,NPTS)
6364  FORMAT(7E10.0)
      IF(ICONL.EQ.0)GO TO 7511
      READ(5,6364)XM(MM),YM(MM),PM(MM),QM(MM),TM(MM),THM(MM),WM(MM)
      DO 6186 J=1,NSP
6186  ALPM(J,MM)=0.
7511  CONTINUE
      IF(ICONL.EQ.1)WRITE(6,5005)MM,PM(MM),QM(MM),TM(MM),THM(MM),WM(MM)
5005  FORMAT(//20X*DATA AT COWL*/10X*NUMBER OF POINTS IN PRANDTL-MEYER F
     1AN IS *I2/10X*PRESSURE           =*E13.5/10X*VELOCITY           =*E
     113.5/10X*TEMPERATURE        =*E13.5/10X*FLOW INCLINATION  =*E13.5/
     110X*FUEL TO AIR RATIO =*E13.5)
      IF(IVIS.EQ.0)GO TO 832
      READ(5,63)XSTR,PR,REC,REIN,SH
      IF(ITW.GT.0)GO TO 832
      DO 831 L=1,3
 831  READ(5,63)AH(L),BH(L),CH(L)
 832  CONTINUE
      IF(IREFL.EQ.0) GO TO 4000
 916  CONTINUE
      DO 4005 I=1,NPTS
      II=NPTS-I+1
      X(II)=XF(I)
      Y(II)=-YF(I)
      Q(II)=QF(I)
      T(II)=TF(I)
      P(II)=PF(I)
      TH(II)=-THF(I)
      R(II)=RF(I)
      W(II)=WF(I)
```

```
      DO 4010 J=1,NSP
 4010 ALP(J,II)=ALPF(J,I)
 4005 CONTINUE
      DO 4006 I=1,NPTS
      XF(I)=X(I)
      YF(I)=Y(I)
      QF(I)=Q(I)
      TF(I)=T(I)
      PF(I)=P(I)
      THF(I)=TH(I)
      RF(I)=R(I)
      WF(I)=W(I)
      DO 4007 J=1,NSP
 4007 ALPF(J,I)=ALP(J,I)
 4006 CONTINUE
      DUM=-YBP
      YBP=-YBOD
      YBOD=DUM
      DUM=-THBP
      THBP=-THBOD
      THBOD=DUM
      YEND=-YEND
      THEND=-THEND
      IF(IOVER.EQ.2) RETURN
 4000 CONTINUE
      XJ=J1
      XJ1=J2
      WTMOLE(1)=1.008
      WTMOLE(2)=16.
      WTMOLE(3)=18.016
      WTMOLE(4)=2.016
      WTMOLE(5)=32.0
      WTMOLE(6)=17.008
      WTMOLE(7)=28.014
      WTMOLE(8)=44.011
      WTMOLE(9)=28.011
      WTMOLE(10)=44.1
      RO=1.987
      CALL COEFF(5,TIN,AZ,BZ,CZ,DZ,EZ,FZ,GZ)
      CPIN=(AZ+BZ*TIN+CZ*TIN**2+DZ*TIN**3+EZ*TIN**4)*RO/WTMOLE(5)
      CALL COEFF(7,TIN,AZ,BZ,CZ,DZ,EZ,FZ,GZ)
      CPII=(AZ+BZ*TIN+CZ*TIN**2+DZ*TIN**3+EZ*TIN**4)*RO/WTMOLE(7)
      RINF=RO/WINF
      CPIN=.232*CPIN+.768*CPII
      GAMINF=1./(1.-RINF/CPIN)
      GAMINF=1.4
      EIN= (GAMINF-1.) * EMINF**2
      PIN=1./GAMINF/EMINF**2
      IF(IDEAL.EQ.1)CPI=49712.52*GAMEY/(GAMEY- 1.)/XMWT
      WRITE(6,6899) EMINF,TIN,WINF,PINF
 6899 FORMAT(//  50X,*INFINITY CONDITIONS*/50X,*==================*/
     1/40X,*MACH ====================*,E13.5/40X,*TEMPERATURE (DEGREES
     2 K) ===*,E13.5/40X,*MOLECULAR WEIGHT ==========*,E13.5/40X
     1*PRESSURE (PSF) ============*E13.5)
      WRITE(6,6723)
 6723 FORMAT(///40X,*OUTPUT VARIABLES ARE*/40X,*NONDIMENSIONALIZED*/
     140X,*AS FOLLOWS =*//40X,*X BY RTH*/40X,*Y BY RTH*/40X,*Q BY FREE S
```

```
     2TREAM VELOCITY*/40X,*T BY FREE STREAM TEMPERATURE*/40X,*P BY FREE
     3STREAM PRESSURE*)
      IF(IEQ.EQ.0) WRITE(6,5003)
5003  FORMAT(          /40X,*ALP(J) IS MASS FRACTION OF SPECIES J*)
      DO 6897 I=1,NPTS
      PF(I)=PF(I)*PIN
6897  CONTINUE
      IF(ICONL.EQ.1)PM(MM)=PM(MM)*PIN
      UINF=1716.*TIN*1.8/PIN
      RHOINF= PINF/TIN/1.8/1716.
      H16=GAMINF/WINF/2.*EMINF*EMINF
      H17=1./H16
   63 FORMAT(8E10.0)
      PINF=PINF/2116.
      DO 4321 I=1,NPTS
      DO 83 J=1,NSP
   83 ALPDUM(J)=ALPF(J,I)
      CALL ALL (PF(I),QF(I),RHOF(I),RF(I),WF(I),GAMF(I),EMF(I),
     1XMUF(I),TF(I),ALPDUM,IEQ,1)
4321  CONTINUE
      IF(ICONL.EQ.0)RETURN
      IDEALS=0
      IEQS=IEQ
      CPIS=CPIN
      GAMES=GAMINF
      XMWS=WINF
      IF(IDEAL.NE.1)GOTO 717
      IDEALS=IDEAL
      GAMES=GAMEY
      CPIS=CPI
      XMWS=XMWT
  717 CPI=CPIN*25.02006*1.E+03
      GAMEY=GAMINF
      IDEAL=1
      IEQ=1
      XMWT=WINF
      DO 84 J=1,NSP
   84 ALPDUM(J)=ALPM(J,MM)
      CALL ALL (PM(MM),QM(MM),RHM(MM),RM(MM),WM(MM),GM(MM),EMM(MM),
     1XMUM(MM),TM(MM),ALPDUM,IEQ,1)
      IEQ=IEQS
      IDEAL=IDEALS
      GAMEY=GAMES
      CPI=CPIS
      XMWT=XMWS
      RETURN
      END
```

```
      SUBROUTINE COEFF(I,T,A    ,B    ,C    ,D    ,E    ,F    ,G    )
      IF(T-1000)10,10,20
   10 GO TO (15,16,13,11,12,17,14,18,19),I
   11 A    = 2.8460849E 00
      B    = 4.1932116E-03
      C    =-9.6119332E-06
      D    = 9.5122662E-09
      E    =-3.3093421E-12
      F    =-9.6725372E 02
      G    =-1.4117850E 00
      GO TO 40
   12 A    = 3.7189946E 00
      B    =-2.5167288E-03
      C    = 8.5837353E-06
      D    =-8.2998716E-09
      E    = 2.7082180E-12
      F    =-1.0576706E 03
      G    = 3.9080704E 00
      GO TO 40
   13 A    = 4.1565016E 00
      B    =-1.7244334E-03
      C    = 5.6982316E-06
      D    =-4.5930044E-09
      E    = 1.4233654E-12
      F    =-3.0288770E 04
      G    =-6.8616246E-01
      GO TO 40
   14 A    = 3.6916148E 00
      B    =-1.3332552E-03
      C    = 2.6503100E-06
      D    =-9.7688341E-10
      E    =-9.9772234E-14
      F    =-1.0628336E 03
      G    = 2.2874980E 00
      GO TO 40
   15 A    = 2.5000000E 00
      B    = 0.0
      C    = 0.0
      D    = 0.0
      E    = 0.0
      F    = 2.5470497E 04
      G    =-4.6001096E-01
      GO TO 40
   16 A    = 3.0218894E 00
      B    =-2.1737249E-03
      C    = 3.7542203E-06
      D    =-2.9947200E-09
      E    = 9.0777547E-13
      F    = 2.9137190E 04
      G    = 2.6460076E 00
      GO TO 40
   17 A    = 3.8234708E 00
      B    =-1.1187229E-03
      C    = 1.2466819E-06
      D    =-2.1035896E-10
      E    =-5.2546551E-14
      F    = 3.5852787E 03
```

```
   G    = 5.8253029E-01
   GO TO 40
18 A=2.1701
   B=1.0378115E-02
   C=-1.0733938E-05
   D=6.3459175E-09
   E=-1.6280701E-12
   F=-4.8352602E+04
   G=1.0664388E+01
   GO TO 40
19 A=3.7871332
   B=-2.1709526E-03
   C=5.0757337E-06
   D=-3.4737726E-09
   E=7.7216841E-13
   F=-1.4363508E+04
   G=2.6335459
   GO TO 40
20 GO TO (25,26,23,21,22,27,24,28,29),I
21 A    = 3.0436897E 00
   B    = 6.1187110E-04
   C    =-7.3993551E-09
   D    =-2.0331907E-11
   E    = 2.4593791E-15
   F    =-8.5491002E 02
   G    =-1.6481339E 00
   GO TO 40
22 A    = 3.5976129E 00
   B    = 7.8145603E-04
   C    =- 2.2386670E-07
   D    = 4.2490159E-11
   E    =-3.3460204E-15
   F    =-1.1927918E 03
   G    = 3.7492659E 00
   GO TO 40
23 A    = 2.6707532E 00
   B    = 3.0317115E-03
   C    =-8.5351570E-07
   D    = 1.1790853E-10
   E    =-6.1973568E-15
   F    =-2.9888994E 04
   G    = 6.8838391E 00
   GO TO 40
24 A    = 2.8545761E 00
   B    = 1.5976316E-03
   C    =-6.2566254E-07
   D    = 1.1315849E-10
   E    =-7.6897070E-15
   F    =-8.9017445E+02
   G    = 6.3902879E 00
   GO TO 40
25 A    = 2.5000000E 00
   B    = 0.0
   C    = 0.0
   D    = 0.0
   E    = 0.0
   F    = 2.5470497E 04
```

```
      G    =-4.6001096E-01
      GO TO 40
   26 A    = 2.5372567E 00
      C    =-8.8017921E-09
      D    = 5.9643621E-12
      E    =-5.5743608E-16
      F    = 2.9230007E 04
      G    = 4.9467942E 00
      GO TO 40
   27 A    = 2.8895544E 00
      B    = 9.9835061E-04
      C    =-2.1879904E-07
      D    = 1.9802785E-11
      E    =-3.8452940E-16
      F    = 3.8811792E 03
      G    = 5.5597016E 00
      GO TO 40
   28 A=4.4129266
      B=3.1922896E-03
      C=-1.297823E-06
      D=2.4147446E-10
      E=-1.6742986E-14
      F=-4.8944043E+04
      G=-7.2875769E-01
      GO TO 40
   29 A=2.9511519
      B=1.55255767E-03
      C=-6.1911411E-07
      D=1.1350336E-10
      E=-7.7882732E-15
      F=-1.4231827E-04
      G=6.531445
   40 RETURN
      END
```

```
      SUBROUTINE ALL(P,Q,RH,R,W,GAM,EM,XMU,T,ALPDUM,IEQ,I66)
      COMMON/IEQ/IEB,PIN,RHOINF,UINF,PINF
      COMMON/A/ TIN,CPIN,RO
      COMMON/D/ GAMINF,EMINF,RINF,WINF
      COMMON/B/ WTMOLE
      COMMON /SP/ NSP
      COMMON /ENTH/ HX
      DIMENSION H1(10),CP1(10),ALPDUM(10),WTMOLE(10)
      CPX=0.
      IF(IEQ.EQ.1)GO TO 69
      WX=0.
      CPX=0.
      HX=0.
      DO 10 J=1,NSP
   10 WX=WX+ALPDUM(J)/WTMOLE(J)
      W=1./WX
      IF(I66.EQ.1)RH=P*W*EMINF**2*GAMINF/RO/T/WINF
      IF(I66.EQ.0)
     1T=P*W*EMINF**2*GAMINF/RO/RH/WINF
      CALL THERMO(T,H1,CP1,DUM)
      DO 20 J=1,NSP
      CPX=CPX+ALPDUM(J)*CP1(J)
      HX=HX+ALPDUM(J)*H1(J)
   20 CONTINUE
      IF(I66.EQ.1)R=HX+Q*Q/2.
      IF(I66.EQ.0)
     1Q=SQRT(2.*(R-HX))
      GAM=CPX/(CPX-RO/W/CPIN)
      A=GAM*P/RH
      A=SQRT(A)
      EM=Q/A
      XMU=ASIN(1./EM)
      RETURN
   69 CONTINUE
      IER=0
      IT=1
      IF(I66.EQ.0)GO TO 40
      HX=FH(P,W,T)
      R=HX+Q*Q/2.
      RH=RHEQ(HX,P,W,T)
      GO TO 45
   40 HX=R-Q**2/2.
      RHT=RHEQ(HX,P,W,T)
      ER=(RH-RHT)/RH
      IF(ABS(ER).LT.1.E-03)GO TO 45
      CALL ERR(IER,IT,Q,ER,1.01,Q1,ER1)
      IF(IER.EQ.1)GO TO 102
      IT=IT+1
      GO TO 40
   45 GAM=FGAM(T,P,W)
      A=SQRT(GAM*P/RH)
      EM=Q/A
      XMU=ASIN(1./EM)
      RETURN
  102 WRITE(6,105)
  105 FORMAT(* TOO MANY ITERATIONS IN ALL *)
      STOP
```

```
      SUBROUTINE BODL(XI,YI,THI,XL,YL,EM2,XN,YN,THN)
      COMMON/SHAPE/A1(5,2),A2(5,2),A3(5,2),XXU(5),XXL(5),XINTU,XINTL
      XI=XI-XINTL
      XL=XL-XINTL
      ICK=1
      IER=0
      L=5
      ASL=TAN(THI)
      XN=(YI-YL+XL*EM2-XI*ASL)/(EM2-ASL)
    5 CONTINUE
      IF(XN.LT.XXL(5)) L=4
      IF(XN.LT.XXL(4)) L=3
      IF(XN.LT.XXL(3)) L=2
      IF(XN.LT.XXL(2)) L=1
      YN=A1(L,2)*XN*XN+A2(L,2)*XN+A3(L,2)
      YT=YL+(XN-XL)*EM2
      ER=(YN-YT)
      IF(ABS(ER).LT.1.E-04) GO TO 10
      CALL ERR(IER,ICK,XN,ER,1.01,XN1,ER1)
      IF(IER.EQ.0)GO TO 350
      WRITE(6,3512)
 3512 FORMAT(* TOO MANY ITERATIONS IN BODL*)
      STOP
  350 L=5
      ICK=ICK+1
      GO TO 5
   10 THN=ATAN(2.*A1(L,2)*XN+A2(L,2))
      XI=XI+XINTL
      XL=XL+XINTL
      XN=XN+XINTL
      RETURN
      END
```

```
      SUBROUTINE BODU(XI,YI,THI,XL,YL,EM1,X,Y,TH)
      COMMON/SHAPE/A1(5,2),A2(5,2),A3(5,2),XXU(5),XXL(5),XINTU,XINTL
      XI=XI-XINTU
      XL=XL-XINTU
      X=X-XINTU
      ICK=1
      IER=0
    5 L=5
      IF(X.LT.XXU(5)) L=4
      IF(X.LT.XXU(4)) L=3
      IF(X.LT.XXU(3)) L=2
      IF(X.LT.XXU(2)) L=1
      Y=A1(L,1)*X*X+A2(L,1)*X+A3(L,1)
      YT=YL+(X-XL)*EM1
      ER=(Y-YT)
      IF(ABS(ER).LT.1.E-04)GO TO 10
      CALL ERR(IER,ICK,X,ER,1.01,XN1,ER1)
      IF(IER.EQ.0)GO TO 350
      WRITE(6,3512)
 3512 FORMAT(1X, * TOO MANY ITERATIONS IN BODU *)
      STOP
  350 CONTINUE
      ICK=ICK+1
      GO TO 5
   10 TH=ATAN(2.*A1(L,1)*X+A2(L,1))
      XI=XI+XINTU
      XL=XL+XINTU
      X=X+XINTU
      RETURN
      END
```

```
      SUBROUTINE COWL(OPT)
      COMMON/COWL/ICOWL,MM,XM(9),YM(9),PM(9),WM(9),RHM(9),THM(9),QM(9),
     1RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/VAR/RHO(200),
     1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
     2             XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
     3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
     4XMASSN(200),ALPN(10,200),SI(10),HI(10),TEMP(20)
     5,ALPDUM(10)
      COMMON /SP/ NSP
      COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
      COMMON/A/ TIN,CPIN,RO
      COMMON/D/ GAMINF,EMINF,RINF,WINF
      COMMON/C1/ EMC1,TC1,QC1
      COMMON/IDEAL/IDEAL,GAMEY,XMWT ,CPI
      COMMON/ICU/EMC2
      DO 4385 J=1,NSP
 4385 ALPDUM(J)=ALPM(J,MM)
      IER=0
      ITT=1
      BET=(THM(MM)-OPT*XMUM(MM)+TH(1))*1.1
      IFAN=MM-3
    3 CONTINUE
      IDEALS=0
      IEQS=IEQ
      CPIS=CPIN
      GAMES=GAMINF
      XMWS=WINF
      IF(IDEAL.NE.1)GOTO 717
      IDEALS=IDEAL
      GAMES=GAMEY
      CPIS=CPI
      XMWS=XMWT
  717 CPI=CPIN*25.02006*1.E+03
      GAMEY=GAMINF
      IDEAL=1
      IEQ=1
      XMWT=WINF
      II=MM-1
      CALL SHOCK(BET,QM(MM),THM(MM),GM(MM),EMM(MM),RHM(MM),PM(MM),
     1RM(MM),WM(MM),TM(MM),XMUM(MM),
     2QM(II),THM(II),GM(II),EMM(II),RHM(II),PM(II),RM(II),WM(II),
     3TM(II),XMUM(II),ALPDUM,1.,IEQ)
      XM(II)=XM(MM)
      YM(II)=YM(MM)
      EMC2=EMM(II)
      EMC1=EMM(II)
      DO 4386 J=1,NSP
 4386 ALPM(J,II)=ALPDUM(J)
      KK=II-1
      D=0.
      CALL INT(0.,XM(II),YM(II),THM(II),PM(II),QM(II),RHM(II),RM(II),
     1WM(II),GM(II),EMM(II),XMUM(II),TM(II),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,XM(KK),YM(KK),THM(KK),PM(KK),QM(KK),RHM(KK),RM(KK),WM(KK),
     1GM(KK),EMM(KK),XMUM(KK),TM(KK),ALPDUM,0,IEQ)
```

```
      IEQ=IEQS
      IDEAL=IDEALS
      GAMEY=GAMES
      CPI=CPIS
      XMWT=XMWS
      DP=(P(1)-PM(II))/FLOAT(IFAN-1)
      II=1
      DO 4387 J=1,NSP
      ALPM(J,II)=ALP(J,1)
 4387 ALPDUM(J)=ALP(J,1)
      D=0.
      CALL INT(0.,X(1),Y(1),TH(1),P(1),Q(1),RHO(1),R(1),W(1),GAM(1),
     1EM(1),XMU(1),T(1),
     1D,D,D,D,D,D,D,D,D,D,D,D
     1,XM(II),YM(II),THM(II),PM(II),QM(II),RHM(II),RM(II),WM(II),
     1 GM(II),EMM(II),XMUM(II),TM(II),ALPDUM,0,IEQ)
      DO 12 LL=2,IFAN
      N=LL
      KK=N-1
      XM(N)=XM(KK)
      YM(N)=YM(KK)
      PM(N)=PM(KK)-DP
      DO 4388 J=1,NSP
 4388 ALPM(J,N)=ALPDUM(J)
      A=1.
      B=0.
      CALL SL(PM(KK),QM(KK),RHM(KK),RM(KK),WM(KK),GM(KK),EMM(KK),
     1XMUM(KK),TM(KK),PM(N),QM(N),RHM(N),RM(N),WM(N),GM(N),EMM(N),
     1XMUM(N),TM(N),ALPDUM,IEQ,A,B)
      A1=.5*(GM(N)/SIN(XMUM(N))/COS(XMUM(N))+GM(KK)/SIN(XMUM(KK))/COS
     1(XMUM(KK)))
      ALNR=ALOG(PM(N)/PM(KK))
      THM(N)=THM(KK)+OPT*ALNR/A1
   12 CONTINUE
      ER4=THM(IFAN)-THM(IFAN+1)
      IF(ABS(ER4).LT.1.E-04) GO TO 15
      CALL ERR(IER,ITT,BET,ER4,1.05,BET1,ER41)
      IF(IER.EQ.1)GO TO 102
      ITT=ITT+1
      GO TO 3
  102 WRITE(6,203)
  203 FORMAT(* ERROR IN BETA LOOP IN COWL*)
      STOP
   15 CONTINUE
      WRITE(6,85)BET
   85 FORMAT(1X,E13.5)
      WRITE(6,86)(K,PM(K),QM(K),TM(K),THM(K),RHM(K),XMUM(K),K=1,MM)
   86 FORMAT(1X,I5,6E13.5)
      RETURN
      END
```

```
      SUBROUTINE COWLO(I,THM,EM,BET,PMM)
      COMMON/FVAR/
     1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
     2XMASSF(200),              HF(200),SF(200),ALPD(10),
     3THETA(20)
      COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
     110,200)
      COMMON/D/ GAMINF,EMINF,RINF,WINF
      COMMON/C1/ EMC1,TC1,QC1
      COMMON /SP/ NSP
      DIMENSION ALPDUM(10)
      J=I+1
      BET=THF(I)-XMUF(I)
      BET=BET- .1*ABS(BET)
      ITT=1
      DO 4 JJ=1,NSP
    4 ALPDUM(JJ) =ALPF(JJ,I)
      IER=0
    3 CONTINUE
      CALL SHOCK(BET,QF(I),THF(I),GAMF(I),EMF(I),RHOF(I),PF(I),RF(I),
     1WF(I),TF(I),XMUF(I),QF(J),THF(J),GAMF(J),EMF(J),RHOF(J),PF(J),
     2RF(J),WF(J),TF(J),XMUF(J),ALPDUM,-1.,IEQ)
      P2=PF(J)*GAMINF*EMINF*EMINF
      P2=P2/PMM
      TH2=THF(J)
      CALL PRM(P2,THM,EM,TH2T,EM3,-1)
      ER4=TH2T-TH2
      IF(ABS(ER4).LT.1.E-04) GO TO 15
      CALL ERR(IER,ITT,BET,ER4,1.05,BET1,ER41)
      IF(IER.EQ.1)GO TO 102
      ITT=ITT+1
      GO TO 3
  102 WRITE(6,203)
  203 FORMAT(* ERROR IN BETA LOOP IN COWLO*)
      STOP
   15 CONTINUE
      DO 300 JJ=1,NSP
  300 ALPF(JJ,J)=ALPF(JJ,I)
      XF(J)=XF(I)
      YF(J)=YF(I)
      EMC1=EM3
      DUM1=1.+(GAMINF-1.)/2.*EMINF*EMINF
      DUM2=1.+(GAMINF-1.)/2.*EM3*EM3
      TC1=DUM1/DUM2
      QC1=EM3/EMINF*SQRT(TC1)
      RETURN
      END
```

```
      SUBROUTINE SHOCK(BET,Q1,TH1,G1,EM1,RH1,P1,H1,PHI1,T1,XMU1,
     1Q2,TH2,G2,EM2,RH2,P2,H2,PHI2,T2,XMU2,ALPDUM,FSH,IEQ)
      COMMON/A/ TIN,CPIN,RO
      COMMON/D/ GAMINF,EMINF,RINF,WINF
      DIMENSION ALPDUM(10)
      IT=1
      IER=0
      V1=Q1*Q1
      HS1=H1-V1/2.
      VT=Q1*COS(BET-TH1)
      U1=ABS(Q1*SIN(BET-TH1))
      GM1=G1-1.
      GP1=G1+1.
      XM1=EM1*SIN(BET-TH1)
      XMS=RH1*U1
      IF(IT.EQ.1)UM=U1*(GM1*XM1*XM1+2.)/GP1/XM1/XM1
    7 RH2=XMS/UM
      P2=XMS*(U1-UM)+P1
      V2=VT*VT+UM*UM
      H2=H1
      HS2=H2-V2/2.
      PHI2=PHI1
      IF(IEQ.EQ.0)GO TO 10
      RH2T=RHEQ(HS2,P2,PHI2,T2)
      ER=(RH2-RH2T)/RH1
      GO TO 12
   10 T2=P2*PHI2*GAMINF*EMINF **2/RO/RH2/WINF
      CALL THERMO(T2,HS2T,DUM,DUM)
      ER=(HS2T-HS2)/HS1
   12 CONTINUE
      IF(ABS(ER).LT.1.E-03)GO  TO 9
      CALL ERR(IER,IT,UM,ER,.99,UM1,ER1)
      IF(IER.EQ.1)GO TO 100
      IT=IT+1
      GO TO 7
  100 WRITE(6,200)
  200 FORMAT(* ERROR IN HUGONIOT LOOP IN SHOCK*)
      WRITE(6,46)IEQ,FSH,BET,TH1,P1,Q1,G1,EM1,RH1,H1,PHI1,T1,
     1P2,UM,U1,VT,RH2,T2,HS2,ER
   46 FORMAT(1X,I2,9E13.5/3X,10E13.5)
      STOP
    9 IF(FSH.GT.0.) TH2=BET-ATAN(UM/VT)
      IF(FSH.LT.0.) TH2=ATAN(UM/VT)+BET
      Q2=SQRT(V2)
      CALL ALL(P2,Q2,RH2,PHI2,H2,G2,EM2,XMU2,T2,ALPDUM,IEQ,1)
      RETURN
      END
```

```
      SUBROUTINE SHOCPT(IS,M,BET,BETN,A,B)
      COMMON/VAR/RHO(200),
     1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
     2             XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
     3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
     4XMASSN(200),ALPN(10,200),SI(10),HI(10),TEMP(20)
     5,ALPDUM(10)
      COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
      COMMON/ETX/XJ,XJ1,NPTS,IO,IREFL,ICHEM,IPUNCH,IDESGN,IR,NXX,XBP,
     1YBP,THBP,RAD,XBOD,YBOD,THBOD,RADB,XEND,THEND,RTH,YEXIT,THST,TEST,
     1IRFL,Y0,RADB2,RRAD(20),    NSTAR,YNOZ,EIN,     PEN,H16,H17
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      IF(B.EQ.0.) BETN=BET+(THN(IS-1)+XMUN(IS-1)-TH(M-1)-XMU(M-1))
      I=IS
      J=IS+1
      L=IS
      ITT=1
      IER=0
      DO 75 JJ=1,7
   75 ALPDUM(JJ)=ALPN(JJ,I)
    3 CALL SHOCK(BETN,QN(I),THN(I),GAMN(I),EMN(I),RHON(I),PN(I),
     1RN(I),WN(I), TN(I),XMUN(I),QN(J),THN(J),GAMN(J),EMN(J),RHON(J),
     2PN(J),RN(J),WN(J),TN(J),XMUN(J),ALPDUM,1.,IEQ)
      EM1=XM1(.5,.5,THN(J),XMUN(J),TH(M),XMU(M))
      EM2=XM2(.5,.5,TH(M),XMU(M),TH(M+1),XMU(M+1))
      YDUM=(EM1*Y(M)-EM2*YN(L)+EM1*EM2*(XN(L)-X(M)))/(EM1-EM2)
      RAT=(YDUM-Y(M))/(Y(M+1)-Y(M))
      IF(IS.EQ.2.AND.M.EQ.2) RAT=0.
      CALL INT(RAT,X(M),Y(M),TH(M),P(M),Q(M),RHO(M),R(M),W(M),GAM(M),
     1EM(M),XMU(M),T(M), X(M+1),Y(M+1),TH(M+1),P(M+1),Q(M+1),
     2RHO(M+1),R(M+1),W(M+1),GAM(M+1),EM(M+1),XMU(M+1),T(M+1),
     3X2,Y2,TH2,P2,Q2,RH2,R2,W2,GAM2,EM2,XMU2,T2,ALPDUM,1,IEQ)
      A1=F1(A,B,XMU2,GAM2,P2,XMUN(J),GAMN(J),PN(J))
      A2=F2(A,B,1.,XJ,XJ1,X2,Y2,TH2,XMU2,XN(J),YN(J),THN(J),XMUN(J))
      DUM1=A2*(XN(J)-X2)
      DUM=(TH2-THN(J)-DUM1)/A1
      PTEST=P2*EXP(DUM)
      ER4=(PTEST-PN(J))/P(M)
      IF(ABS(ER4).LT.1.E-04) GO TO 15
      CALL ERR(IER,ITT,BETN,ER4,1.05,BETN1,ER41)
      IF(IER.EQ.1)GO TO 102
      ITT=ITT+1
      GO TO 3
  102 WRITE(6,203)
  203 FORMAT(* ERROR IN BETA LOOP IN SHOCPT*)
      STOP
   15 CONTINUE
      XN(J)=XN(I)
      YN(J)=YN(I)
      DO 300 JJ=1,7
  300 ALPN(JJ,J)=ALPN(JJ,I)
      RETURN
      END
```

```
      SUBROUTINE PRM(P,TH1,XM1,TH2,XM2,IS)
      COMMON/D/ GAMINF,EMINF,RINF,WINF
      G=GAMINF
      GM1=G-1.
      GP1=G+1.
      DUM=1.+GM1/2.*XM1*XM1
      P=P**(GM1/G)
      XM2=(DUM/P-1.)*2./GM1
      XM2=SQRT(XM2)
      GX=SQRT(GP1/GM1)
      DUM1=SQRT(XM1*XM1-1.)
      DUM2=SQRT(XM2*XM2-1.)
      DTH=    GX*(ATAN(DUM2/GX)-ATAN(DUM1/GX))+ATAN(DUM1)-ATAN(DUM2)
      TH2=TH1+FLOAT(IS)*DTH
      RETURN
      END
```

```
      SUBROUTINE PRM(P,TH1,XM1,TH2,XM2,IS)
      COMMON/D/ GAMINF,EMINF,RINF,WINF
      G=GAMINF
      GM1=G-1.
      GP1=G+1.
      DUM=1.+GM1/2.*XM1*XM1
      P=P**(GM1/G)
      XM2=(DUM/P-1.)*2./GM1
      XM2=SQRT(XM2)
      GX=SQRT(GP1/GM1)
      DUM1=SQRT(XM1*XM1-1.)
      DUM2=SQRT(XM2*XM2-1.)
      DTH=    GX*(ATAN(DUM2/GX)-ATAN(DUM1/GX))+ATAN(DUM1)-ATAN(DUM2)
      TH2=TH1+FLOAT(IS)*DTH
      RETURN
      END
```

```
      FUNCTION FT(P1,F,H5)
      COMMON/IPP/IPP
      COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/A/ TIN,CPIN,RO
      COMMON/IDEAL/IDEAL,GAMEY,XMWT ,CPI
      DATA I63/0/
      IF(IDEAL.EQ.1)GO TO 6666
      IFLAG=0
      IHOLD=0
      P=P1/PIN*PINF*1.01325E+05
      H=H5*UINF/10.7639/1.E+06
      F2=F*F
      A10=ALOG(P)/2.3-5.
      Z9=.125*A10*A10              -.275*A10
      IT=1
      IF(I63.EQ.1) GO TO 1000
      I63=1
      T=1500.
      T0=1500.
      IF(F.GE.0.) GO TO 120
      T=600.
      T0=T
 1000 CONTINUE
      IF(F.LT.0.) GO TO 400
      GO TO 120
   50 E0=(H-H1)/H
      IF(ABS(E0).LT.1.E-04) GO TO 340
  500 T =T0*1.1
  502 IT=2
      IF(F.LT.0.) GO TO 400
      GO TO 120
  100 E1=(H-H1)/H
      IF(ABS(E1).LT.1.E-04) GO TO 340
      IT=IT+1
      IF(IT.LT.21) GO TO 10
      IF(ABS(T-2000.).LT.10.) GO TO 830
      IF(IHOLD.EQ.0) GO TO 800
      WRITE(6,831) P1,H5,T
  831 FORMAT(* ERROR IN FT*/* P1 = *E13.5,5X,*H1 = *E13.5,5X,*T = *E13.5
     1)
      STOP
  800 T=THOLD
      T0=T
      H=HHOLD
      IT=1
      IHOLD=1
      IF(T.LE.2000.) IHOLD=-1
      GO TO 1000
  830 IF(IFLAG.EQ.1) GO TO 504
      IFLAG=1
      T0=2000.
      T=2000.
      IF(F.LT.0.) GO TO 400
      GO TO 120
  504 WRITE(6,11)  E1
   11 FORMAT(* TEMPERATURE IN FT SET TO 2000      -      ERROR = *E13.5)
```

```
      GO TO 340
   10 T9=T0-E0*(T -T0)/(E1-E0)
  505 E0=E1
      T0=T
      T=T9
      IF(F.LT.0.) GO TO 400
  120 A=1.E-07*(-.1042*F2  +.8242*F+.987)
      B=.001*(.01167*F2 +.1503*F+.938)
      C=-.0284*F2 +.6731*F+.4293
      IF(F.LE.1.) GO TO 190
      A=1.E-07*(1.787*F2 -5.48*F+5.4)
      B=.001*(-.1867*F2 +1.11*F+ '76)
      C=-.0933*F2 +3.975*F-2.808
  190 IF(T.LE.2000..AND.IHOLD.NE.1) GO TO 290
      A=.000001*(1.792*F2 +.3983*F+.31)
      B=.001*(-9.05*F2 -.07917*F+.245)
      C=10.86*F2 -.1183*F+.97
      IF(F.LE.1.) GO TO 290
      A=.000001*(4.81*F2 -13.9*F+11.59)
      B=.001*(-23.08*F2 +66.82*F-52.61)
      C=27.05*F2 -73.73*F+58.39
  290 H1=A*T*T+B*T+C
      IF(T.LE.2000..AND.IHOLD.NE.1) GO TO 370
      H1=H1*(1.+(1.+F)*(T/2000.-1.)*Z9)
  370 CONTINUE
      GO TO 350
  400 T2=T*T
      T3=T2*T
      T4=T3*T
      T5=T4*T
      IF(F.LT.-1.5) GO TO 450
      XMM1=16.043
      A1=4.2497678
      A2=-6.9126562E-03
      A3=3.1602134E-05
      A4=-2.9715432E-08
      A5=9.5103580E-12
      A6=-1.0186632E+04
      GO TO 460
  450 CONTINUE
      A1=1.1202436
      A2=1.3905716E-02
      A3=2.6568374E-06
      A4=-1.1560272E-08
      A5=5.2386929E-12
      A6=5.3328896E+03
      XMM1=28.054
  460 H1=A1*T+A2*T2/2.+A3*T3/3.+A4*T4/4.+A5*T5+A6
      H1=H1*8314./XMM1/1.E+06
  350 IF(IT.EQ.1) GO TO 50
      GO TO 100
  340 T0=T
      FT=T/TIN
      THOLD=T
      HHOLD=H
      RETURN
 6666 H=H5* UINF
```

```
      FT=H*5./9./CPI/TIN
      RETURN
      END
```

```
      FUNCTION FH(P1,F,T1)
      COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/A/ TIN,CPIN,RO
      COMMON/IDEAL/IDEAL,GAMEY,XMWT ,CPI
      T=T1*TIN
      IF(IDEAL.EQ.1)GO TO 6666
      P=P1/PIN*PINF*1.01325E+05
      F2=F*F
      IF(F.LT.0.) GO TO 400
      IF(T.GT.2000.) GO TO 190
      IF(F.GT.1.) GO TO 191
  120 A=1.E-07*(-.1042*F2  +.8242*F+.987)
      B=.001*(.01167*F2 +.1503*F+.938)
      C=-.0284*F2 +.6731*F+.4293
      GO TO 290
  191 A=1.E-07*(1.787*F2 -5.48*F+5.4)
      B=.001*(-.1867*F2 +1.11*F+.176)
      C=-.0933*F2 +3.975*F-2.808
      GO TO 290
  190 IF(F.GT.1.) GO TO 192
      A=.000001*(1.792*F2 +.3983*F+.31)
      B=.001*(-9.05*F2 -.07917*F+.245)
      C=10.86*F2 -.1183*F+.97
      GO TO 290
  192 A=.000001*(4.81*F2 -13.9*F+11.59)
      B=.001*(-23.08*F2 +66.82*F-52.61)
      C=27.05*F2 -73.73*F+58.39
  290 H1=A*T*T+B*T+C
      IF(T.LE.2000.) GO TO 370
      A10=ALOG(P)/2.3-5.
      Z9=.125*A10*A10              -.275*A10
      H1=H1*(1.+(1.+F)*(T/2000.-1.)*Z9)
  370 H1=H1*1.E+06
      GO TO 340
  400 T2=T*T
      T3=T2*T
      T4=T3*T
      T5=T4*T
      H1=A1*T+A2*T2/2.+A3*T3/3.+A4*T4/4.+A5*T5+A6
      H1=H1*8314./XMM1
  340 CONTINUE
      FH=H1*10.7639/UINF
      RETURN
 6666 FH=CPI*T*9./5./UINF
      RETURN
      END
```

```
      FUNCTION FGAM(T1,P1,F)
      COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/A/ TIN,CPIN,RO
      COMMON/IDEAL/IDEAL,GAMEY,XMWT ,CPI
      IF(IDEAL.EQ.1)GO TO 6666
      T=T1*TIN
      T2=T*T
      P=P1/PIN*PINF*1.01325E+05
      XM=0.
      IF(F.LT.0.) GO TO 550
      IF(T.LE.1000.) GO TO 440
      XM=-2.15E-08*T2 +.000091*T-.0695
  440 XN=4.E-09*T2 -.00002*T-.019
      IF(F.LE.1.) GO TO 470
      XN=.0339*SQRT(T)-.000391*T-.681
  470 G=-1.833E-07*T2 +.000075*T+1.367
      IF(T.LT.500.) GO TO 520
      G=2.E-08*T2 -.000138*T+1.423
      IF(T.LT.2000.) GO TO 520
      G=7.267E-08*T2 -.000457*T+1.85
  520 G=G+XM*(ALOG(P)/2.3-5.)+XN*(F-1.)
      GO TO 530
  550 T3=T2*T
      T4=T3*T
      CP=A1+A2*T+A3*T2+A4*T3+A5*T4
      G=CP*(CP-1.)
  530 CONTINUE
      FGAM=G
      RETURN
 6666 FGAM=GAMEY
      RETURN
      END
```

```
      FUNCTION RHEQ(H,P1,F,T)
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/A/ TIN,CPIN,RO
      COMMON/IDEAL/IDEAL,GAMEY,XMWT ,CPI
      T1=FT(P1,F,H)
      T=T1*TIN
      IF(IDEAL.EQ.1)GO TO 6666
      P=P1/PIN*PINF*1.01325E+05
      IF(F.LT.0.) GO TO 2260
      FNM=1.53*F*F-5.895*F+28.965
      FNN=1.6*F*F-10.6*F+33.6
      IF(T.GT.2000.) GO TO 2030
      XM=FNM
      IF(F.LT.1.) GO TO 2160
      XM=FNN
      GO TO 2160
2030  FF=F*F
      A=-2.3*FF+4.01*F+1.736
      B=8.61*FF-15.42*F-6.66
      C=-16.88*FF+33.21*F+14.58
      XN=-.4375*FF+.0625*F+2.08
      D=A*(ALOG(P)/2.3)**1.5+B*(ALOG(P)/2.3)+C
      XM=FNM-D*((T-2000.)/1000.)**XN
      IF(F.LT.1.) GO TO 2160
      A=-.822*FF+2.363*F+1.905
      B=2.76*FF-7.56*F-8.68
      C=-3.6*FF+7.36*F+27.15
      XN=-.47*FF+1.825*F+.35
      D=A*(ALOG(P)/2.3)**1.5+B*(ALOG(P)/2.3)+C
      XM=FNN-D*((T-2000.)/1000.)**XN
      GO TO 2160
2260  KF=F-.5
      IF(KF.EQ.-1)XM=16.043
      IF(KF.EQ.-2)XM=28.054
2160  RHEQ=P*XM/T/8314.3*6.2428E-02/32.174
      T=T/TIN
      RHEQ=RHEQ/RHOINF
      RETURN
6666  RHEQ=P1*XMWT*5.*UINF/T/9./49712.52
      T=T/TIN
      RETURN
      END
```

```
      SUBROUTINE ERROR(IIII)
      WRITE(6,100) IIII
  100 FORMAT(7H1ERROR=I5)
      CALL EXIT
      RETURN
      END
```

```
FUNCTION XM1(ALPHA,BETA,TA,XA,TC,XC)
XM1=ALPHA*TAN(TA+XA)
IF(BETA.GT.0.)XM1=XM1+BETA*TAN(TC+XC)
RETURN
END
```

```
      FUNCTION XM2(AL,B,TA,XA,TC,XC)
      XM2=AL*TAN(TA-XA)
      IF(B.GT.0.)XM2=XM2+B*TAN(TC-XC)
      RETURN
      END
```

```
FUNCTION XM3(A,B,TD,TC)
XM3=A*TAN(TD)
IF(B.GT.0.0)XM3=XM3+B*TAN(TC)
RETURN
END
```

```
      FUNCTION F1(A, B, XMU1, GAM1, P1, XMU2,
     1GAM2, P2)
      F1=SIN(XMU1)*COS(XMU1)/GAM1
      IF(B.GT.0.0)F1=(F1+SIN(XMU2)*
     1COS(XMU2)/GAM2    )/2.
      RETURN
      END
```

```
      FUNCTION   F2(A,B,OPT,XJ,XJ1,X,Y,TH,XMU,XN,YN,THN,XMUN)
      F21=0.
      IF(XJ.EQ.0.) GO TO 15
      F21=A*SIN(TH)*SIN(XMU)/COS(TH+OPT*XMU)/Y
      IF(B.GT.0.) F21=F21+B*SIN(THN)*SIN(XMUN)/COS(THN+OPT*XMUN)/YN
   15 F22=0.
      IF(XJ1.EQ.0.) GO TO 10
      F22=A*COS(TH)*SIN(XMU)/COS(TH+OPT*XMU)
      IF(B.GT.0.) F22=F22+B*COS(THN)*SIN(XMUN)/COS(THN+OPT*XMUN)
   10 F2=F21+F22
      RETURN
      END
```

```
      SUBROUTINE DRTEST(XN,YN,EM1,BET,IDROP,L,M)
      COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
      EM2=TAN(BET)
      XNT=(Y(M)-Y(M+L)-EM1*X(M)+EM2*X(M+L))/(EM2-EM1)
      YNT=Y(M)+EM1*(XNT-X(M))
      DISNOR=SQRT((XN-X(M))**2+(YN-Y(M))**2)
      DISEX =SQRT((XNT-X(M))**2+(YNT-Y(M))**2)
      IF((DISEX-DISNOR)/DISEX.LT..1) IDROP=1
      RETURN
      END
```

```
      SUBROUTINE XMASSS(RATM,NPTS)
      COMMON/FVAR/
     1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
     2XMASSF(200),              HF(200),SF(200),ALPD(10),
     3THETA(20)
      COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
     110,200)
      DO 170 I=1,NPTS
      CALL FM (FM1,EMF(I),GAMF(I))
      FM2=FM1/RATM
      ITM=1
      IER=0
      EMT=RATM*EMF(I)
  197 CONTINUE
      CALL FM(FMT,EMT,GAMF(I))
      ERM=(FM2-FMT)/FM2
      IF(ABS(ERM).LT.1.E-03)GO TO 171
      DUMD=1./RATM
      CALL ERR(IER,ITM,EMT,ERM,DUMD,EMT1,ERM1)
      IF(IER.EQ.1)GO TO 2
      ITM=ITM+1
      GO TO 197
    2 WRITE(6,3)
    3 FORMAT(* ERROR IN ITERATION LOOP IN XMASSS*)
      STOP
  171 CONTINUE
      DUM=SQRT((GAMF(I)+1.)/(GAMF(I)-1.))
      ETSQ=SQRT(EMT*EMT-1.)
      ESQ=SQRT(EMF(I)*EMF(I)-1.)
      XNU2=DUM*ATAN(ETSQ/DUM)-ATAN(ETSQ)
      XNU1=DUM*ATAN(ESQ/DUM)-ATAN(ESQ)
      DNU=XNU2-XNU1
      CALL PM1(DNU,I)
  170 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GEM(XA,YA,SLA,XB,YB,SLB,XC,YC)
      XC=(YB-YA+SLA*XA-SLB*XB)/(SLA-SLB)
      YC=YA+SLA*(XC-XA)
      RETURN
      END
```

```
      SUBROUTINE THERMO(TI,H,CP,DCP)
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON /SP/ NSP
      COMMON/A/ TIN,CPIN,RO
      COMMON/B/ WTMOLE
      DIMENSION WTMOLE(10)
      DIMENSION H(10),CP(10),DCP(10)
      T=TI*TIN
      C1=RO/CPIN
      C2=C1/TIN
      C3=C1*TIN
      N=NSP
      DO 10 J=1,N
      H1=C2/WTMOLE(J)
      H2=C1/WTMOLE(J)
      H3=C3/WTMOLE(J)
      CALL COEFF(J,T,A,B,C,D,E,F,G)
      H(J)=T*(A+T*(B/2.+T*(C/3.+T*(D/4.+E/5.*T))))+F
      H(J)=H(J)*RO*4.506557*1.E+04/WTMOLE(J)/UINF
      CP(J)=A+T*(B+T*(C+T*(D+E*T)))
      CP(J)=CP(J)*H2
      DCP(J)=B+T*(2.*C+T*(3.*D+4.*E*T))
      DCP(J)=DCP(J)*H3
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SL(P1,Q1,RH1,R1,W1,GAM1,EM1,XMU1,T1,
     1P2,Q2,RH2,R2,W2,GAM2,EM2,XMU2,T2,ALPDUM,IEQ,A,B)
      R2=R1
      RH2=RH1*(P2/P1)**(1./GAM1)
      IF(IEQ.EQ.1)W2=W1
      IF(IEQ.EQ.1.AND.B.EQ.0.)Q2=Q1+(P1-P2)/RH1/Q1
      CALL ALL(P2,Q2,RH2,R2,W2,GAM2,EM2,XMU2,T2,ALPDUM,IEQ,0)
      RETURN
      END
```

```
      SUBROUTINE DPOINT(K,L,M,N,NPTS,A,B)
      COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/VAR/RHO(200),
     1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
     2             XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
     3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
     4XMASSN(200),ALPN(10,200),SI(10),HI(10),TEMP(20)
     5,ALPDUM(10)
      COMMON /SP/ NSP
      COMMON/DD/XD,YD,THD,PD,QD,RHD,RD,WD,EMD,GAMD,XMUD,TD
      ITD=0
      IF(M.EQ.1)GO TO 195
      XD=.5*(X(M)+X(M-1))
      SLD=.5*(TAN(THN(L))+.5*(TAN(TH(M))+TAN(TH(M-1))))
      QD=Q(M-1)
      SLM=(Y(M)-Y(M-1))/(X(M)-X(M-1))
      S2=SQRT((X(M-1)-X(M))**2+(Y(M-1)-Y(M))**2)
   10 CALL GEM(XN(L),YN(L),SLD,X(M),Y(M),SLM,XD,YD)
      SD=SQRT((XD-X(M))**2+(YD-Y(M))**2)
      IF(ITD.GT.0)GO TO 11
      IF(SD.GT.S2)GO TO 100
   11 RATD=1.-SD/S2
      XT=XD
      THD=TH(M-1)+RATD*(TH(M)-TH(M-1))
      XD=X(M-1)+RATD*(X(M)-X(M-1))
      ERD=ABS((XT-XD)/(X(M)-X(M-1)))
      IF(ERD.LT.1.E-03)GO TO 15
      SLD=(TAN(THN(L))+TAN(THD))/2.
      ITD=ITD+1
      IF(ITD.LT.10)GO TO 10
      WRITE(6,75)
   75 FORMAT(*TOO MANY ITERATIONS IN DPOINT*)
      WRITE(6,76)K,XN(K),YN(K),THN(K),XD,YD,RATD,THD ,ERD
      WRITE(6,76)L,XN(L),YN(L),THN(L)
      WRITE(6,76)M,X(M),Y(M),TH(M)
      IF(M.GT.1)JJ=M-1
      IF(M.GT.1)WRITE(6,76)JJ,X(JJ),Y(JJ),TH(JJ)
   76 FORMAT(1X,I5,8E13.5)
      STOP
   15 DO 14 J=1,NSP
   14 ALPDUM(J)=ALP(J,M-1)+RATD*(ALP(J,M)-ALP(J,M-1))
      CALL INT(RATD,X(M-1),Y(M-1),TH(M-1), P(M-1),Q(M-1),RHO(M-1),
     1R(M-1),W(M-1),GAM(M-1),EM(M-1),XMU(M-1),T(M-1),X(M),Y(M),TH(M),
     2P(M),Q(M),RHO(M),R(M),W(M),GAM(M),EM(M),XMU(M),T(M),
     3D1,D2,THD,PD,QD,RHD,RD,WD, GAMD,EMD,XMUD,TD,ALPDUM,1,IEQ)
      RETURN
  100 CONTINUE
      SLP=(YN(K)-Y(M-1))/(XN(K)-X(M-1))
      SLD=.5*(TAN(THN(L))+.5*(TAN(THN(K))+TAN(TH(M-1))))
      XD=.5*(XN(K)+X(M-1))
  101 CALL GEM(XN(L),YN(L),SLD,XN(K),YN(K),SLP,XD,YD)
      RATD=(XD-X(M-1))/(XN(K)-X(M-1))
      XT=XD
      THD=TH(M-1)+RATD*(THN(K)-TH(M-1))
      XD=X(M-1)+RATD*(XN(K)-X(M-1))
      ERD=ABS((XT-XD)/(XN(K)-X(M-1)))
```

```
      IF(ERD.LT.1.E-03)GO TO 150
      SLD=(TAN(THN(L))+TAN(THD))/2.
      ITD=ITD+1
      IF(ITD.LT.10)GO TO 101
      WRITE(6,75)
      STOP
  150 DO 140 J=1,NSP
  140 ALPDUM(J)=ALP(J,M-1)+RATD*(ALPN(J,K)-ALP(J,M-1))
      CALL INT(RATD,X(M-1),Y(M-1),TH(M-1), P(M-1),Q(M-1),RHO(M-1),
     1R(M-1),W(M-1),GAM(M-1),EM(M-1),XMU(M-1), T(M-1),
     2XN(K),YN(K),THN(K),PN(K),QN(K),RHON(K),RN(K),WN(K),GAMN(K),
     3EMN(K),XMUN(K),TN(K),D1,D2,THD,PD,QD,RHD,RD,WD,GAMD,EMD,XMUD,
     4TD,ALPDUM,1,IEQ)
      RETURN
  195 CONTINUE
      QD=Q(M)
      SLD=.5*(TAN(THN(L))+.5*(TAN(THN(K))+TAN(TH(M))))
      XD=.5*(XN(K)+X(M))
      I75=0
      IF(ABS(XN(K)-X(M)).GT.1.E-06)I75=1
      IF(I75.EQ.1)GO TO 290
      XD=(XN(K)+X(M))/2.
  191 IF(I75.EQ.1)GO TO 290
      YD=YN(L)+SLD*(XN(L)-XD)
      GO TO 291
  290 SLP=(YN(K)-Y(M))/(XN(K)-X(M))
      CALL GEM(XN(L),YN(L),SLD,XN(K),YN(K),SLP,XD,YD)
  291 RATD=(YD-Y(M))/(YN(K)-Y(M))
      YT=YD
      THD=TH(M)+RATD*(THN(K)-TH(M))
      YD=Y(M)+RATD*(YN(K)-Y(M))
        ERD=(YT-YD)/(YN(K)-Y(M))
      IF(ABS(ERD).LT.1.E-03)GO TO 197
      SLD=(TAN(THD)+TAN(THN(L))) /2.
      ITD=ITD+1
      IF(ITD.LT.10)GO TO 191
      WRITE(6,75)
      STOP 1
  197 DO 198 J=1,NSP
  198 ALPDUM(J)=ALP(J,M)+RATD*(ALPN(J,K)-ALP(J,M))
      CALL INT(RATD,X(M),Y(M),TH(M),P(M),Q(M),RHO(M),R(M),W(M),GAM(M),
     1EM(M),XMU(M),T(M),XN(K),YN(K),THN(K),PN(K),QN(K),RHON(K),RN(K),
     2WN(K),GAMN(K),EMN(K),XMUN(K),TN(K),D1,D2,THD,PD,QD,RHD,RD,WD,GAMD,
     3EMD,XMUD,TD,ALPDUM,1,IEQ)
      RETURN
      END
```

```
      SUBROUTINE INT(RAT,X1,Y1,TH1,P1,Q1,RH1,R1,W1,GAM1,EM1,XMU1,T1,
     1X2,Y2,TH2,P2,Q2,RH2,P2,W2,GAM2,EM2,XMU2,T2,
     2X3,Y3,TH3,P3,Q3,RH3,R3,W3,GAM3,EM3,XMU3,T3,ALPDUM,IALL,IEQ)
      DIMENSION ALPDUM(10)
      X  3=X  1+RAT*(X  2-X  1)
      Y  3=Y  1+RAT*(Y  2-Y  1)
      T  3=T  1+RAT*(T  2-T  1)
      P  3=P  1+RAT*(P  2-P  1)
      R  3=R  1+RAT*(R  2-R  1)
      W  3=W  1+RAT*(W  2-W  1)
      Q  3=Q  1+RAT*(Q  2-Q  1)
      TH 3=TH 1+RAT*(TH 2-TH 1)
      GAM3=GAM1+RAT*(GAM2-GAM1)
      PRG1=P1/RH1**GAM1
      PRG2=PRG1
      IF(RAT.NE.0.)PRG2=P2/RH2**GAM2
      PRG3=PRG1+RAT*(PRG2-PRG1)
      RH3=(P3/PRG3)**(1./GAM3)
      IF(IALL.EQ.1)GO TO 20
      EM 3=EM 1+RAT*(EM 2-EM 1)
      XMU3=XMU1+RAT*(XMU2-XMU1)
      RETURN
   20 CALL ALL(P3,Q3,RH3,R3,W3,GAM3,EM3,XMU3,T3,ALPDUM,IEQ,0)
      RETURN
      END
```

```
      SUBROUTINE ERR(I,IT,X,ER,F,X1,ER1)
      IF(IT.LT.15)GO TO 12
      I=1
      RETURN
   12 IF(IT.GT.2)GO TO 14
      ER1=ER
      X1=X
      X=X*F
      IF(X.EQ.X1)X=X+.02
      RETURN
   14 XD=X1-ER1*(X-X1)/(ER-ER1)
      ER1=ER
      X1=X
      X=XD
      RETURN
      END
```

```
      SUBROUTINE VIS(T,XMUU)
      COMMON/A/TIN,CPIN,RO
      TC=198.*5./TIN/9.
      XMUU=(1.+TC)*(T**1.5)/(T+TC)
      RETURN
      END
```

```
      SUBROUTINE WUZZY(N,NPTS,KMAX,LMAX,IPP,IFZ,LWUZ)
      COMMON/LDOWN/LDOWN
      COMMON/ICMPLT/ICMPLT
      COMMON/VAR/RHO(200),
     1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
     2             XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
     3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
     4XMASSN(200),ALPN(10,200),SI(10),HI(10),TEMP(20)
     5,ALPDUM(10)
      COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
      LS=2
      L=2
      K=1
      SLP1=TAN(THN(K)+XMUN(K))
      M=3
      IF(N.LE.NPTS)M=1
      IF(ICMPLT.EQ.2)M=2
   43 IF(K.GT.1)SLP1=(YN(K)-Y(M-1))/(XN(K)-X(M-1))
      IF(IFZ.EQ.1.AND.L.EQ.LDOWN)RETURN
      SLP2=(YN(L)-Y(M))/(XN(L)-X(M))
   39 CONTINUE
      IF(L.EQ.LWUZ)RETURN
      IF(ABS(SLP2-SLP1).LT.1.E-06)GO TO 40
      CALL GEM(XN(L),YN(L),SLP2,XN(K),YN(K),SLP1,XS,YS)
      IF(XS.LT.XN(L))GO TO 40
      IF((XS-XN(L))/(XN(L)-X(M)).GT.2.5)GO TO 40
      IPT=IPP+1
      BETA=.5*(SLP1+SLP2)
      WRITE(6,10)IPT,L,K,M,LS,N,NPTS,
     1                          XN(L),X(M),XN(K),X(M-1),YN(L),Y(M),YN(K),
     1Y(M-1),SLP1,SLP2,BETA,XS,YS
   10 FORMAT(1X,7I5/1X,8E13.5/1X,8E13.5)
      WRITE(6,33)
   33 FORMAT(  * UP RUNNING SHOCK DETECTED * )
      WRITE(6,34)IPT,LS,XS,YS,BETA
   34 FORMAT(* LINE NO. = *,I4,4X* POINT NO. = *,I4   ,4X*XS = *,E13.5,
     14X* YS = *,E13.5,4X* SHOCK ANGLE = *,E13.5)
      LL=L
      LM=LMAX-1
      IF(L.EQ.LMAX)LL=LM
      DO 46 J=LL,LM
      XN(J)=XN(J+1)
      YN(J)=YN(J+1)
      PN(J)=PN(J+1)
      QN(J)=QN(J+1)
      TN(J)=TN(J+1)
      WN(J)=WN(J+1)
      RN(J)=RN(J+1)
      THN(J)=THN(J+1)
      EMN(J)=EMN(J+1)
      RHON(J)=RHON(J+1)
      XMUN(J)=XMUN(J+1)
      DO 1500 JL=1,7
 1500 ALPN(JL,J)=ALPN(JL,J+1 )
   46 CONTINUE
      LMAX=LMAX-1
      LS=LS-1
```

```
      M=M+1
   40 K=K+1
      L=L+1
      M=M+1
      LS=LS+1
      IF(L.LT.LMAX)GO TO 43
      IF(L.GT.LMAX)RETURN
      IF(IFZ.EQ.1.AND.L.EQ.LDOWN)RETURN
      M=KMAX
      K=L-1
      SLP1=(YN(K)-Y(M))/(XN(K)-X(M))
      SLP2=TAN(THN(L)+XMUN(L))
      GO TO 39
      END
```

```
      SUBROUTINE FUZZY(K,L,M,N,LMAX,KMAX,NPTS,IPP,IFZ)
      COMMON/LDOWN/LDOWN
      COMMON/VAR/RHO(200),
     1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
     2             XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
     3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
     4XMASSN(200),ALPN(10,200),SI(10),HI(10),TEMP(20)
     5,ALPDUM(10)
      COMMON/XY/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
      COMMON/XCOWL/XCOWL
      IFZ=0
      DUMX=(XN(1)-X(1))**2
      DUMY=(YN(1)-Y(1))**2
      TEST=SQRT(DUMX+DUMY)
      IF(TEST.EQ.0.)RETURN
      SLP=TAN(TH(M)+XMU(M))
      SLM=TAN(THN(K)-XMUN(K))
      CALL GEM(XN(K),YN(K),SLM,X(M),Y(M),SLP,XC,YC)
      DX=(XC-X(M))**2
      DY=(YC-Y(M))**2
      DC=SQRT(DX+DY)
      IF((DC/TEST).GT.0.2)RETURN
      LM=LMAX-1
      LDOWN=L
      I=L
      J=M
   85 XMUN(I)=XMU(J)
      YN(I)=Y(J)
      X  N(I)=X  (J)
      P  N(I)=P  (J)
      Q  N(I)=Q  (J)
      T  N(I)=T  (J)
      W  N(I)=W  (J)
      R  N(I)=R  (J)
      TH N(I)=TH (J)
      EM N(I)=EM (J)
      RHON(I)=RHO(J)
      GAMN(I)=GAM(J)
      DO 1500 JJ=1,7
 1500 ALPN(JJ,I)=ALP(JJ,J)
      I=I+1
      J=J+1
      IF(I.GT.LM)GO TO 45
      GO TO 85
   45 CONTINUE
      IPT=IPP+1
      BETA=.5*(TAN(TH(M)-XMU(M))+SLM)
      WRITE(6,33)
   33 FORMAT(* DOWN RUNNING SHOCK DETECTED * )
      WRITE(6,34)IPT,L,XC,YC,BETA
   34 FORMAT(* LINE NO. = *,I4,4X* POINT NO. = *,I4   ,4X*XS = *,E13.5,
     14X* YS = *,E13.5,4X* SHOCK ANGLE = *,E13.5)
      LMAX=LMAX+1
      IF(N.GT.NPTS)LMAX=KMAX-1
      IFZ=1
      RETURN
      END
```

```
      SUBROUTINE GNURE(RH,Q,P,T,W,R,ALPDUM,X,X1,CF,ST,L)
      COMMON/HOT/AH(3),BH(3),CH(3),XSTR,PR,REC,REIN,RT,SH,IT,IVIS
      COMMON/SP/NSP
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      DIMENSION ALPDUM(10),H1(10),CP1(10)
      HDEL=R*Q*Q/2.
      HAW=1.+REC*Q*Q/2./HDEL
      IF(IT .EQ.0)TW=AH(L)*(X-X1)**2+BH(L)*(X-X1)+CH(L)
      IF(IT .EQ.1)GO TO 46
      IF(IEQ.EQ.0)GO TO 13
      HW=FH(P,W,TW)/HDEL
      GO TO 48
   13 CALL THERMO(TW,H1,CP1,DUM)
      HW=0.
      DO 20 J=1,NSP
      HW=HW+ALPDUM(J)*H1(J)
   20 CONTINUE
      HW=HW/HDEL
      GO TO 48
   46 HW=HAW
   48 A=HAW-1.
      B=HW-1.
      C=SQRT((A+B)**2+4.*A)
      FC=A/(ASIN((A-B)/C)+ASIN((A+B)/C))**2
      FRX=HAW**(.772)/(FC*(HW)**(1.474))
      CALL VIS(T,XMMU)
      REX=RH*Q*(X+XSTR)/XMMU

      REXI=FRX*REX*REIN*RT
      CFI=.088*(ALOG10(REXI)-2.3686)/(ALOG10(REXI)-1.5)**3
      CF=CFI/FC
      ST=CF*SH/2.
      RETURN
      END
```

```
      SUBROUTINE SNARF(X1,Y1,Z1,X2,Y2,Z2,X3,Y3,Z3,X4,Y4,Z4,AVX,AVY,AVZ,
     1XNX,XNY,XNZ,AS,XO,YO,ZO)
      DIMENSION XPA(4),YPA(4),ZPA(4),XI(4),ETA(4)
      XPA(1)=X1
      YPA(1)=Y1
      ZPA(1)=Z1
      ZPA(2)=Z2
      YPA(2)=Y2
      XPA(2)=X2
      XPA(3)=X3
      YPA(3)=Y3
      ZPA(3)=Z3
      ZPA(4)=Z4
      YPA(4)=Y4
      XPA(4)=X4
      T1X=X3-X1
      T1Y=Y3-Y1
      T1Z=Z3-Z1
      T2X=X4-X2
      T2Y=Y4-Y2
      T2Z=Z4-Z2
      XNX=T2Y*T1Z-T1Y*T2Z
      XNY=T1X*T2Z-T2X*T1Z
      XNZ=T2X*T1Y-T1X*T2Y
      VN=SQRT(XNX**2+XNY**2+XNZ**2)
      XNX=XNX/VN
      XNY=XNY/VN
      XNZ=XNZ/VN
      D=XNX*(AVX-X1)+XNY*(AVY-Y1)+XNZ*(AVZ-Z1)
      PD=ABS(D)
      T=SQRT(T1X*T1X+T1Y*T1Y+T1Z*T1Z)
      T1X=T1X/T
      T1Y=T1Y/T
      T1Z=T1Z/T
      T2X=XNY*T1Z-XNZ*T1Y
      T2Y=XNZ*T1X-XNX*T1Z
      T2Z=XNX*T1Y-XNY*T1X
      DO 1000 J=1,4
      XPA(J)=XPA(J)+XNX*D
      YPA(J)=YPA(J)+XNY*D
      ZPA(J)=ZPA(J)+XNZ*D
      D=-D
      XDIF=XPA(J)-AVX
      YDIF=YPA(J)-AVY
      ZDIF=ZPA(J)-AVZ
      XI(J)=T1X*XDIF+T1Y*YDIF+T1Z*ZDIF
 1000 ETA(J)=T2X*XDIF+T2Y*YDIF+T2Z*ZDIF
      XIO=(XI(4)*(ETA(1)-ETA(2))+XI(2)*(ETA(4)-ETA(1)))/(ETA(2)-ETA(4))
     1/3.
      ETAO=-ETA(1)/3.
      DO 1020 J=1,4
      XI(J)=XI(J)-XIO
 1020 ETA(J)=ETA(J)-ETAO
      XO=AVX+T1X*XIO+T2X*ETAO
      YO=AVY+T1Y*XIO+T2Y*ETAO
      ZO=AVZ+T1Z*XIO+T2Z*ETAO
      AS=(ETA(2)-ETA(4))*(XI(3)-XI(1))/2.
```

```
      AS=ABS(AS)
      RETURN
      END
```

```
      SUBROUTINE LTHM(X1,Y1,Z1,X2,Y2,Z2,X3,Y3,Z3,X4,Y4,Z4,P1,P2,P3,P4,
     1Q1,Q2,Q3,Q4,RH1,RH2,RH3,RH4,R1,R2,R3,R4,W1,W2,W3,W4,
     2TH1,TH2,TH3,TH4,ALPDUM,XK1,XK2,XK3,XK4,XXTHX,XYLFT,XXMOM,CF,ST,LH)
      COMMON/LTM/XSHFT,YSHFT,DUMA,DUMB,DUMC,DUM1,DUM2,DUM3,DUM4
      COMMON/ETX/XJ,XJ1,NPTS,ID,IREFL,ICHEM,IPUNCH,IDESGN,IR,NXX,XBP,
     1YBP,THBP,RAD,XBOD,YBOD,THBOD,RADB,XEND,THEND,RTH,YEXIT,THST,TEST,
     1IRFL,Y0,RADB2,RRAD(20),    NSTAR,YNOZ,EIN,     PEN,H16,H17
      COMMON/PFF/PFINF
      COMMON/VISF/XVTHX,YVLFT,XVMOM
      COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
      COMMON/HOT/AH(3),BH(3),CH(3),XSTR,PR,REC,REIN,RT,SH,IT,IVIS
      DIMENSION ALPDUM(10)
      P=XK1*P1+XK2*P2+XK3*P3+XK4*P4
      Q=XK1*Q1+XK2*Q2+XK3*Q3+XK4*Q4
      R=XK1*R1+XK2*R2+XK3*R3+XK4*R4
      W=XK1*W1+XK2*W2+XK3*W3+XK4*W4
      RH=XK1*RH1+XK2*RH2+XK3*RH3+XK4*RH4
      TH=XK1*TH1+XK2*TH2+XK3*TH3+XK4*TH4
      AVX=XK1*X1+XK2*X2+XK3*X3+XK4*X4
      AVY=XK1*Y1+XK2*Y2+XK3*Y3+XK4*Y4
      AVZ=XK1*Z1+XK2*Z2+XK3*Z3+XK4*Z4
      CALL SNARF(X1,Y1,Z1,X2,Y2,Z2,X3,Y3,Z3,X4,Y4,Z4,AVX,AVY,AVZ,XNX,
     1XNY,XNZ,ASS,XO,YO,ZO)
      CF=0.
      IF(IVIS.EQ.1)CALL GNURE(RH,Q,P,W,R,ALPDUM,XO,XBP,CF,ST,LH)
      IF(IVIS.EQ.1)CALL GNURE(RH,Q,P,T,R,       XO,XBP,CF,ST,LH)          C
      RHQ=RH*Q*Q/2.
      PAV=(P/PIN-1.)*PINF*2116.
      DXTHX=-PAV*XNX*ASS
      DYLFT=-PAV*XNY*ASS
      XNZZ=1.
      IF(LH.EQ.3)XNZZ=XNZ
      DXTHXV=-CF*PFINF*XNZZ*COS(TH)*ASS*RHQ
      DYLFTV=CF*PFINF*SIN(TH)*ASS*RHQ
      XMS=XO-XSHFT
      YMS=YO-YSHFT
      DMOMV=YMS*DXTHXV-XMS*DYLFTV
      XVTHX=XVTHX+DXTHXV
      YVLFT=YVLFT+DYLFTV
      XVMOM=XVMOM+DMOMV
      DXTHX=DXTHX+DXTHXV
      DYLFT=DYLFT+DYLFTV
      DMOM=YMS*DXTHX-XMS*DYLFT
      XXTHX=XXTHX+DXTHX
      XYLFT=XYLFT+DYLFT
      XXMOM=XXMOM+DMOM
      RETURN
      END
```

REFERENCE

1. Del Guidice, P., Dash, S. and Kalben, P., "A Source Flow Characteristic Technique for the Analysis of Scramjet Exhaust Flow Fields," ATL TR 213 (NASA CR-132697) May 1975.