N71-36417

NASA TECHNICAL MEMORANDUM

NASA TM X-2328

NASA TM X-2328

CASE FILE COPY

A COMPUTER PROGRAM TO DETERMINE RADIATING, NONADIABATIC, INVISCID FLOW OVER A BLUNT BODY BY THE METHOD OF INTEGRAL RELATIONS

by Frances W. Taylor

Langley Research Center
Hampton, Va. 23365

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • OCTOBER 1971

1. Report No. NASA TM X-2328	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A COMPUTER PROGRAM TO DETERMINE RADIATING, NONADIABATIC, INVISCID FLOW OVER A BLUNT BODY BY THE METHOD OF INTEGRAL RELATIONS		5. Report Date October 1971
		6. Performing Organization Code
7. Author(s) Frances W. Taylor		8. Performing Organization Report No. L-7807
		10. Work Unit No. 136-13-05-04
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va. 23365		11. Contract or Grant No.
		13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

A computer program (Langley program D1250) has been developed in support of the study of the radiating, nonadiabatic, inviscid flow properties (pressure, temperature, density, velocities, and enthalpy) around a blunt body in equilibrium air by use of a modified method of integral relations. This report describes the digital computer program including the methods used in the digital approximation, flow charts, D1250 program code, instructions for the user, and a test case with input and output listings.

17. Key Words (Suggested by Author(s)) Equilibrium air; Blunt-body flow fields; Integral-relations solutions; Radiative heat transfer	18. Distribution Statement Unclassified – Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	164	$3.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

CONTENTS

A COMPUTER PROGRAM TO DETERMINE RADIATING, NONADIABATIC, INVISCID FLOW OVER A BLUNT BODY BY THE METHOD OF INTEGRAL RELATIONS

By Frances W. Taylor
Langley Research Center

SUMMARY

A computer program (Langley program D1250) has been developed in support of the study of the radiating, nonadiabatic, inviscid flow properties (pressure, temperature, density, velocity, and enthalpy) around a blunt body in equilibrium air by use of a modified method of integral relations. This report describes the digital computer program including the methods used in the digital approximation, flow charts, D1250 program code, instructions for the user, and a test case with input and output listings.

INTRODUCTION

A modified approach to the first-order approximation in the method of integral relations for the numerical calculation of the inviscid, adiabatic, subsonic flow field about a blunt-nose body traveling at hypersonic speeds as described in references 1 and 2 has been extended to include the radiating nonadiabatic case (ref. 3). Langley computer program D1250 was developed to make the calculations for the radiating nonadiabatic flow of air in chemical equilibrium. Results obtained in reference 3 agree with results from inverse and time-dependent techniques. The agreement indicates that this relatively simple method of solution provides an accurate description of the blunt-body flow field in the subsonic region.

A description of the computer program is presented herein along with the methods used in the digital approximations, flow charts, program code, instructions for the user, and a test case with input and output listings.

SYMBOLS

A_j coefficients in governing differential equations

a_η tangential velocity gradient

B_j coefficients in governing differential equations

C coefficients in governing differential equations

E_j coefficients in governing differential equations

$G_{j,\eta}$ functions appearing in governing partial differential equations which are differentiated with respect to y

H total enthalpy, $h + \frac{u^2 + v^2}{2}$

h static enthalpy

$I_{j,\eta}$ functions appearing in governing partial differential equations which are differentiated with respect to x

p pressure

Q curvature of body, $\frac{R_B}{R_b}$

$q_{R,\eta}$ total radiation heat flux

R universal gas constant

R_B body radius of curvature at $x = 0$

R_b local body radius of curvature (see fig. 1)

R_1 weighted heat flux

r radius measured from axis of symmetry of body (see fig. 1)

r_b normal distance from axis of symmetry to a point on body (see fig. 1)

T temperature

U_∞ free-stream velocity

u,v velocity components in x- and y-direction, respectively

V_R resultant velocity

$\overline{W}_{REF}$ molecular weight of cold air, 28.96 g/mole

x coordinate along body surface (see fig. 1)

y coordinate normal to body surface (see fig. 1)

Z compressibility factor

z axial coordinate (see fig. 1)

δ shock displacement distance (see fig. 1)

δ_o value of shock displacement distance at axis of symmetry

η transformed y-coordinate, y/δ

θ_b body inclination angle (see fig. 1)

ρ density

ω shock-wave angle (see fig. 1)

Subscripts:

j used (as first subscript) to denote a particular governing differential equation:

1 shock-geometry equation

2 continuity equation

3 x-momentum equation

4 y-momentum equation

5 energy equation

s shock-oriented properties

stag stagnation condition

η denotes location within shock layer:

0 body surface

1 at shock wave

∞ free-stream conditions

When double subscripts are used, the first (j) denotes the governing equation number and the second (η) denotes location within shock layer.

Primes denote dimensional quantities.

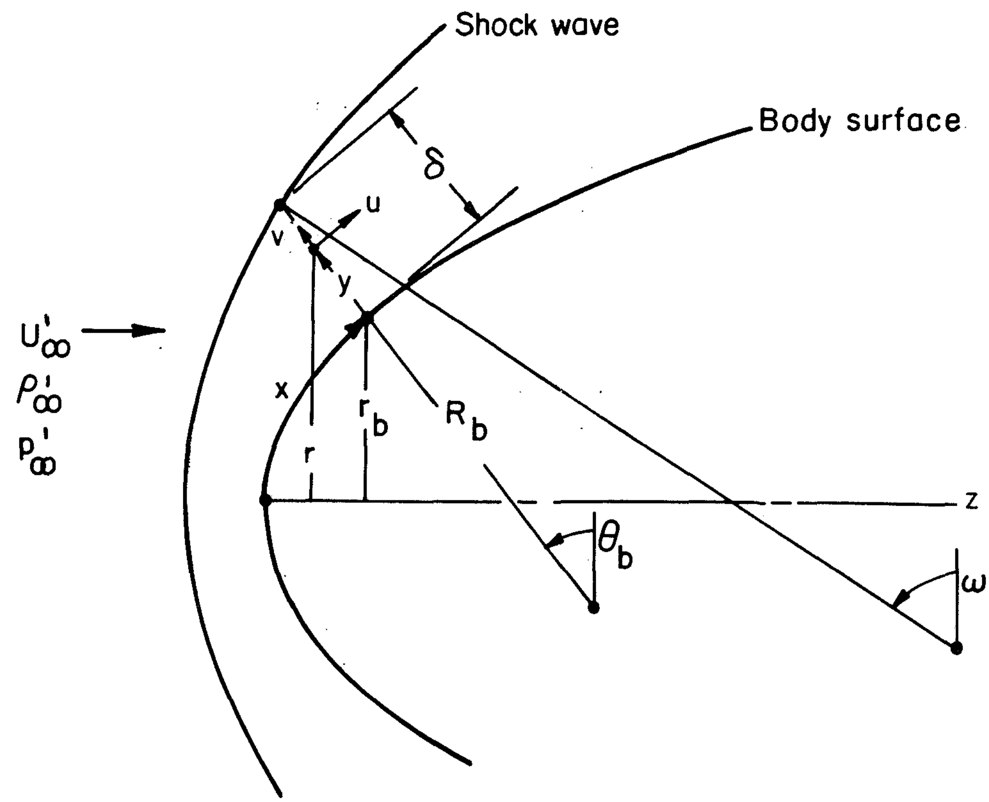


Figure 1.- Flow-field coordinate system.

PROBLEM DESCRIPTION

The equations which govern inviscid, radiating, nonadiabatic steady flow of equilibrium air over a blunt body traveling at hypersonic speeds are a system of nonlinear partial differential equations derived from the laws of conservation of mass, momentum, and energy. The modified method of integral relations, as described in reference 3, is used to transform the governing equations into a set of ordinary differential equations that are numerically integrated to yield the details of the thermodynamic and flow properties within the shock layer. The equations appear in the form used in reference 1. A slightly different notation is used in reference 3. The ordinary differential equations which form the basis for Langley program D1250 are as follows:

$$\left.\begin{aligned}
\frac{d\delta}{dx} &= -E_1 = (1 + Q\delta)\tan\left(\omega - \theta_b\right) \\
\frac{d\omega}{dx} &= \frac{-A_4 \frac{d\delta}{dx} + E_4}{B_4} \\
\frac{dI_{2,0}}{dx} &= \frac{-A_2 \frac{d\delta}{dx} + B_2 \frac{d\omega}{dx} + E_2}{C} \\
\frac{dI_{3,0}}{dx} &= u_0 \frac{dI_{2,0}}{dx} \\
\frac{dI_{5,0}}{dx} &= \frac{-A_5 \frac{d\delta}{dx} + B_5 \frac{d\omega}{dx} + E_5}{C}
\end{aligned}\right\} \tag{1}$$

The equations for the fluxes of mass, momentum (in the x-direction), and energy at the body surface are

$$\left.\begin{aligned}
I_{2,0} &= \rho_0 u_0 \\
I_{3,0} &= p_0 + \rho_0 {u_0}^2 \\
I_{5,0} &= \rho_0 u_0 H_0
\end{aligned}\right\} \tag{2}$$

The quantities have been nondimensionalized as follows:

$$x = \frac{x'}{R'_B} \qquad \delta = \frac{\delta'}{R'_B} \qquad p = \frac{p'}{\rho'_\infty \left(U'_\infty\right)^2}$$

$$y = \frac{y'}{R'_B} \qquad \rho = \frac{\rho'}{\rho'_\infty} \qquad H = \frac{H'}{\left(U'_\infty\right)^2}$$

$$u = \frac{u'}{U'_\infty} \qquad R_b = \frac{R'_b}{R'_B} \qquad h = \frac{h'}{\left(U'_\infty\right)^2}$$

$$v = \frac{v'}{U'_\infty} \qquad r = \frac{r'}{R'_B}$$

where primes denote dimensional quantities.

The coefficients of the governing differential equations are developed in reference 1. The expressions for the coefficients are

$$A_2 = 3\left(I_{2,0} - I_{2,1}\right) + \frac{2\delta \cos \theta_b}{r_b}\left(I_{2,0} - I_{2,1}\right)$$

$$A_4 = -\left(3 + \frac{2\delta \cos \theta_b}{r_b}\right)I_{4,1}$$

$$A_5 = 3\left(I_{5,0} - I_{5,1}\right) + \frac{2\delta \cos \theta_b}{r_b}\left(I_{5,0} - I_{5,1}\right)$$

$$B_j = \delta\left(3 + \frac{2\delta \cos \theta_b}{r_b}\right)\frac{\partial I_{j,1}}{\partial \omega} \qquad (j = 2,4,5)$$

$$C = \delta\left(3 + \frac{\delta \cos \theta_b}{r_b}\right)$$

$$E_1 = \frac{-(1 + Q\delta)}{Q} \tan\left(\omega - \theta_b\right)\frac{d\theta_b}{dx}$$

$$E_2 = \frac{3\delta}{r_b}\left(I_{2,0} + I_{2,1}\right)\frac{dr_b}{dx} + \delta\left(3 + \frac{2\delta \cos \theta_b}{r_b}\right)\frac{\partial I_{2,1}}{\partial \theta_b}\frac{d\theta_b}{dx}$$

$$- \frac{\delta^2 \sin \theta_b}{r_b}\left(I_{2,0} + 2I_{2,1}\right)\frac{d\theta_b}{dx} + 6(1 + \delta Q)\left(1 + \frac{\delta \cos \theta_b}{r_b}\right)G_{2,1}$$

$$E_4 = \frac{3\delta}{r_b} I_{4,1} \frac{dr_b}{dx} + \delta\left(3 + \frac{2\delta \cos \theta_b}{r_b}\right)\frac{\partial I_{4,1}}{\partial \theta_b}\frac{d\theta_b}{dx} - \frac{2\delta^2 \sin \theta_b}{r_b} I_{4,1} \frac{d\theta_b}{dx}$$

$$+ 6(1 + \delta Q)\left(1 + \frac{\delta \cos \theta_b}{r_b}\right)G_{4,1} - 6G_{4,0} - 3\left(\delta Q + \frac{\delta \cos \theta_b}{r_b}\right)\left(I_{3,0} + I_{3,1}\right)$$

$$- \frac{2\delta^2 Q \cos \theta_b}{r_b}\left(I_{3,0} + 2I_{3,1}\right) + \frac{3\delta \cos \theta_b}{r_b}\left(\rho_0 u_0^2 + \rho_1 u_1^2\right)$$

$$+ \frac{\delta^2 Q \cos \theta_b}{r_b}\left(\rho_0 u_0^2 + 2\rho_1 u_1^2\right)$$

$$E_5 = \frac{3\delta}{r_b}\left(I_{5,0} + I_{5,1}\right)\frac{dr_b}{dx} - \frac{\delta^2 \sin \theta_b}{r_b}\left(I_{5,0} + 2I_{5,1}\right)\frac{d\theta_b}{dx}$$

$$+ \delta\left(3 + \frac{2\delta \cos \theta_b}{r_b}\right)\frac{\partial I_{5,1}}{\partial \theta_b}\frac{d\theta_b}{dx} + 6\left(1 + \frac{\delta \cos \theta_b}{r_b}\right)(1 + \delta Q)G_{5,1} + 6R_1$$

where

$$G_{2,1} = \rho_1 v_1$$

$$G_{4,0} = p_0$$

$$G_{4,1} = p_1 + \rho_1 v_1^2$$

$$G_{5,1} = \rho_1 v_1 H_1$$

$$I_{2,0} = \rho_0 u_0$$

$$I_{2,1} = \rho_1 u_1$$

$$I_{3,0} = p_0 + \rho_0 u_0^2$$

$$I_{3,1} = p_1 + \rho_1 u_1^2$$

$$I_{4,0} = 0$$

$$I_{4,1} = \rho_1 u_1 v_1$$

$$I_{5,0} = \rho_0 u_0 H_0$$

$$I_{5,1} = \rho_1 u_1 H_1$$

$$R_1 = (1 + \delta Q)\left(1 + \frac{\delta \cos \theta_b}{r_b}\right) q_{R,1} - q_{R,0}$$

Provision has been made in the governing equations for coupled radiating flow-field analysis. The radiation program, RATRAP (ref. 4), is an independent program which was incorporated into D1250 as subprograms.

The governing differential equations are solved by a fourth-order Runge-Kutta integration technique (see appendix A) to give shock-layer thickness, shock angle, and the fluxes of mass, momentum, and energy at the body surface. The numerical integration proceeds from the stagnation point ($x = 0$); however, direct substitution of the initial values into the governing differential equations at $x = 0$ results in indeterminate (0/0) expressions. (See ref. 3.) Application of L'Hospital's rule yields the proper starting values for the nonzero derivatives:

$$\left(\frac{d\omega}{dx}\right)_{x=0} = \frac{\left(3 + 3\delta_o + \delta_o^2\right)\left(p_{stag} - p_1 + v_1\right)}{\delta_o\left(3 + 2\delta_o\right)\left(1 - \rho_1\right)v_1}$$

$$\left(\frac{dI_{2,0}}{dx}\right)_{x=0} = \frac{\delta_o\left(3 + 2\delta_o\right)\left(1 - \rho_1\right)\left(\frac{d\omega}{dx}\right)_{x=0} - \left(3 + 3\delta_o + \delta_o^2\right)}{-\delta_o\left(3 + \delta_o\right)}$$

$$\left(\frac{dI_{5,0}}{dx}\right)_{x=0} = H_{stag}\left(\frac{dI_{2,0}}{dx}\right)_{x=0}$$

where

$$H_{stag} = \left(H_1\right)_{x=0} - \frac{3R_{1,stag}}{\delta_o\left(3 + \delta_o\right)\left(\frac{dI_{2,0}}{dx}\right)_{x=0}}$$

$$p_{stag} = \frac{\rho_{stag}a_{0,stag}^2}{-\beta}$$

$$R_{1,stag} = \left[\left(1 + \delta_o\right)^2 q_{R,1} - q_{R,0}\right]_{x=0}$$

and β is the input value PEEP (ref. 3, eq. (36)). These equations contain δ_o, the shock displacement distance at the axis of symmetry (x = 0). Since δ_o is initially assumed, a correct value has to be established for the flow-field solution. The regularity conditions at the sonic point, that is, a sonic velocity u_0 and a zero mass flux derivative $\left(\frac{dI_{2,0}}{dx} = 0\right)$, provide the convergence criteria for the proper δ_o.

A Newton-Raphson iteration technique (ref. 5) is used to obtain the set of properties on the body which are consistent with the integrated fluxes. Rankine-Hugoniot relations and the shock angle are used to compute the properties immediately behind the shock. The fluxes ρu, ρuv, and ρuH and the resultant velocity are assumed to vary linearly across the shock layer. Thus, the post-shock and the body properties along with this assumption of linear variation within the shock layer are sufficient to generate consistent velocity components and enthalpies across the entire shock layer. These quantities are computed by the following relations:

$$v_\eta = \frac{I_{4,\eta}}{I_{2,\eta}}$$

$$H_\eta = \frac{I_{5,\eta}}{I_{2,\eta}}$$

$$V_{R,\eta} = V_{R,0} + \left(V_{R,1} - V_{R,0}\right)\eta$$

The pressure distribution is then calculated from the quadratic expression

$$p_\eta = p_0 + \left(\delta Q \rho_0 u_0^2\right)\eta + \left(p_1 - p_0 - \delta Q \rho_0 u_0^2\right)\eta^2$$

The remaining state properties are computed from the equilibrium-air correlations of reference 1.

The integration continues until the pressure at the body diverges, either increasing or decreasing rapidly. This divergence indicates that the sonic point on the body, which is a singular point, has been reached. An increasing divergence of the pressure indicates that the initial δ_0 was too large, and a decreasing divergence of the pressure indicates that δ_0 was too small. The program is stopped after a specified number of iterations on δ_0 or when a maximum value of x, which is an input, has been reached.

PROGRAM ORGANIZATION

D1250 Labeled COMMON

The following list contains all the FORTRAN variables appearing in labeled COMMON, except those used by the radiation package, in the order and with the dimensional information used in program D1250:

COMMON label	FORTRAN variable	Description
/REAI/	IREAD	Set to 0 in EQURATS so that the NAMELIST input in MAIN will only be read the first time through MAIN
/MAINP/	AA1(6)	Coefficients used in the governing differential equations, computed in COEF
	AC	Program variable computed in MAIN
	AO	a_0

COMMON label	FORTRAN variable	Description
/MAINP/	AOVERB	Ratio of semiminor axis to semimajor axis of an ellipse
	A1	a_1
	BB1(6)	Coefficients used in the governing differential equations, computed in COEF
	CAPHO	H_0
	CAPH1	H_1
	CAPQ	Q
	CC	Program variable computed in MAIN
	CC1	Coefficient used in the governing differential equations, computed in COEF
	CCI	Initial computing interval used by INT1
	CCUVAR(8)	Double-precision array used by INT1 to store values of independent and dependent variables at which derivatives will be evaluated in DERSUB
	CII	Initial interval away from singular point of stagnation streamline
	CIMAX	Absolute value of maximum computing interval used by INT1
	COSTB	$\cos \theta_b$
	COSW	$\cos \omega$
	CWMTB	$\cos\left(\omega - \theta_b\right)$

COMMON label	FORTRAN variable	Description
/MAINP/	DAF	$\frac{\delta \cos \theta_b}{r_b}$ computed in DERSUB, used in COEF
	DDELDX	$\frac{d\delta}{dx}$
	DDER(8)	Array in which derivatives are stored
	DD1	Coefficient used in governing differential equations, computed in COEF
	DELL	Lower limit for δ
	DELS	δ^2
	DELTA	δ
	DELTN	δ_o
	DELU	Upper limit for δ
	DIODX(6)	$\frac{dI_{j,0}}{dx}$ (j = 2,3,4,5)
	DI1DW(6)	$\frac{\partial I_{j,1}}{\partial \omega}$ (j = 2,3,4,5)
	DOSRB	$\frac{\delta}{r_b}$ computed in DERSUB, used in COEF
	DP1DW	$\frac{dp_1}{d\omega}$
	DRBDX	$\frac{dr_b}{dx}$
	DRO1DW	$\frac{d\rho_1}{d\omega}$
	DTBDX	$\frac{d\theta_b}{dx}$
	DUSDW	$\frac{du_s}{d\omega}$
	DU1DW	$\frac{du_1}{d\omega}$

COMMON label	FORTRAN variable	Description
/MAINP/	DVSDW	$\frac{dv_s}{d\omega}$
	DV1DW	$\frac{dv_1}{d\omega}$
	DWDX	$\frac{d\omega}{dx}$
	EELE1(7)	Relative error used by INT1
	EELE2(7)	Relative zeros, used by INT1
	EELT(3)	Values for return to program from INT1
	EE1(6)	Coefficients used in governing differential equations, computed in COEF
	EERVAL(8)	Array used by INT1
	EMUREF	$\overline{W}_{REF}$
	EO1	Coefficient appearing in the differential equations, computed in COEF
	EPSR	Accuracy criterion for R_1 iteration in MAIN
	EPS21	Accuracy criterion for iteration on ρ
	GGO(6) GG1(6)	Coefficients used in governing differential equations, computed in COEF
	HONE	H_1
	ICOSW	Control to set COSW to exactly 0 when $\omega = \frac{\pi}{2}$
	IERR	Integer value supplied by INT1 as an error code

COMMON label	FORTRAN variable	Description
/MAINP/	IGEO	Control in GEO for body shape: 1 sphere 2 ellipsoid 3 hyperboloid
	ITEXT	Time history print option used by INT1
	ITTEST	Iteration limit in PROPIT
	KEKONT	Counter for number of iterations for δ_o
	KETEST	Number of iterations desired on δ_o
	KKKK	Radiation option: 0 do not compute radiation 1 adiabatic radiation 2 nonadiabatic radiation
	OPERA	$\frac{\sin \theta_b}{r_b}$ computed in DERSUB, used in COEF
	P	p
	PEEP	Coefficient in equation describing pressure variation in stagnation region (see ref. 3, eq. (36))
	PIN	p_∞
	PO	p_0
	PSTAG	Stagnation pressure
	P1	p_1
	QD	$Q\delta$

COMMON label	FORTRAN variable	Description
/MAINP/	R	Universal gas constant
	RB	Body radius of curvature at axis of symmetry (x = 0)
	RBX	Body radius of curvature at any x-coordinate
	RHOIN	ρ_∞
	RHON	Initial guess for ρ
	RHOO	ρ_0
	RHO1	ρ_1
	R1	Weighted heat flux
	SINTB	$\sin \theta_b$
	SINSQW	$\sin^2 \omega$
	SINW	$\sin \omega$
	SMALLB	Semimajor axis of an ellipse, nondimensionalized with R_B
	SMALRB	r_b
	STAENT	Static enthalpy
	SSPEC	Print control used by INT1 (if SSPEC = 0, control will be returned after every acceptable integration step; if SSPEC ≠ 0, control will be returned at specified increment of independent variable)
	SWMTB	$\sin(\omega - \theta_b)$
	T	T'

COMMON label	FORTRAN variable	Description
/MAINP/	TCG	Accuracy criterion on iteration for ρ_0 in RANH
	TEAN	Initial guess for T'
	THETAB	θ_b
	TO	T_0
	T1	T_1
	UIN	U_∞
	UINS	$U_\infty{}^2$
	UO	u_0
	US	u_s
	U1	u_1
	V	v
	VO	v_0
	VS	v_s
	V1	v_1
	VVAR(8)	Double-precision array used by INT1 which contains independent variable followed by dependent variables
	W	ω
	X	Coordinate along body surface
	XIO(6)	$I_{j,0}$ (j = 2,3,4,5)

COMMON label	FORTRAN variable	Description
/MAINP/	XI1(6)	$I_{j,1}$
	XMAX	Maximum value of x allowed
	Z1	z_1
	ZO	z_0
/QQQ/	QI1	Curve-fit coefficients to radiation distribution around body, used for all but final δ_0 iteration
	QI2	
	QO1	
	QO2	
	QRY1	Total radiation heat flux at shock
	QRYO	Total radiation heat flux at body
	QSTAG	Stagnation heat flux

The following table is a cross-reference between labeled COMMON and D1250 subprograms (where X denotes labeled COMMON appearing in each subprogram and the radiation labeled COMMON blocks are WON, RAD, AAA, CIONCL):

Subprogram	COMMON label						
	REAI	MAINP	QQQ	WON	RAD	AAA	CIONCL
EQURATS	X						
MAIN	X	X	X		X	X	X
RANH		X					
GEO		X					
FIRST		X					
THEP							
THER							
CONT		X	X				
CHER		X					
PROPIT							
COEF		X					
CALD		X					
DERSUB		X					
CHSUB							
PROD		X		X	X	X	X
FOFX		X					
RADFLUX		X		X	X	X	X
LINE				X	X	X	X
CONTM				X	X	X	X
MU							
FEMP					X	X	X
DEFIOJ							
ORDERI							
ORDERV							
INVERT							
EQUIL					X	X	X
CHGBAL					X	X	X
ZHV							
LTP					X	X	X
HAFACE							
DTLNEQ							
HTP					X	X	X
TRAP1							
FLUT							
INOCAL					X	X	X
TRAP							
MASBAL							

D1250 Subprogram Descriptions, Flow Charts, and Listings

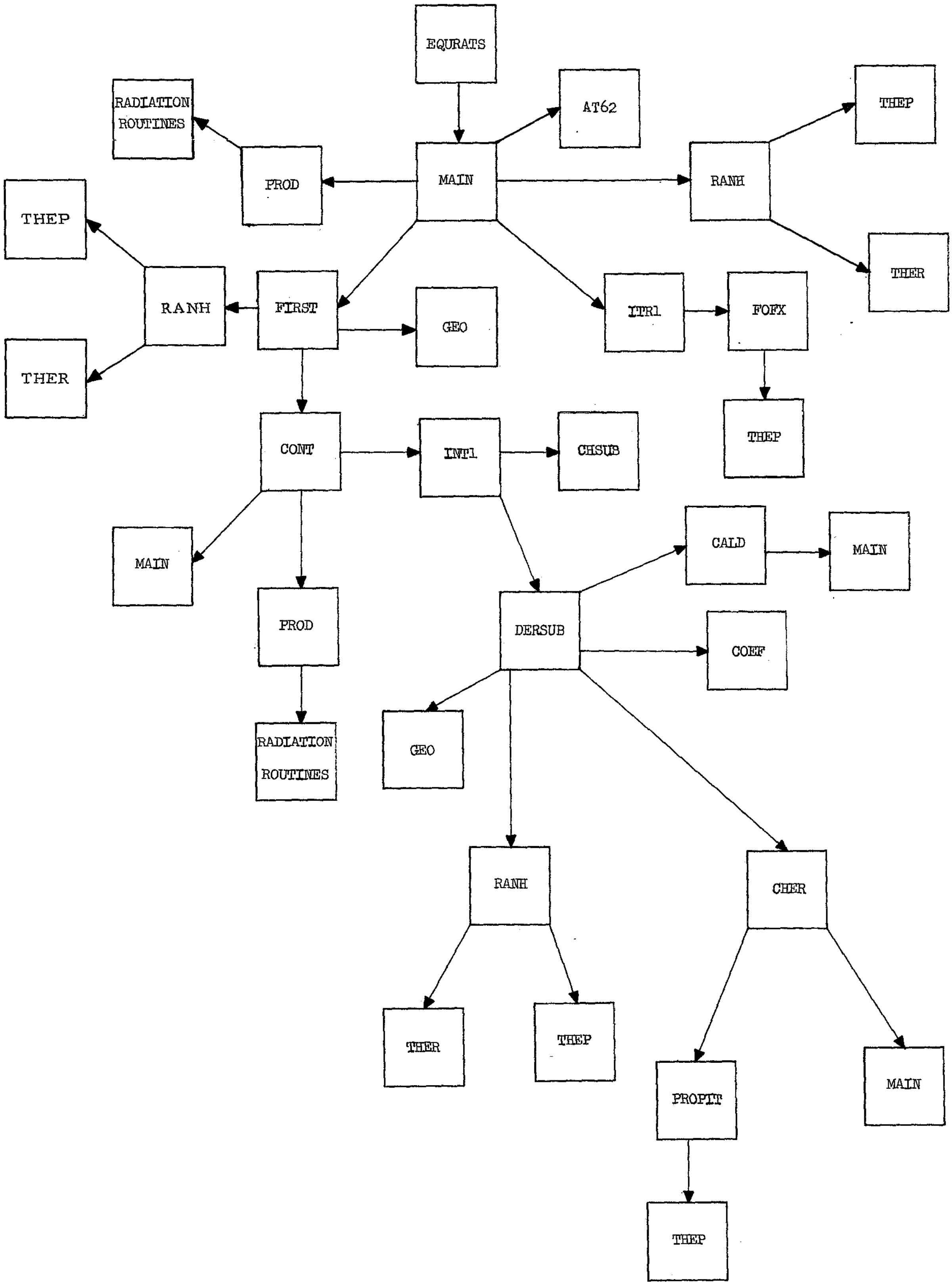
Langley program D1250 is one of a series of programs developed to analyze blunt-body flow-field data by the method of integral relations. Since many of the same computational methods were used in the various flow-field programs, each procedure was written as an independent subprogram to be called as needed. The radiation subprograms form an independent program (ref. 4) which has been added to D1250.

This section of the report presents a brief description of the subprograms used, a statement of the function of each subprogram, individual flow charts, and subprogram listings. Listings of the radiation subprograms are also included. A list of each subprogram and its description is given as follows:

Subprogram	Description
EQURATS	Writes program title and calls MAIN
MAIN	Reads and writes NAMELIST input, EQRAD, initializes program variables, and computes stagnation-streamline solution
RANH	Calculates post-shock conditions by use of Rankine-Hugoniot equations
GEO	Computes body geometry
FIRST	Computes properties at first step off stagnation line
THEP	Thermodynamics routine which solves correlation equation for equilibrium air
THER	Calculates partial derivatives of equilibrium-air properties
CONT	Calls integration routine, performs iteration on δ_o for sphere-pressure results, and writes output
CHER	Performs an additional test on δ_o iteration
PROPIT	Iteration subroutine for body properties
COEF	Calculates coefficients of governing differential equations

Subprogram	Description
CALD	Computes governing differential equations which are used in DERSUB
DERSUB	Called by Runge-Kutta integration routine INT1 to evaluate the derivatives
CHSUB	Called by INT1 to allow the user certain logical control
FOFX	A function subprogram called by ITR1 for p_0 $\left(p_{stag}\right)$ iteration
PROD	Reads and writes NAMELIST input for radiation subprograms, calls subprograms to compute radiation, and computes thermodynamic properties within shock layer

A directed graph of the FORTRAN subprograms used in D1250 is given in the flow chart on the following page.


EQURATS
AT62
RADIATION ROUTINES
PROD
MAIN
RANH
THEP
THER
THEP
RANH
FIRST
GEO
ITR1
FOFX
THER
CONT
INT1
CHSUB
THEP
CALD
MAIN
MAIN
PROD
DERSUB
COEF
RADIATION ROUTINES
GEO
RANH
CHER
THER
THEP
PROFIT
MAIN
THEP

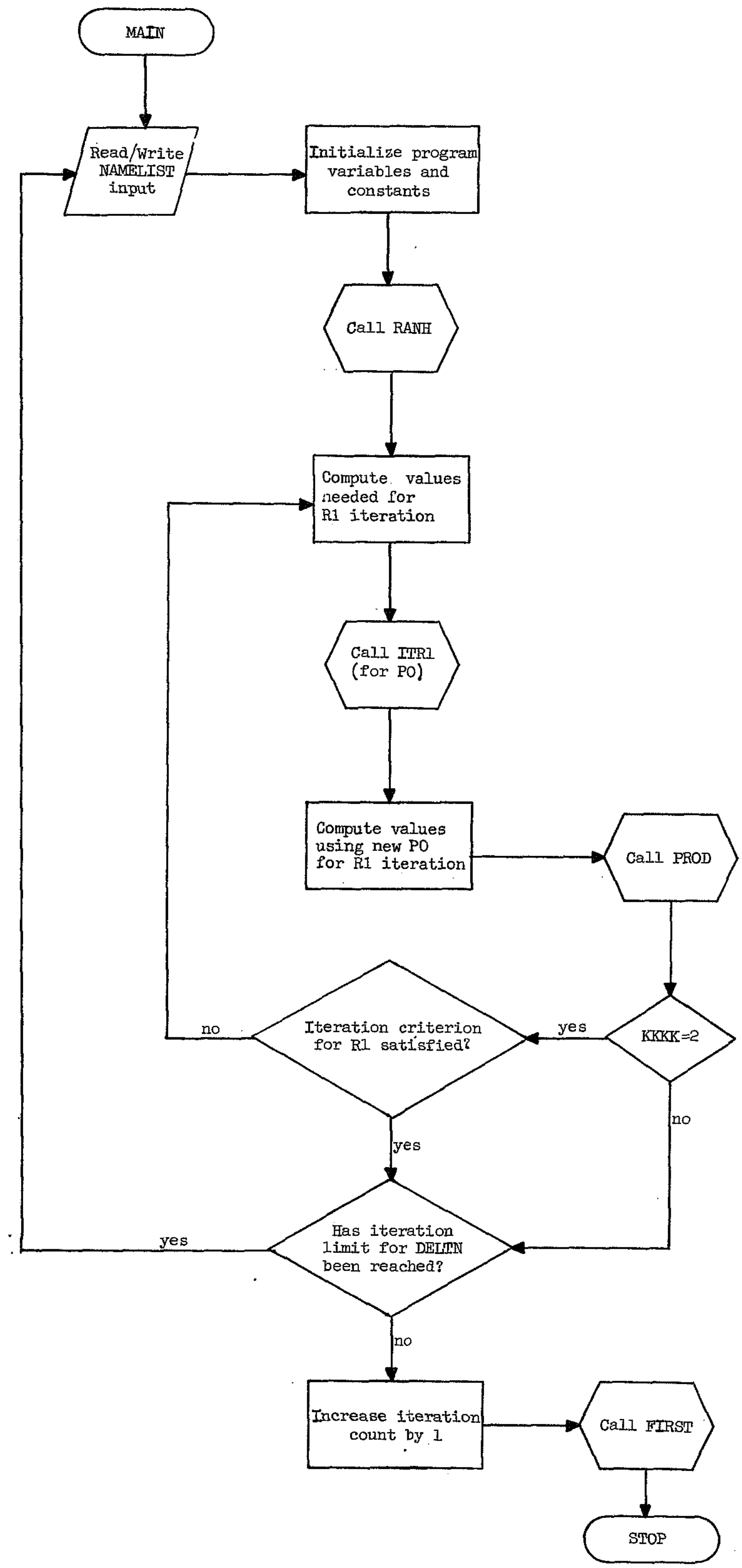
EQURATS

EQURATS writes the program identification and calls MAIN.

```
      PROGRAM EQURATS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,PUNCH)
C
C
C     EQUILIBRIUM WITH RADIATION PROGRAMED BY FRANCES W. TAYLOR
C
      COMMON /REAI/ IREAD
      WRITE (6,1)
      IREAD=0
      CALL MAIN
      STOP
C
C
1     FORMAT (1H120X58HEQUILIBRIUM WITH RADIATION  PROGRAMED BY FRANCES
     1W. TAYLOR/)
      END
```

MAIN

The function of subprogram MAIN is to call the NAMELIST input, EQRAD, to initialize the program, and to compute the stagnation-line solution. The stagnation-line solution is obtained by an iteration on p_0 $\left(\text{in MAIN } p_0 = p_{stag}\right)$ by using the library routine ITR1. The program is ended either after a specific number of iterations on δ_o, which is controlled by the input KETEST, or when a maximum value of x has been reached. The flow chart for subprogram MAIN is as follows:


MAIN
Read/Write NAMELIST input
Initialize program variables and constants
Call RANH
Compute values needed for R1 iteration
Call ITR1 (for PO)
Compute values using new PO for R1 iteration
Call PROD
KKKK=2
yes
no
Iteration criterion for R1 satisfied?
no
yes
Has iteration limit for DELTN been reached?
yes
no
Increase iteration count by 1
Call FIRST
STOP

```
      SUBROUTINE MAIN
      DOUBLE PRECISION VVAR,CCUVAR
C
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     3D1DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(16),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      COMMON /REAI/ IREAD
      COMMON /QQQ/ QI1,QI2,QO1,QO2,QRY1,QRYO,QSTAG
      DIMENSION ANS(4)
      EXTERNAL FOFX
      NAMELIST /EQRAD/ ALT,AOVERB,CCI,CII,CIMAX,DELTX,DUMBTIM,EELE1,EELE
     12,EELT,EITR1,EITR2,EMUREF,EPSR,EPS21,IALT,IGEO,ITEXT,ITTEST,KETEST
     2,KKKK,PEEP,PIN,QI1,QI2,QO1,QO2,R,RB,RHON,RHOIN,R1,SSPEC,TEAN,TCG,U
     3IN,XMAX
C     ALT        ALTITUDE FOR AT62
C     AOVERB     A BODY GEOMETRY PARAMETER
C     CCI        INITIAL COMPUTING INTERVAL
C     CIMAX      ABSOLUTE VALUE OF MAXIMUM COMPUTING INTERVAL USED BY INT1
C     CII        INITIAL LINEAR INTEGRATION STEP IN FIRST
C     DELTX      INITIAL GUESS                            USED IN ITR1
```

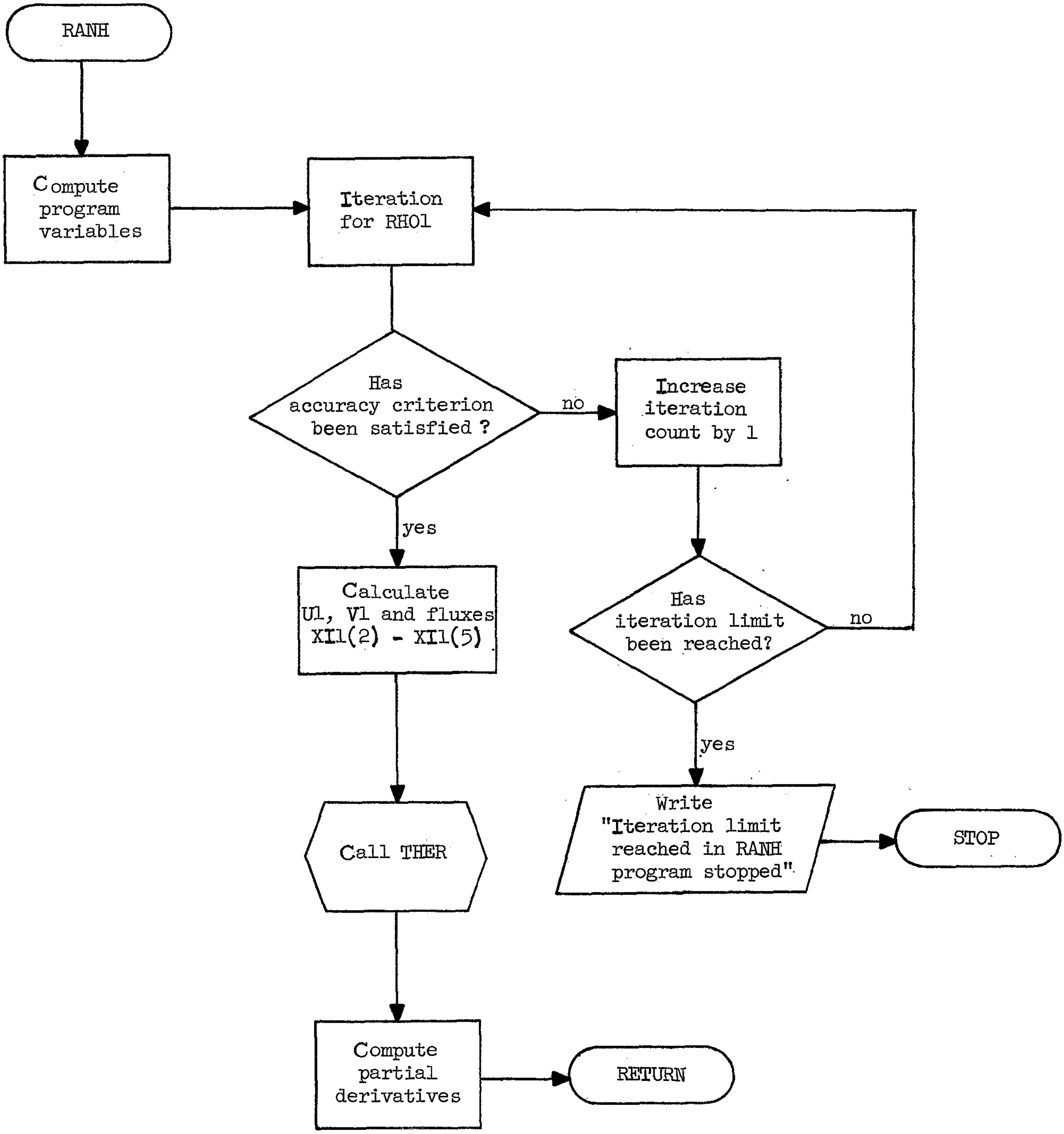
```
C     EELE1     RELATIVE ERROR                                    USED BY INT1
C     EELE2     RELATIVE ZERO                                     USED BY INT1
C     EELT      VALUE FOR RETURN TO PROGRAM                       USED BY INT1
C     EITR1     RELATIVE ERROR                                    USED IN ITR1
C     EITR2     ABSOLUTE ERROR                                    USED IN ITR1
C     EMUREF    MOLECULAR WEIGHT OF COLD AIR  USED IN THEP
C     EPSR      ACCURACY FOR R1 ITERATION IN MAIN
C     EPS21     ACCURACY FOR RHO ITERATION IN PROPIT
C     IALT      =1 CALL AT62
C     IGEO      A TEST IN GEO FOR SPHERE,ELLIPSOID OR HYPERBOLOID
C     ITEXT     TIME HISTORY PRINT OPTION  =0 NO PRINTOUT         USED BY INT1
C     ITTEST    ITERATION LIMIT USED IN PROPIT
C     KETEST    THE NUMBER OF PASSES THROUGH MAIN
C     KKKK      IF 0 NO RADIATION,IF 1 ADIABATIC RADIATION IS COMPUTED
C               IF 2 NONADIABATIC RADIATION IS COMPUTED
C     PEEP      PRESSURE VARIATION COEFFICIENT
C     PIN       FREE STREAM PRESSURE
C     R         GAS CONSTANT
C     RB        BODY RADIUS
C     RHOIN     FREE STREAM DENSITY
C     RHON      INITIAL VALUE OF RHO
C     R1        INITIAL GUESS FOR WEIGHTED HEAT FLUX
C     SSPEC     PRINT CONTROL                                     USED BY INT1
C     TCG       ACCURACY ON ITERATION FOR DENSITY IN RANH
C     TEAN      INITIAL VALUE OF T
C     UIN       FREE STREAM VELOCITY
C     XMAX      WHEN X=XMAX THE PROGRAM IS STOPPED
C
      XLAST=X
      IREAD=IREAD+1
      IF (IREAD-1) 1,1,3
1     READ (5,EQRAD)
      IF (EOF,5) 10,2
2     WRITE (6,EQRAD)
      III=0
      KEKONT=0
      IF (IREAD.EQ.1) IPROD=0
      IREAD=IREAD+1
      R2=R1
3     KEKONT=KEKONT+1
      IF (KEKONT.GT.KETEST) GO TO 1
      IF (KKKK.NE.2) R1=0
      IF (III.NE.0) GO TO 4
```

```
      IF (IALT.NE.1) GO TO 4
      CALL AT62 (ALT,ANS)
      PIN=ANS(2)*478.80258
      RHOIN=ANS(1)*.515379
      WRITE (6,11) RHOIN,PIN
4     X=0
      W=3.1415927/2.
      THETAB=3.1415927/2.
C
C     ICOSW IS 0 WHEN COS(W)=0  ICOSW=1 COS(W) IS COMPUTED
C
      ICOSW=0
      UINS=UIN**2
      DRBDX=1.
      DTBDX=-1.
      SMALRB=0
      RBX=1.
      CAPQ=1.
      T=TEAN
      CALL RANH
      IF (III.NE.0) GO TO 5
      RO78=DUMBTIM/RHO1
      DELU=1.1*RO78
      DELL=.8*RO78
5     III=III+1
      DELTN=(DELL+DELU)/2.
      DELTA=DELTN
      QD=CAPQ*DELTA
      WRITE (6,12) DELTN,XLAST
      TWODEL=2.*DELTA
      THRDEL=3.*DELTA
      DELS=DELTA**2
      AC=(3.+THRDEL+DELS)/V1
      BC=DELTA*(3.+TWODEL)
      CC=DELTA*(3.+DELTA)
      U0=0
      V0=0
      SINTB=1.
      DIM=2.*DELTA*SINTB/DRBDX
6     PO=P1+.5*RHO1*V1**2
      R1=R2
      CALL ITR1 (PO,DELTX,FOFX,EITR1,EITR2,100,ICODE)
      IF (ICODE.GT.0) WRITE (6,13) ICODE
```

```
      P1MPO=P1-PO
      RHOO=-(AC**2*P1MPO**2)/(PEEP*CC**2*PO)
      CAPHO=CAPH1-(3.*R1)/(AC*P1MPO)
      RHOOAO=(AC*P1MPO)/CC
      DWDX=AC*(PO-P1+V1)/(BC*(1.-RHO1))
      A1=(DWDX*(1.-RHO1)+1.)/RHO1
      AO=RHOOAO/RHOO
      DELTD=DELTA*RB
      USTAR=0
      IF (KEKONT.EQ.KETEST) WRITE (6,14) UO,RHOO,AO,RHOOAO,CAPHO,PO,DWDX
     1,DELTD,DELTA
      IPROD=IPROD+1
C
C     IF KKKK=0 THE RADIATION IS NOT COMPUTED, KKKK=1 ADIABATIC
C     RADIATION IS COMPUTED, KKKK=2 FOR NONADIABATIC RADIATION
C
      CALL PROD (USTAR,IPROD,AO,A1,QRYO,QRY1)
      IF (KKKK.NE.2) GO TO 9
      R1P=(1.+DELTA)**2*QRY1-QRYO
      ABR=ABS((R1P-R1)/R1P)
      IF (ABR-EPSR) 8,8,7
7     R2=R1P
      GO TO 6
C
C     KEKONT COUNTS THE NUMBER OF PASSES THRU  MAIN
C
C
C     TEST FOR NEXT TO LAST TIME
C
8     IF ((KETEST-KEKONT).NE.1) GO TO 9
      QSTAG=1.E-7*QRYO*RHOIN*UINS*UIN
9     DELTA=(DELU+DELL)/2.
      PSTAG=PO
      CALL FIRST
10    STOP
C
C
11    FORMAT (1HO6X4HAT626X5HRHOINE15.8,6X3HPINE15.8)
12    FORMAT (1HO6X5HDELTNE15.8,6X1HXE15.8)
13    FORMAT (1HO6X6HICODE=I4,10X27H ITERATION DID NOT CONVERGE)
14    FORMAT (1H15X27HSTAGNATION POINT CONDITIONS6X2HUOE15.8,4X4HRHOOE15
     1.8,6X2HAOE15.8/35X6HRHOOAOE15.8,6X2HHOE15.8,6X2HPOE15.8,4X4HDWDXE1
     25.8/6X24HSHOCK STAND-OFF DISTANCE5X5HDELTDE15.8,1X8HDELTA/RBE15.8/
     3)
      END
```

RANH

RANH computes the post-shock conditions (properties, fluxes, and partial derivatives with respect to ω) with the use of the Rankine-Hugoniot equations. It is called by MAIN for the stagnation-line solution and then by DERSUB in each integration step. The flow chart for subprogram RANH is as follows:

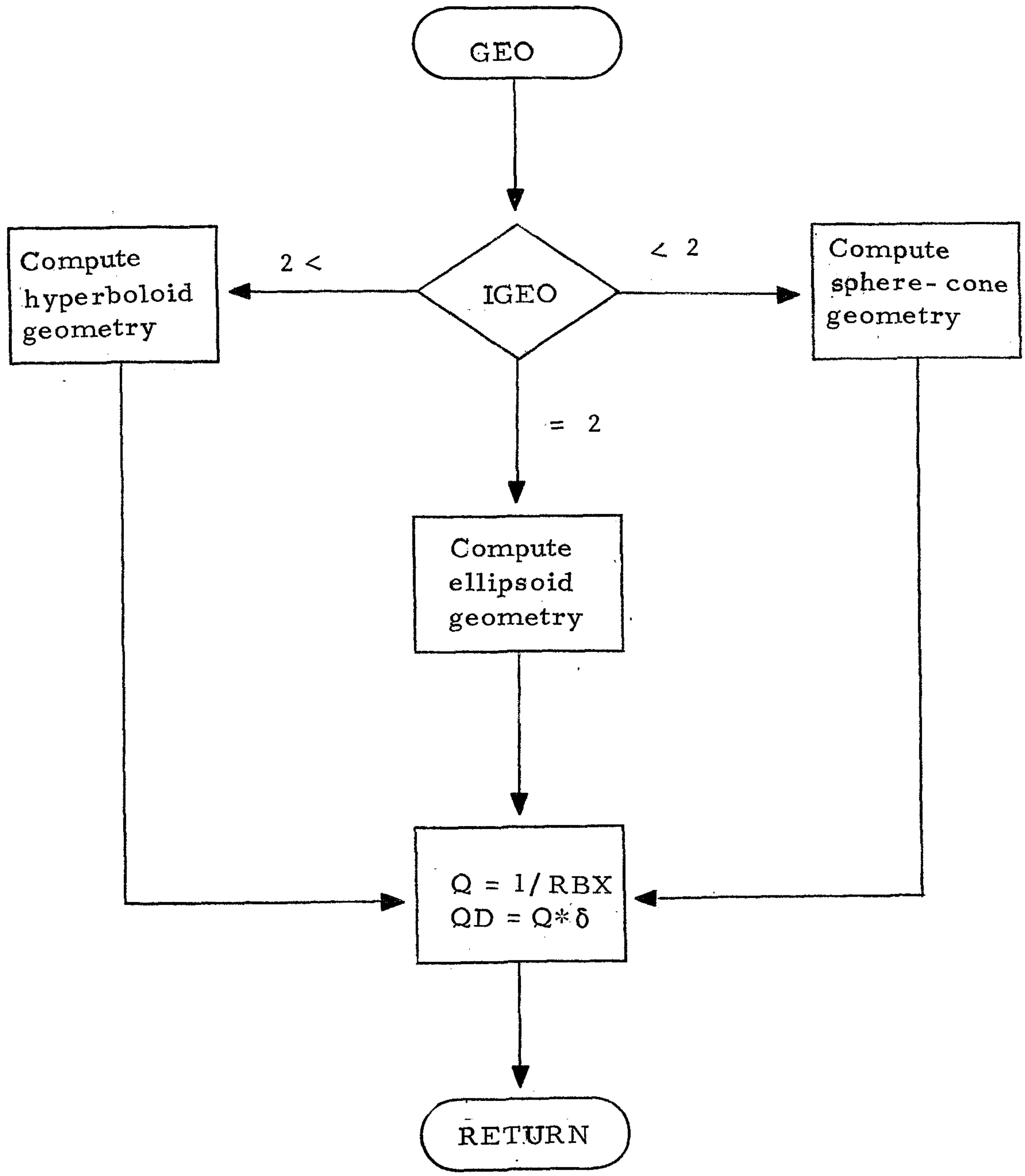


```
      SUBROUTINE RANH
      DOUBLE PRECISION VVAR,CCUVAR
C
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     3O1DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
C
C     RANKINE HUGONIOT RELATIONS FOR EQUILIBRIUM COMPOSITION
C
      IRHO=0
      DTBDW=0
      SINW=SIN(W)
      IF (ICOSW) 1,1,2
1     COSW=0
      SWMTB=0
      GO TO 3
2     COSW=COS(W)
      SWMTB=SIN(W-THETAB)
3     CWMTB=COS(W-THETAB)
      SWS=SINW**2
      US=COSW
      RHO1=RHON
4     VS=-SINW/RHO1
      CAPH1=.5+3.5*PIN/(RHOIN*UINS)
      HONE=CAPH1
      STAENT=CAPH1-(US**2+VS**2)/2.
      CALL THEP (R,P1,RHO1,T1,Z1,STAENT,EMUREF,PIN,RHOIN,UINS,KEZ)
      RHO1P=(PIN/(RHOIN*UINS)+SWS-P1)/VS**2
      FRHO1=RHO1-RHO1P
      DELRO1=.1
      RHO1D=RHO1+DELRO1
      VP=-SINW/RHO1D
      STAP=CAPH1-(US**2+VP**2)/2.
      CALL THEP (R,PD,RHO1D,TX,ZX,STAP,EMUREF,PIN,RHOIN,UINS,KEZ)
      RHO1DP=(PIN/(RHOIN*UINS)+SWS-PD)/VP**2
```

```
      FPRHO1=(RHO1D-RHO1DP-FRHO1)/DELRO1
      AFMFP=ABS(FRHO1/FPRHO1)
      IF (AFMFP-TCG) 6,6,5
5     RHO1=RHO1-FRHO1/FPRHO1
      IF (IRHO.GT.ITTEST) GO TO 7
      IRHO=IRHO+1
      GO TO 4
6     U1=US*CWMTB-VS*SWMTB
      V1=US*SWMTB+VS*CWMTB
      XI1(2)=RHO1*U1
      XI1(3)=P1+RHO1*U1**2
      XI1(4)=RHO1*U1*V1
      XI1(5)=RHO1*U1*CAPH1
      XI1(1)=0
      CALL THER (R,P1,RHO1,T1,Z1,STAENT,EMUREF,PIN,RHOIN,UINS,C1P,C2P,C1
     1D,C2D)
      DRO1DW=SINW*COSW*(C1D*(1.-1./RHO1**2)-2.*(1.-1./RHO1))/((SWS/RHO1*
     1*2)*(1.-C1D/RHO1)-C2D)
      DSH1DW=SINW*COSW*(1.-1./RHO1**2)+SWS/RHO1**3*DRO1DW
      DP1DW=C1D*DSH1DW+C2D*DRO1DW
      DUSDW=-SINW
      DVSDW=-1./RHO1*(US+VS/RHO1*DRO1DW)
      DU1DW=DUSDW*CWMTB-DVSDW*SWMTB-US*SWMTB*(1.-DTBDW)-VS*CWMTB*(1.-DTB
     1DW)
      DV1DW=DUSDW*SWMTB+DVSDW*CWMTB+US*CWMTB*(1.-DTBDW)-VS*SWMTB*(1.-DTB
     1DW)
      DI1DW(2)=RHO1*DU1DW+U1*DRO1DW
      DI1DW(3)=DP1DW+2.*RHO1*U1*DU1DW+U1**2*DRO1DW
      DI1DW(4)=RHO1*V1*DU1DW+RHO1*U1*DV1DW+U1*V1*DRO1DW
      DI1DW(5)=CAPH1*DI1DW(2)
      RETURN
7     WRITE (6,8)
      STOP
C
C
8     FORMAT (1H06X39HITERATION LIMIT IN RANH PROGRAM STOPPED)
      END
```

GEO

Subprogram GEO computes the body geometry. The user has a choice of three body shapes which are controlled by an input IGEO. IGEO = 1 computes sphere geometry, IGEO = 2 computes ellipsoid geometry, and IGEO = 3 computes hyperboloid geometry. GEO is called by FIRST for the stagnation-line solution and by DERSUB for each integration step. The flow chart for subprogram GEO is as follows:

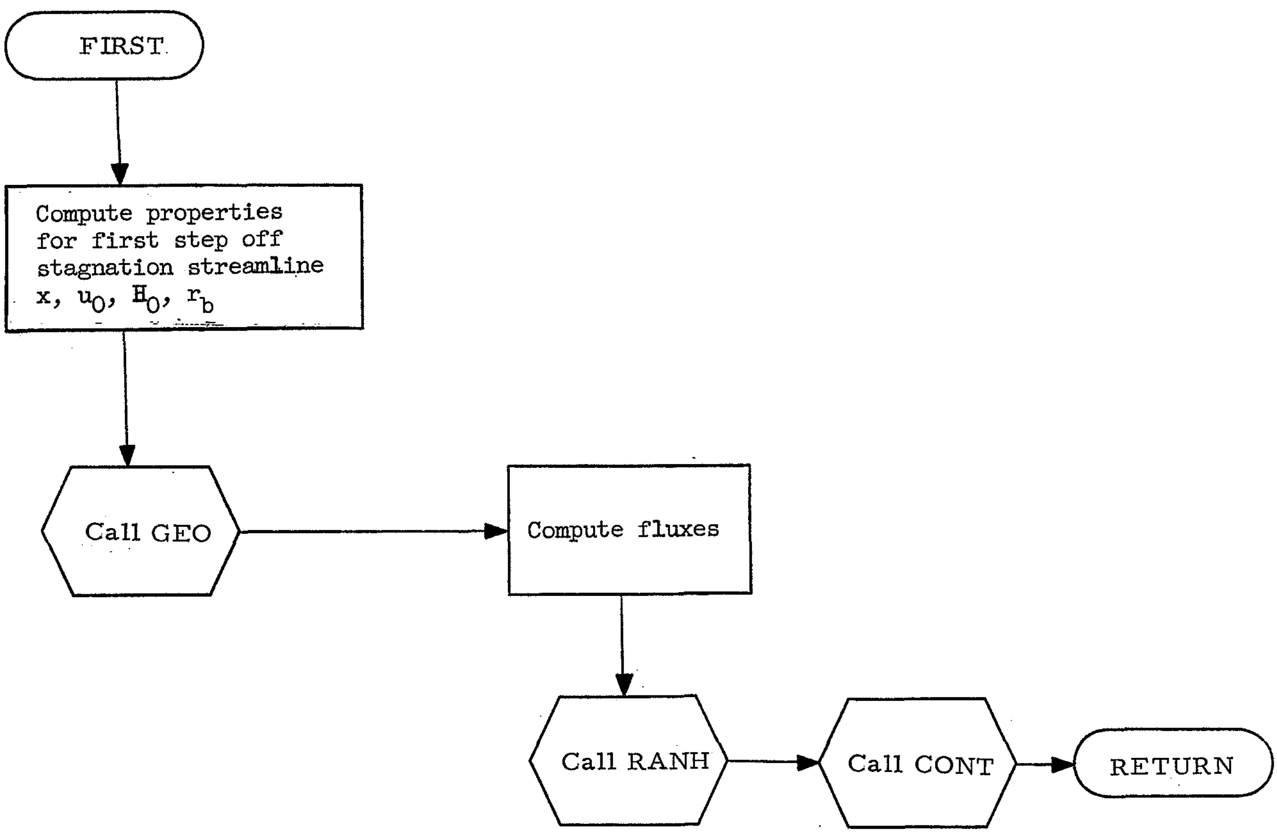


```
      SUBROUTINE GEO
C
      DOUBLE PRECISION VVAR,CCUVAR
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     3O1DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
C
C      IGEO=1 COMPUTE SPHERE GEOMETRY    IGEO=2 COMPUTE ELLIPSOID GEOMETR
C      IGEO=3 COMPUTE HYPERBOLOID GEOMETRY
C
      SMALLB=AOVERB
      IF (IGEO-2) 1,2,3
C
C     SPHERE - CONE
C
C
1     SMALRB=SIN(X)
      THETAB=3.14159265/2.-X
      DRBDX=COS(X)
      DTBDX=-1.
      RBX=1.
      GO TO 4
C     ELLIPSIOD
2     BSQ=SMALLB**2
      RSQ=SMALRB**2
      BSMRS=BSQ-RSQ
      RACE=RSQ/BSMRS
      ZB=AOVERB*SMALLB-AOVERB*SQRT(BSMRS)
      AAA=AOVERB*SMALLB
      PTAN=((SMALLB/AAA)*(AAA-ZB))/(SQRT(2.*AAA*ZB-ZB**2))
      THETAB=ATAN(PTAN)
      RBX=((1.+AOVERB**2*RACE)**(3./2.))/(AOVERB/SQRT(BSMRS)*(1.+RACE))
      CAPQ=1./RBX
      DTBDX=-CAPQ
      GO TO 4
```

```
C     HYPERBOLOID
C
3     BSQ=SMALLB**2
      RSQ=SMALRB**2
      BSPRS=BSQ+RSQ
      RACH=RSQ/BSPRS
      AAA=AOVERB*SMALLB
      SQBSPRS=SQRT(BSPRS)
      ZB=-AAA+AOVERB*SQBSPRS
      PTAN=SQBSPRS/(AOVERB*SMALRB)
      THETAB=ATAN(PTAN)
      RBX=((1.+AOVERB**2*RACH)**(3./2.))/(AOVERB/SQBSPRS*(1.-RACH))
4     CAPQ=1./RBX
      QD=CAPQ*DELTA
      RETURN
      END
```

FIRST

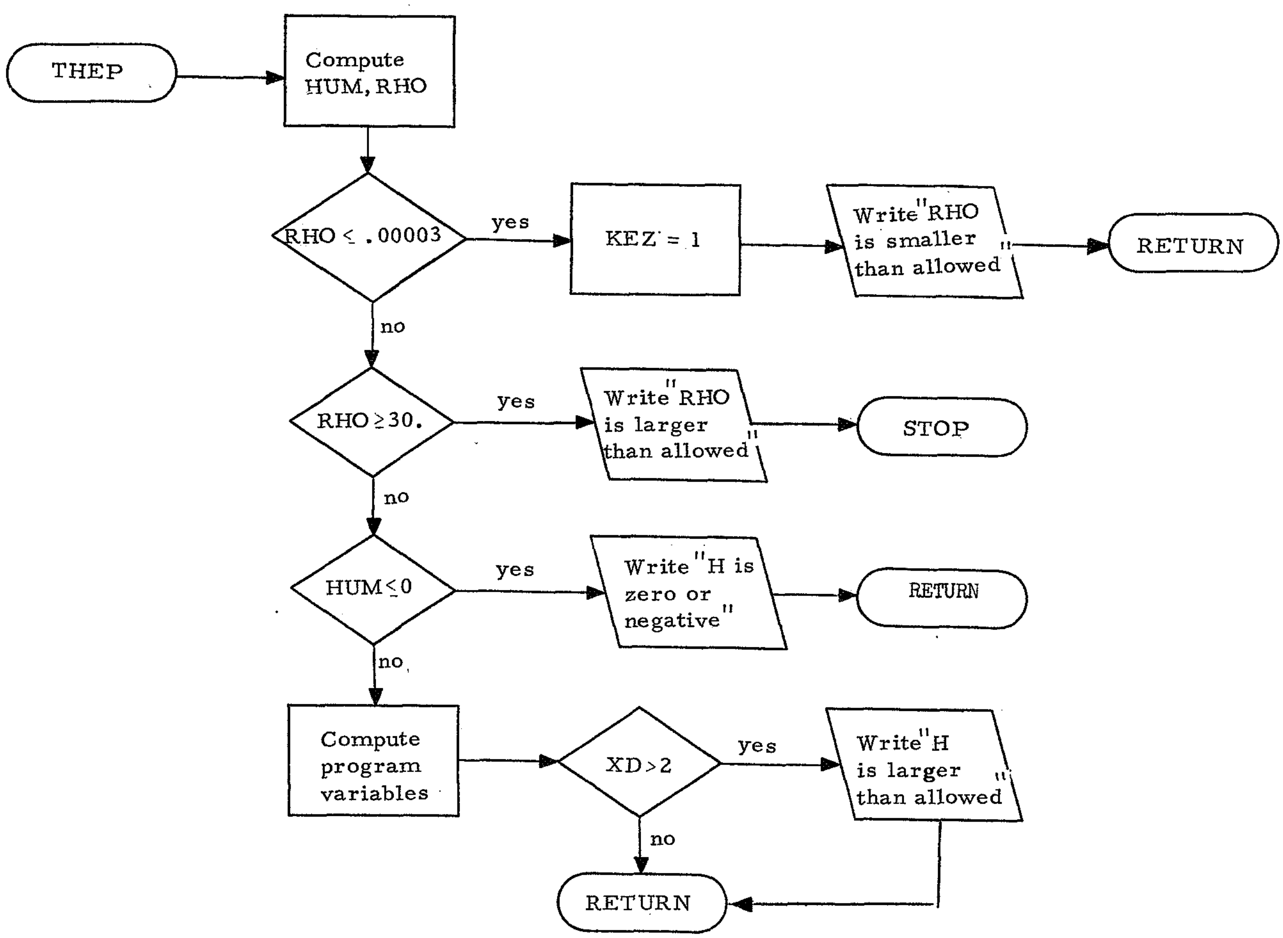
Subprogram FIRST is used to compute the properties at the first step off the stagnation line. The integration cannot start at the stagnation point since it is a singular point. The flow chart for subprogram FIRST is as follows:



```
      SUBROUTINE FIRST
      DOUBLE PRECISION VVAR,CCUVAR
C
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     3O1DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
C
      X=CII
      ICOSW=1
      UO=AO*CII
      W=W+DWDX*CII
      CAPHO=CAPHO+UO**2/2.
      SMALRB=CII
      CALL GEO
      THETAB=3.14159265/2.+DTBDX*CII
      DELTA=DELTA-((1.+QD)/CAPQ)*(W-THETAB)*DTBDX*CII
      XIO(3)=PO+RHOO*UO**2
      XIO(4)=RHOO*VO*UO
      XIO(5)=RHOO*UO*CAPHO
      XIO(2)=RHOO*UO
1     CALL RANH
      CALL CONT
      RETURN
      END
```

THEP

THEP is the thermodynamics routine that solves the correlation equations for equilibrium air (ref. 1). THEP is called by RANH, PROPIT, and FOFX. It has a calling sequence in which R, EMUREF, and the free-stream conditions PIN, RHOIN, and UINS are constants. The values of density RHODUM and static enthalpy STAENT are given at the particular point at which THEP is called. The corresponding pressure PDUM, temperature TDUM, and compressibility ZDUM are calculated. There is an indicator KEZ which is set to 1 if "RHO IS SMALLER THAN ALLOWED." This is only used in PROPIT. When KEZ = 1, PROPIT returns immediately to CHER. CHER then sets DELL = DELTN and calls MAIN. The program starts again with a new δ_o. The flow chart for subprogram THEP is as follows:

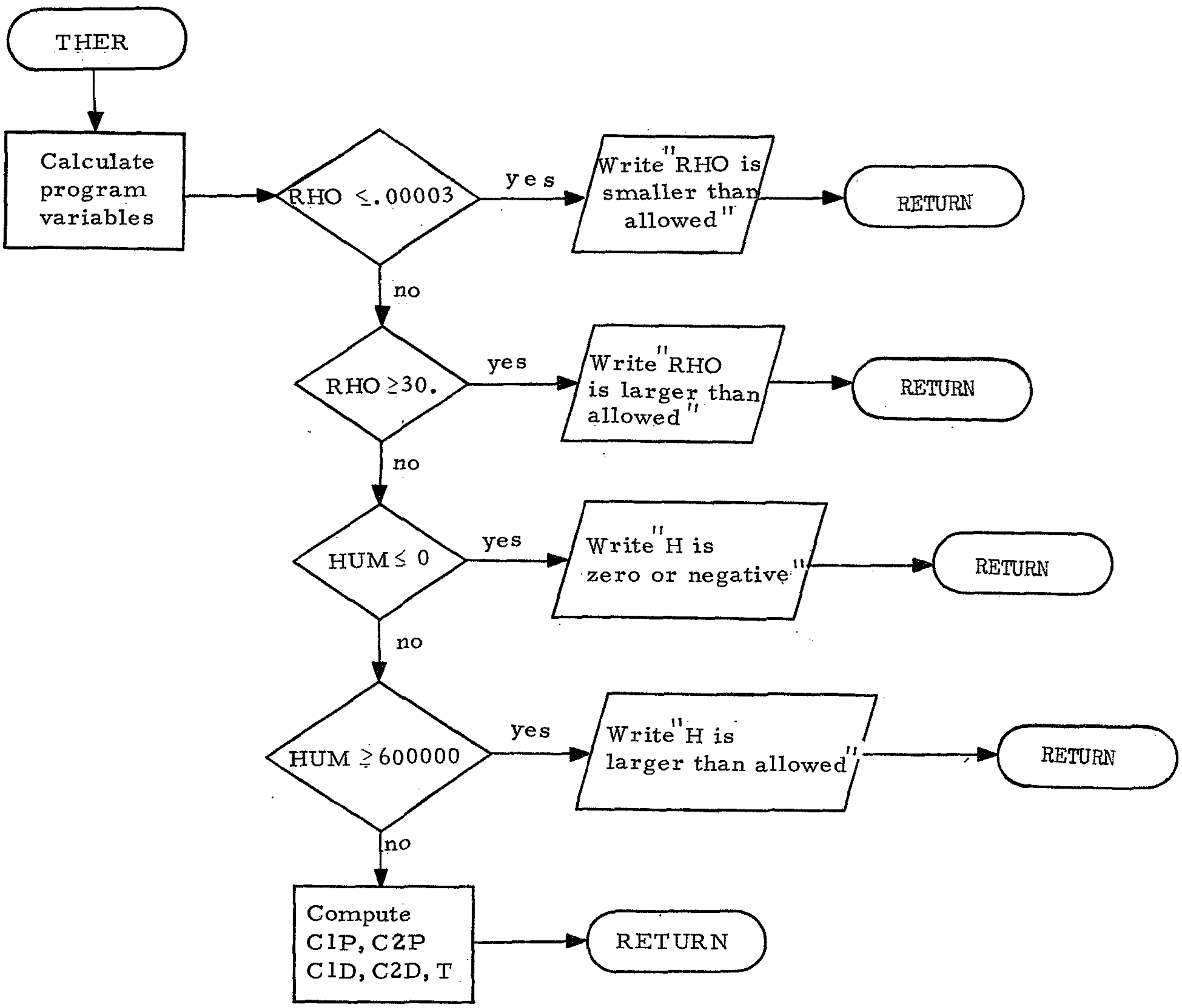


```
      SUBROUTINE THEP (R,PDUM,RHODUM,TDUM,ZDUM,STAENT,EMUREF,PIN,RHOIN,U
     1INS,KEZ)
C
C
C     KEZ WAS ADDED TO PROGRAM 12-14-67
C      IF RHO IS SMALLER THAN ALLOWED OR HH IS 0 OR NEG. WHEN THEP IS
C     CALLED FROM PROPIT KEZ=1 AND THE PROGRAM RETURNS  TO CHER
C     IN CHER DELL=DELTN MAIN IS CALLED
C
C
      KEZ=0
      HUM=EMUREF*UINS*STAENT/R
      RHO=RHOIN/1.29313E-3*RHODUM
      IF (RHO.LE..00003) GO TO 11
      IF (RHO.GE.30.) GO TO 13
      IF (HUM.LE.0.) GO TO 10
      IF (HUM.GT.5800.) GO TO 1
      P=(.975134E-3)*HUM*RHO
      Z=1.0
      GO TO 9
1     IF (HUM.GT.10500.) GO TO 2
      P=.00345*RHO*EXP(.854*ALOG(HUM))
      Z=1.0
      GO TO 9
2     IF (HUM.GE.35500.) GO TO 3
      RHOLOG=ALOG10(RHO)
      XD=5.*ALOG10(HUM)-20.
      PLOG=.955+RHOLOG+(.1545+.0131*RHOLOG)*XD+.016*RHOLOG*XD*(2.75-XD)
      P=EXP(2.302585*PLOG)
      GO TO 5
3     DV=1.565+1.036*ALOG10(RHO)
      IF (HUM.GE.178000.) GO TO 4
      XD=5.*ALOG10(HUM)-24.
      PLOG=.1336*XD+.00934*XD**3+DV
      P=EXP(2.302585*PLOG)
      GO TO 5
4     IF (HUM.GE.600000.) WRITE (6,17)
      PLOG=.95*ALOG10(HUM)-4.58+DV
      P=EXP(2.302585*PLOG)
      GO TO 5
C     COMPUTE Z(H,RHO)
5     XI=1.0-ALOG10(RHO)
```

```
      XD=ALOG10(HUM)-4.+.052*XI-.004*XI**2
      IF (XD.GT.0.) GO TO 6
      Z=1.0
      GO TO 9
6     IF (XD.GT.0.55) GO TO 7
      Z=1.0+.53*XD**2
      GO TO 9
7     IF (XD.GE.1.3) GO TO 8
      XI=1.3-XD
      Z=2.0+XI*(-1.78+XI*(.21+XI*(1.09-.446*XI*XI)))
      GO TO 9
8     IF (XD.GE.2.) WRITE (6,17)
      XI=1.9-XD
      Z=3.831+XI*(-5.019+XI*(3.41+.24*XI))
9     T=(273.*P)/(Z*RHO)
      ZDUM=Z
      TDUM=T
      PDUM=1.01325E6*P/(RHOIN*UINS)
      GO TO 14
10    WRITE (6,16)
      GO TO 12
11    WRITE (6,18)
12    KEZ=1
      GO TO 14
13    WRITE (6,19)
      GO TO 15
14    RETURN
15    STOP
C
C
16    FORMAT (10X22HH IS ZERO OR NEGATIVE )
17    FORMAT (10X25HH IS LARGER THAN ALLOWED )
18    FORMAT (10X28HRHO IS SMALLER THAN ALLOWED )
19    FORMAT (10X27HRHO IS LARGER THAN ALLOWED )
      END
```

THER

Subprogram THER is called by RANH to calculate the partial derivatives of equilibrium-air properties which are used in computing the derivatives at the shock wave. THER has a calling sequence in which R, EMUREF, and the free-stream conditions PIN, RHOIN, and UINS are constants. PDUM (P1), RHODUM (RHO1), and STAENT are computed in RANH. The quantities C1P ($\partial\rho/\partial h$) and C2P ($\partial\rho/\partial p$) are calculated in THER. The flow chart for subprogram THER is as follows:



```
      SUBROUTINE THER (R,PDUM,RHODUM,TDUM,ZDUM,STAENT,EMUREF,PIN,RHOIN,U
     1INS,C1P,C2P,C1D,C2D)
C
C       THIS IS THE NEW THERMOCHEMICAL ROUTINE THER   4-19-67
C
C
      Z=ZDUM
      P=PDUM
      HUM=EMUREF*UINS*STAENT/R
      RHO=RHOIN/1.29313E-3*RHODUM
      RUN=1.
      XC1PDP=5.*ALOG10(HUM)-20.
      IF (RHO.LE..00003) GO TO 8
      IF (RHO.GE.30.) GO TO 9
      IF (HUM.LE.0.) GO TO 6
      IF (HUM.GT.5800.) GO TO 1
      C1P=.975134E-3/RUN*RHO
      C2P=.975134E-3*HUM
      GO TO 5
1     IF (HUM.GT.10500.) GO TO 2
      C1P=.345E-2*.854*RHO/(RUN*HUM**.146)
      C2P=.345E-2*HUM
      GO TO 5
2     IF (HUM.GE.35500.) GO TO 3
      C1P=5.*P/(HUM*RUN)*(.1545+(.0131+.016*(2.75-2.*XC1PDP))*ALOG10(RHO
     1))
      C2P=P/RHO*(1.+XC1PDP*(.0131+.016*(2.75-XC1PDP)))
      GO TO 5
3     DV=1.565+1.036*ALOG10(RHO)
      IF (HUM.GE.178000.) GO TO 4
      C2P=1.036*P/RHO
      C1P=5.*P/(HUM*RUN)*(.1336+.02802*(5.*ALOG10(HUM)-24.)**2)
      GO TO 5
4     IF (HUM.GE.600000.) GO TO 7
      C1P=.95*P/(HUM*RUN)
      C2P=1.036*P/RHO
5     T=(273.*P)/(Z*RHO)
      TDUM=T
      C1D=C1P*1.01325E6/(RHOIN*R)*EMUREF
      C2D=C2P*1.01325E6/(1.29313E-3*UINS)
      GO TO 11
6     WRITE (6,12)
```

```
      GO TO 10
7     WRITE (6,13)
      GO TO 10
8     WRITE (6,14)
      GO TO 10
9     WRITE (6,15)
      GO TO 10
10    CONTINUE
11    RETURN
C
C
12    FORMAT (10X22HH IS ZERO OR NEGATIVE )
13    FORMAT (10X25HH IS LARGER THAN ALLOWED )
14    FORMAT (10X28HRHO IS SMALLER THAN ALLOWED )
15    FORMAT (10X27HRHO IS LARGER THAN ALLOWED )
      END
```

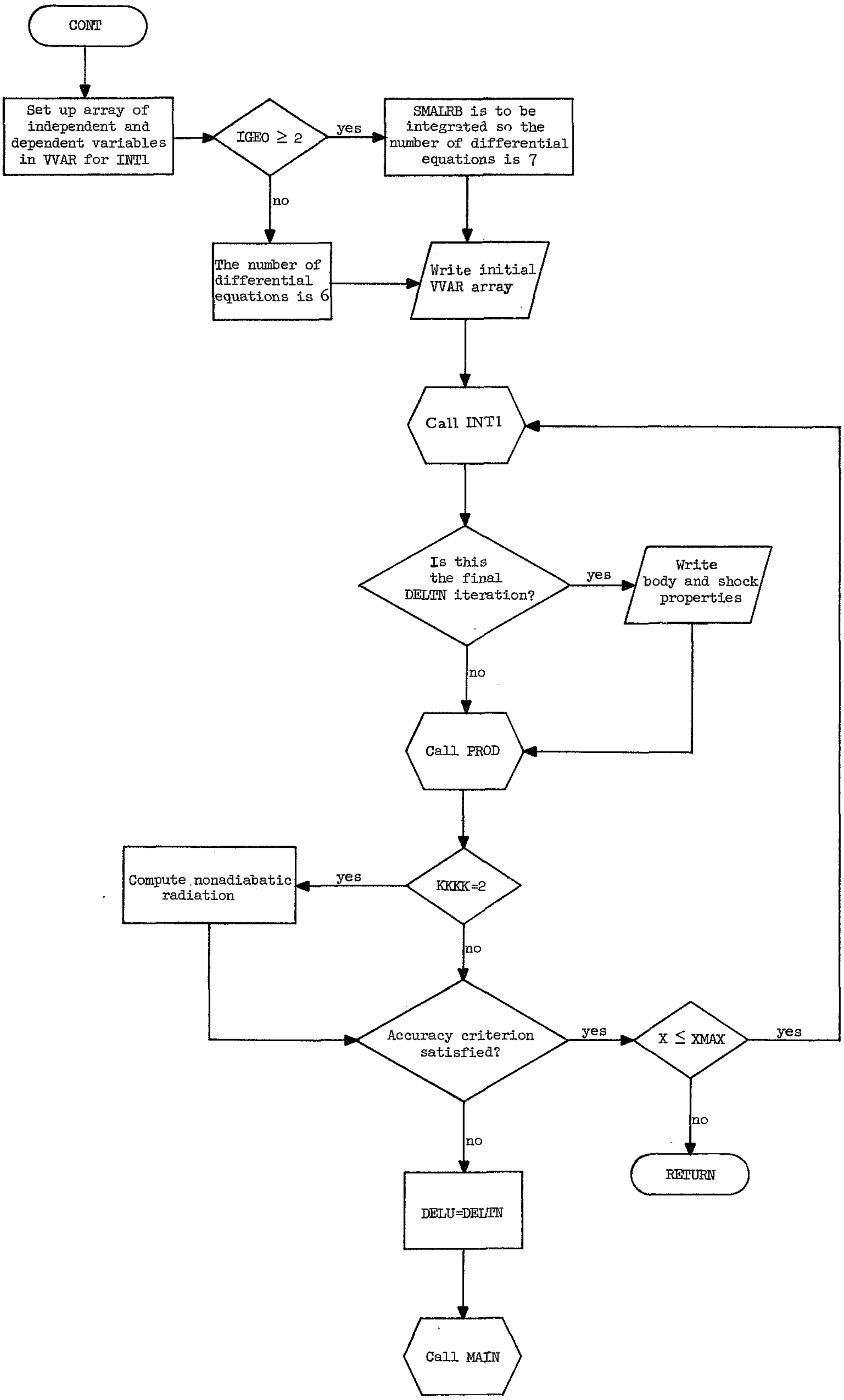
CONT

In subprogram CONT the array of variables for INT1, the integration routine, is established and INT1 is called to evaluate the derivatives. CONT writes the output from the integration routine. PROD is called to compute the η distribution and if KKKK is greater than zero, to compute the radiation. To minimize the use of the time-consuming radiation subroutine RADFLUX, curve fits to the radiation distribution around the body are used for all except the last iteration. The curve-fit expressions are

$$QRY1 = (1 + QI1 \times X^2 + QI2 \times X^4)QRY1_{stag}$$

$$QRYO = (1 + QO1 \times X^2 + QO2 \times X^4)QRYO_{stag}$$

where QI1, QI2, QO1, and QO2 are coefficients which describe the curve fit. The curve-fit coefficients are input values and are based on available data for radiation distributions or on the experience of the user. If no basis exists for these coefficients, the radiation heat fluxes should be computed at each integration step. The flow chart for subprogram CONT is as follows:

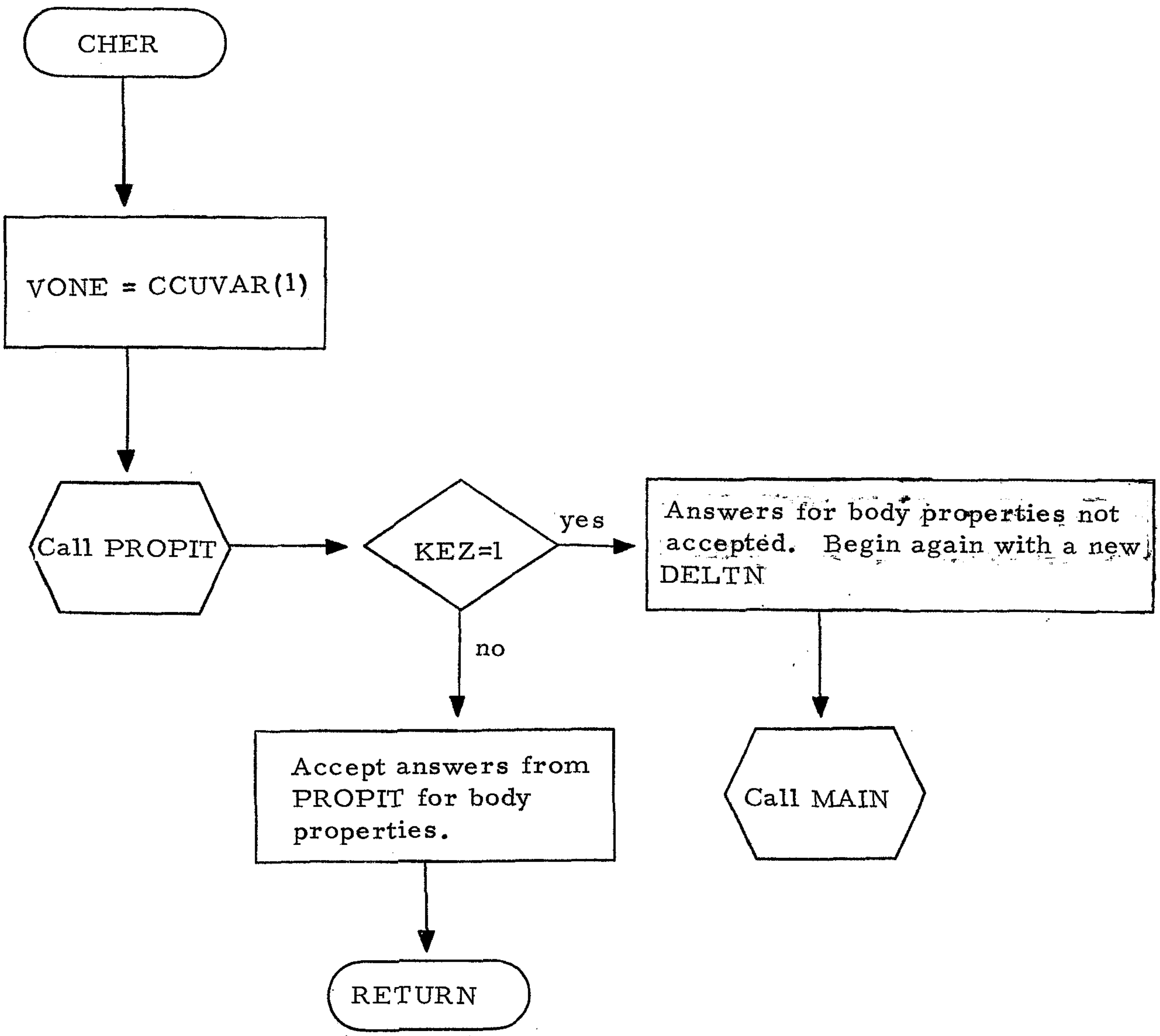

CONT
Set up array of independent and dependent variables in VVAR for INT1
IGEO ≥ 2
yes
SMALRB is to be integrated so the number of differential equations is 7
no
The number of differential equations is 6
Write initial VVAR array
Call INT1
Is this the final DELTN iteration?
yes
Write body and shock properties
no
Call PROD
Compute nonadiabatic radiation
yes
KKKK=2
no
Accuracy criterion satisfied?
yes
X ≤ XMAX
yes
no
RETURN
no
DELU=DELTN
Call MAIN

```
      SUBROUTINE CONT
      DOUBLE PRECISION VVAR,CCUVAR
C
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     301DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,K<KK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
      COMMON /QQQ/ QI1,QI2,QO1,QO2,QRY1,QRYO,QSTAG
      EXTERNAL DERSUB
      EXTERNAL CHSUB
      PCOREL=1.
      IT=0
      VVAR(1)=X
      VVAR(2)=DELTA
      VVAR(3)=W
      DIODX(4)=0
      DO 1 KM=2,5
      VVAR(KM+2)=XIO(KM)
1     CONTINUE
C     IF IGEO IS EQUAL TO 2  DRBDX IS INTEGRATED
C     NE IS THE NUMBER OF EQUATIONS TO BE INTEGRATED
C
      IF (IGEO-2) 2,3,3
2     NE=6
      GO TO 4
3     NE=7
      VVAR(8)=SMALRB
4     IF (KEKONT.LT.KETEST) GO TO 5
      WRITE (6,11) (VVAR(J),J=1,8)
5     CALL INT1 (IT,NE,3,CCI,SSPEC,CIMAX,IERR,VVAR,CCUVAR,DDER,EELE1,EEL
     1E2,EELT,ERRVAL,DERSUB,CHSUB,ITEXT)
      COSTB=COS(THETAB)
      SINTB=SIN(THETAB)
      SMALLRS=(1.+DELTA)*COSTB
      ZS=1.-(1.+DELTA)*SINTB
      DELTD=DELTA*RB
```

```
      IPROD=2
      USTAR=2.
C
C     IF KKKK=0 THE RADIATION IS NOT COMPUTED, KKKK=1 ADIABATIC
C     RADIATION IS COMPUTED, KKKK=2 FOR NONADIABATIC RADIATION
C
      IF (KEKONT.LT.KETEST) GO TO 6
      WRITE (6,12) (CCUVAR(JK),JK=1,8),(XI1(JJ),JJ=2,5),RBX,THETAB,CAPQ,
     1(DDER(IL),IL=2,8)
      CALL PROD (USTAR,IPROD,U0,U1,QRY0,QRY1)
      IF (KKKK.NE.2) GO TO 7
      R1=(1.+QD)*(1.+DAF)*QRY1-QRY0
      QRY0P=1.E-7*QRY0*RHOIN*UINS*UIN
      QRATIO=QRY0P/QSTAG
      GO TO 7
5     XS=X**2
      QSTAR1=(1.+QI1*XS+QI2*XS**2)*QRY1
      QSTAR0=(1.+Q01*XS+Q02*XS**2)*QRY0
      IF (KKKK.NE.2) GO TO 7
      R1=(1.+QD)*(1.+DAF)*QSTAR1-QSTAR0
7     PRATIO=P0/PSTAG
      PDIF=PCOREL-PRATIO
      IF (KEKONT.EQ.KETEST) WRITE (6,13) PRATIO,QRATIO
      IF (PDIF) 8,9,9
8     DELU=DELTN
      CALL MAIN
9     PCOREL=PRATIO
      IF (X-XMAX) 5,5,10
10    RETURN
C
C
11    FORMAT (1H011X44HPROPERTIES AT FIRST STEP OFF STAGNATION LINE/8X1H
     1XD15.8,5X5HDELTAD15.8,9X1HWD15.8,5X5HIO(2)D15.8,5X5HIO(3)D15.8/5X5
     2HIO(4)D15.8,5X5HIO(5)D15.8,4X6HSMALRBD15.8/)
12    FORMAT (1H1/10X25HBODY AND SHOCK PROPERTIES/9X1HXD15.8,5X5HDELTAD1
     15.8,9X1HWD15.8,5X5HIO(2)D15.8,5X5HIO(3)D15.8/5X5HIO(4)D15.8,5X5HIO
     2(5)D15.8,4X6HSMALRBD15.8,5X5HI1(2)E15.8,5X5HI1(3)E15.8/5X5HI1(4)E1
     35.8,5X5HI1(5)E15.8,7X3HRBXE15.8,4X6HTHETABE15.8,9X1HQE15.8/4X6HDDE
     4LDXE15.8,6X4HDWDXE15.8,2X8HDIODX(2)E15.8,2X8HDIODX(3)E15.8,2X8HDIO
     5DX(4)E15.8/2X8HDIODX(5)E15.8,1X9HDSMALRBDXE15.8/)
13    FORMAT (1H06X6HPRATIOE15.8,2X6HQRATIOE15.8/)
      END
```

CHER

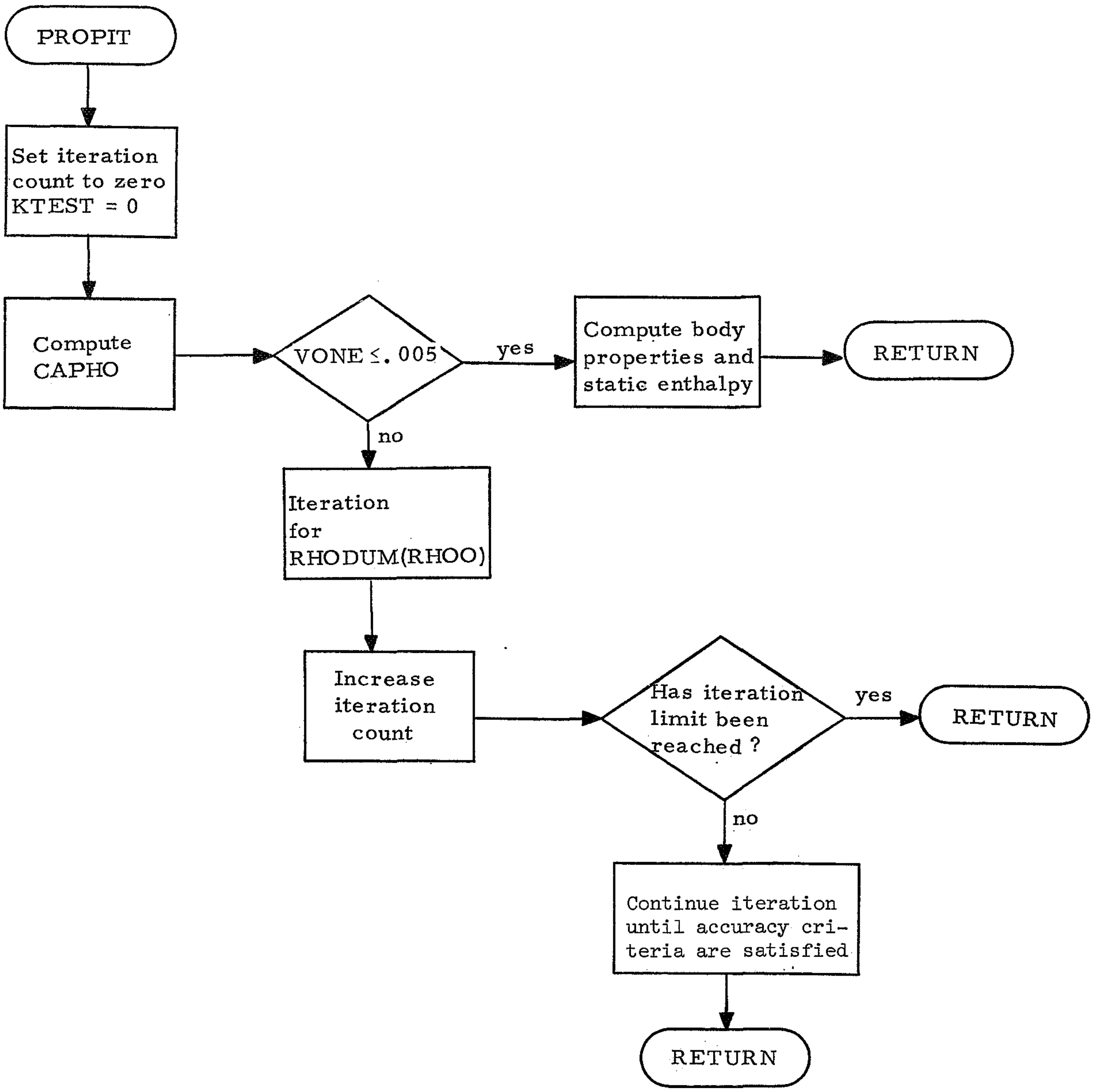
An additional test on the DELTN (δ_0) iteration is performed in CHER. After PROPIT returns to CHER; KEZ is tested. If the RHO computed in THEP is too small, KEZ is set to 1. When this is the case, DELL = DELTN and CHER then calls MAIN to reinitialize the program with a new DELTN. CHER is called by DERSUB. The flow chart for subprogram CHER is as follows:



```
      SUBROUTINE CHER
      DOUBLE PRECISION VVAR,CCUVAR
C
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     3O1DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
C
      VONE=CCUVAR(1)
      CALL PROPIT (R,UINS,XIO,TO,PO,RHOO,ITTEST,RHOIN,STAENT,ZDUM,KEZ,EP
     1S21,AO,VONE,CAPHO,UO,PIN,EMUREF)
      IF (KEZ.EQ.1) GO TO 1
      RETURN
1     DELL=DELTN
      CALL MAIN
      END
```

PROPIT

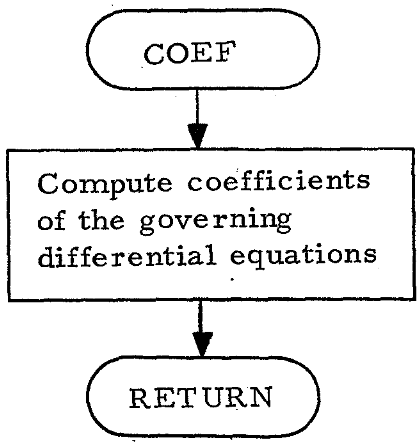
PROPIT is a subprogram called by CHER during each integration step to solve for the body properties through a Newton-Raphson iteration scheme. PROPIT has a calling sequence in which R, UINS, RHOIN, PIN, ITTEST, EPS21, and EMUREF are constants. The variables XIO, AO, and CAPHO are computed for the particular value of VONE, the independent variable X, when PROPIT is called. The body properties, PDUM, RHODUM, UGEN, TGEN, and ZDUM and the static enthalpy STAENT are computed by the subprogram. An indicator KEZ is set in THEP when RHO is too small. The flow chart for subprogram PROPIT is as follows:



```
      SUBROUTINE PROPIT (R,UINS,XIO,TGEN,PDUM,RHODUM,ITTEST,RHOIN,STAENT
     1,ZDUM,KEZ,EPS21,AO,VONE,CAPHO,UGEN,PIN,EMUREF)
C
      DIMENSION XIO(6)
C     KTEST IS THE NUMBER OF ITERATIONS ALLOWED ON RHO
      KTEST=0
      KEZ=0
      CAPHO=XIO(5)/XIO(2)
      XIO2S=XIO(2)**2
      IF (VONE-.005) 1,1,3
1     UGEN=AO*VONE
      UGENS=UGEN**2
      STAENT=CAPHO-UGENS/2.
      RHODUM=XIO(2)/UGEN
      RUGS=RHODUM*UGENS
      PDUM=XIO(3)-RUGS
C
C
2     RETURN
3     STAENT=CAPHO-.5*XIO2S/(RHODUM**2)
      CALL THEP (R,PDUM,RHODUM,TGEN,ZDUM,STAENT,EMUREF,PIN,RHOIN,UINS,KE
     1Z)
      IF (KEZ.EQ.1) RETURN
      FRODUM=RHODUM-(XIO(3)-PDUM)*(RHODUM**2)/XIO2S
      DELRHO=-.1
      RHODMP=RHODUM+DELRHO
      STAD=CAPHO-.5*XIO2S/(RHODMP**2)
      CALL THEP (R,PD,RHODMP,TD,ZD,STAD,EMUREF,PIN,RHOIN,UINS,KEZ)
      FPRHO=(RHODMP-(XIO(3)-PD)*(RHODMP**2)/XIO2S-FRODUM)/DELRHO
      FROFPR=FRODUM/FPRHO
      AFRFPR=ABS(FROFPR)
      IF (AFRFPR-EPS21) 6,6,4
4     KTEST=KTEST+1
      IF (KTEST-ITTEST) 5,7,7
5     RHODUM=RHODUM-FROFPR
      GO TO 3
6     UGEN=XIO(2)/RHODUM
      UGENS=UGEN**2
      RUGS=RHODUM*UGENS
      GO TO 2
7     WRITE (6,8)
      KEZ=1
      RETURN
C
C
8     FORMAT (1H06X34HITTERATION LIMIT REACHED IN PROPIT)
      END
```

COEF

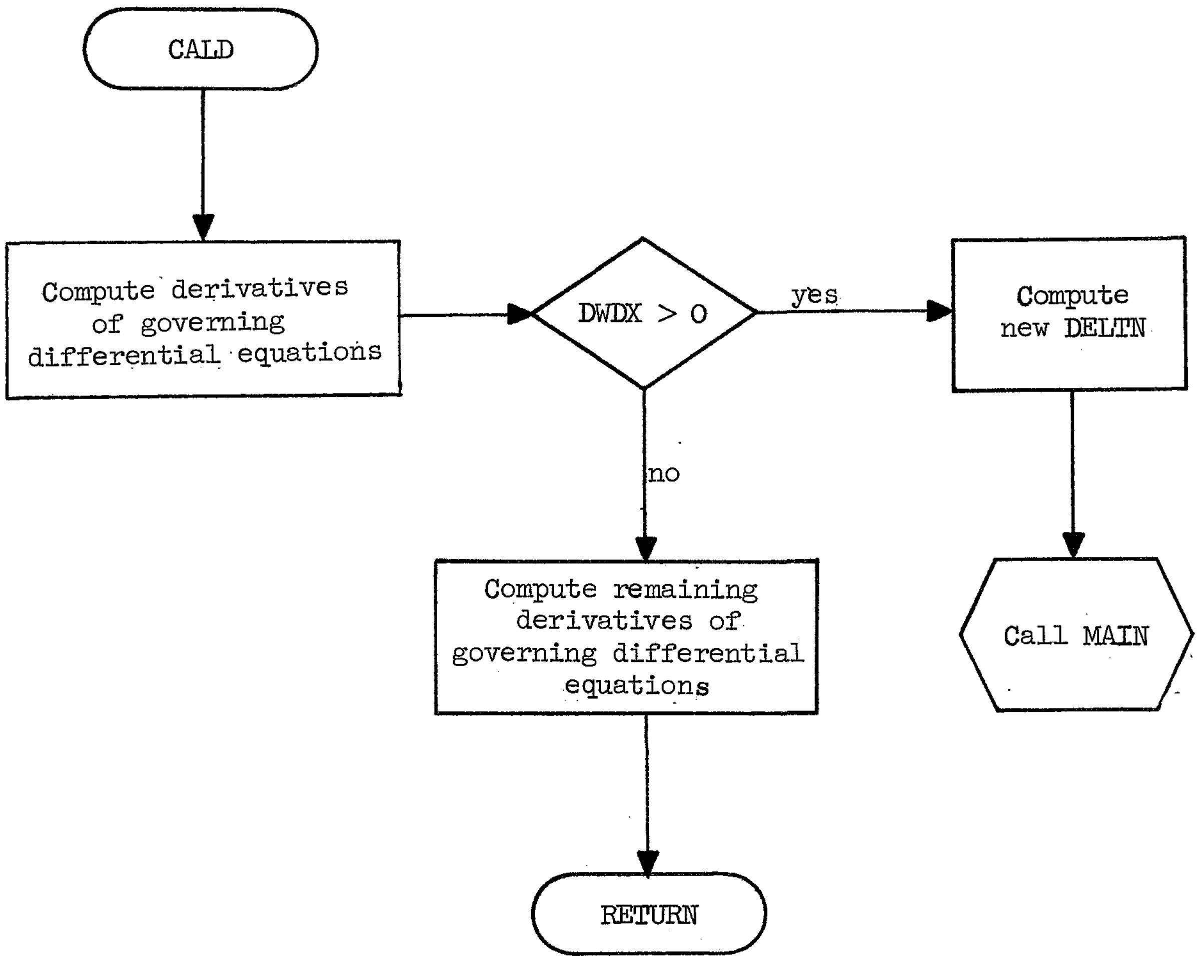
Subprogram COEF is called by DERSUB to calculate the coefficients of the governing differential equations. The flow chart for subprogram COEF is as follows:



```
      SUBROUTINE COEF
C
      DOUBLE PRECISION VVAR,CCUVAR
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     3O1DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
C
      CAPR1=R1
C
      TPTOD=3.+2.*DAF
      AA1(2)=3.*(XIO(2)-XI1(2))+2.*DAF*(XIO(2)-XI1(2))
      AA1(3)=3.*(XIO(3)-XI1(3))+2.*DAF*(XIO(3)-XI1(3))
      AA1(4)=-TPTOD*XI1(4)
      AA1(5)=3.*(XIO(5)-XI1(5))+2.*DAF*(XIO(5)-XI1(5))
      DO 1 J=2,5
      BB1(J)=DELTA*TPTOD*DI1DW(J)
1     CONTINUE
      CC1=DELTA*(3.+DAF)
      DD1=1.
      EO1=-(1.+CAPQ*DELTA)/CAPQ*SWMTB/CWMTB*DTBDX
      GG1(5)=RHO1*V1*CAPH1
      GG1(2)=RHO1*V1
      GG1(3)=RHO1*U1*V1
      GGO(4)=PO
      GG1(4)=P1+RHO1*V1**2
      EE1(2)=3.*DOSRB*(XIO(2)+XI1(2))*DRBDX-DELS*OPERA*(XIO(2)+2.*XI1(2)
     1)*DTBDX+6.*(1.+QD)*(1.+DAF)*GG1(2)+DELTA*TPTOD*GG1(2)*DTBDX
      EE1(3)=3.*DOSRB*(RHOO*UO**2+RHO1*U1**2)*DRBDX-DELS*OPERA*(RHOO*UO*
     1*2+2.*RHO1*U1**2)*DTBDX+QD*(3.+2.*DAF)*XI1(4)+6.*(1.+QD)*(1.+DAF)*
     2XI1(4)+2.*DELTA*TPTOD*XI1(4)*DTBDX
      EE1(4)=3.*DOSRB*XI1(4)*DRBDX-2.*DELS*OPERA*XI1(4)*DTBDX-3.*(QD+DAF
     1)*(XIO(3)+XI1(3))-2.*QD*DAF*(XIO(3)+2.*XI1(3))+6.*(1.+QD)*(1.+DAF)
     2*GG1(4)-6.*GGO(4)+QD*DAF*(RHOO*UO**2+2.*RHO1*U1**2)+3.*DAF*(RHOO*U
     3O**2+RHO1*U1**2)+DELTA*(3.+2.*DAF)*RHO1*(V1**2-U1**2)*DTBDX
      EE1(5)=3.*DOSRB*(XIO(5)+XI1(5))*DRBDX-DELS*OPERA*(XIO(5)+2.*XI1(5)
     1)*DTBDX+6.*(1.+QD)*(1.+DAF)*GG1(5)+6.*R1+DELTA*(3.+2.*DAF)*GG1(5)*
     2DTBDX
      RETURN
      END
```

CALD

The derivatives of the governing differential equations which are used in DERSUB are computed in CALD. CALD is called by DERSUB. The flow chart for subprogram CALD is as follows:



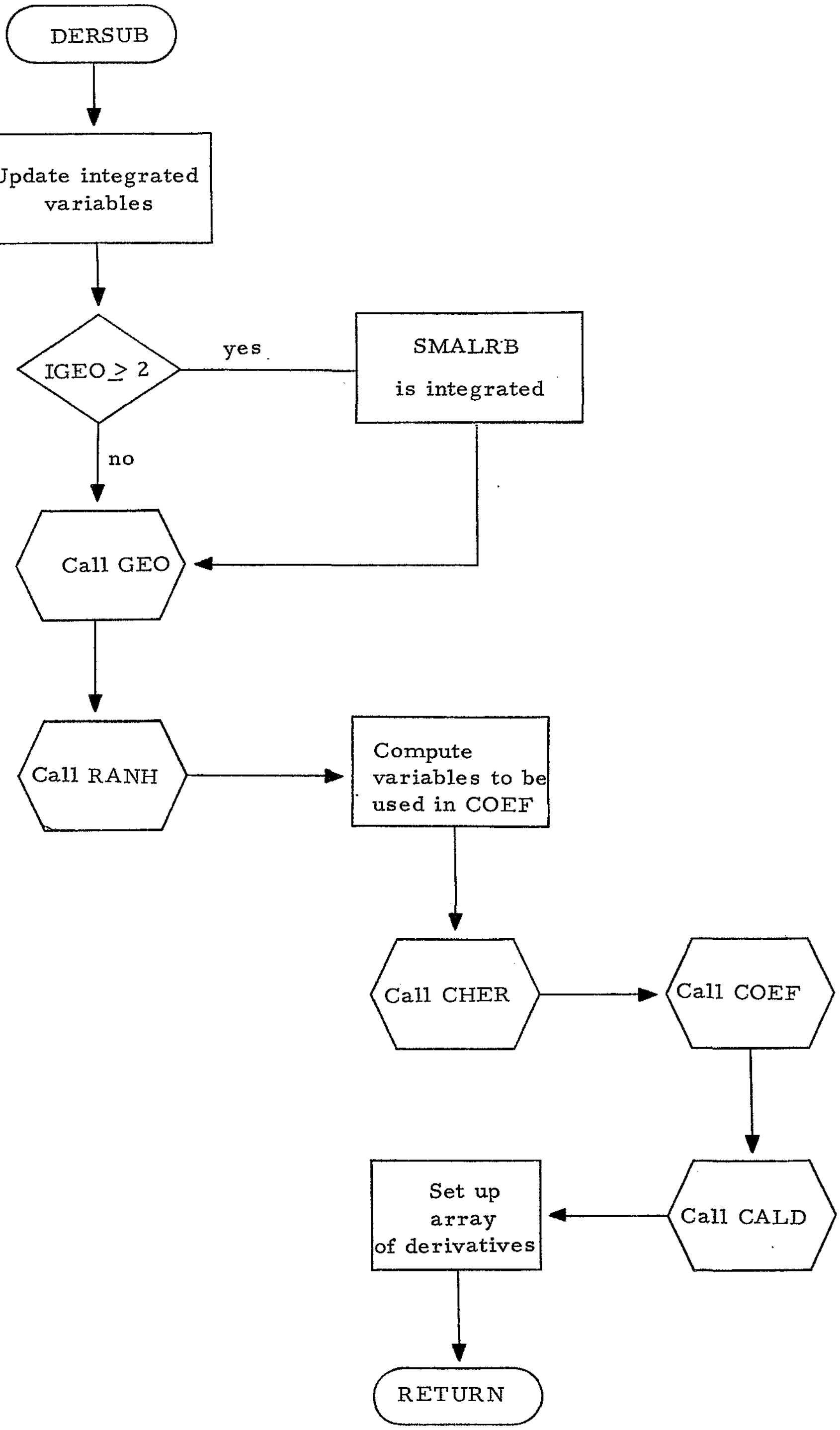
```
      SUBROUTINE CALD
      DOUBLE PRECISION VVAR,CCUVAR


      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     301DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1

      RBS=SMALRB**2
      RACE=RBS/(SMALLB**2-RBS)
      IF (IGEO-2) 3,1,2
      DRBDX=1./SQRT(1.+AOVERB**2*RACE)
      GO TO 3
      DRBDX=1./(1.+AOVERB**2*SMALRB/(SMALLB**2+RBS))
      DDELDX=EO1
      DWDX=(-AA1(4)*DDELDX-EE1(4))/BB1(4)
      IF (DWDX) 5,5,4
      DELU=DELTN
      CALL MAIN
      DIODX(2)=(-AA1(2)*DDELDX-BB1(2)*DWDX-EE1(2))/CC1
      DIODX(3)=UO*DIODX(2)
      DIODX(5)=(-AA1(5)*DDELDX-BB1(5)*DWDX-EE1(5))/CC1
      RETURN
      END
```

DERSUB

DERSUB is a subprogram used by INT1, the integration routine, to evaluate the derivatives. The flow chart for subprogram DERSUB is as follows:



```
      SUBROUTINE DERSUB
      DOUBLE PRECISION VVAR,CCUVAR
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     3O1DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
C
      X=CCUVAR(1)
      DELTA=CCUVAR(2)
      W=CCUVAR(3)
      DO 1 I=2,5
      XIO(I)=CCUVAR(I+2)
1     CONTINUE
      IF (IGEO.GE.2) SMALRB=CCUVAR(8)
      CALL GEO
      CALL RANH
      DOSRB=DELTA/SMALRB
      COSTB=COS(THETAB)
      SINTB=SIN(THETAB)
      DAF=DELTA*COSTB/SMALRB
      OPERA=SINTB/SMALRB
      CALL CHER
      CALL COEF
      CALL CALD
      DDER(2)=DDELDX
      DDER(3)=DWDX
      DO 2 I=2,5
      DDER(I+2)=DIODX(I)
2     CONTINUE
      IF (IGEO.GE.2) DDER(8)=DRBDX
      RETURN
      END
```

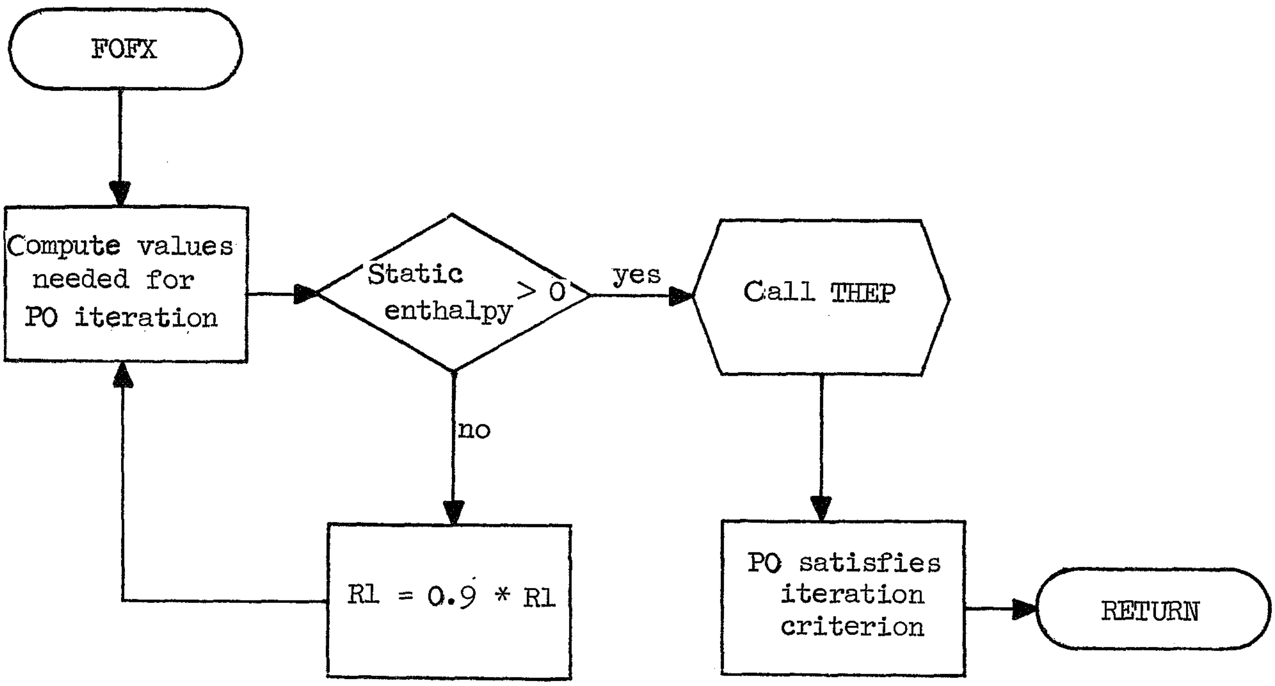
CHSUB

CHSUB is called by INT1. It is written by the user and is described in appendix A. In program D1250 the features of CHSUB are not needed; therefore, CHSUB is a dummy routine.

```
SUBROUTINE CHSUB                                                 E    1
RETURN                                                           E    2
END                                                              E    3-
```

FOFX

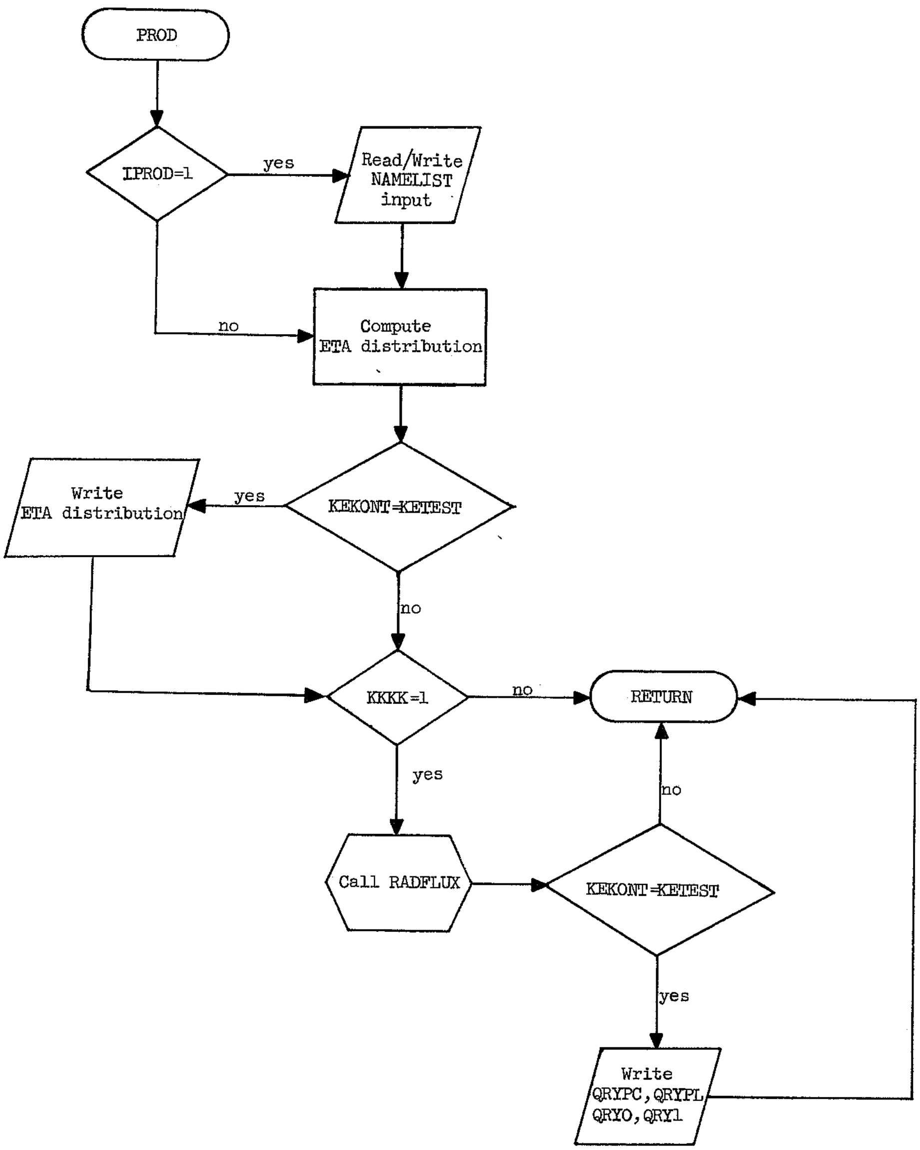
FOFX is a function subprogram called by ITR1 to evaluate p_0 (in FOFX, $p_0 = p_{stag}$). The flow chart for subprogram FOFX is as follows:



```
      FUNCTION FOFX (PDUM)
C
C
      DOUBLE PRECISION VVAR,CCUVAR
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     3O1DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
      ROPE=-(AC**2*(P1-PDUM)**2)/(PEEP*CC**2*PDUM)
1     STAPE=CAPH1-3.*R1/(AC*(P1-PDUM))
      IF (STAPE.GT.0) GO TO 2
      R1=.9*R1
      GO TO 1
2     CALL THEP (R,POX,ROPE,TD,ZD,STAPE,EMUREF,PIN,RHOIN,UINS,KEZ)
      FOFX=POX
      RETURN
      END
```

PROD

Subprogram PROD reads and writes the radiation NAMELIST input RAD1 and calls the subprogram to compute radiation. The thermodynamic properties within the shock layer are computed in the η distribution. PROD has a calling sequence in which USTAR determines whether the properties are off the stagnation point. If they are off the stagnation point, USTAR becomes the velocity at the body surface. IPROD is the option to read the radiation input data. AUODUM and AU1DUM represent a_0 and a_1 when PROD is called by MAIN and u_0 and u_1 when PROD is called by CONT. QRYO and QRY1 are computed by RADFLUX and are the total radiation heat fluxes at the body and shock, respectively. The flow chart for subprogram PROD is as follows:



```
      SUBROUTINE PROD (USTAR,IPROD,AUODUM,AU1DUM,QRYO,QRY1)
C
      DOUBLE PRECISION VVAR,CCUVAR
C
      COMMON /MAINP/ AA1(6),AC,AO,AOVERB,A1,BB1(6),CAPHO,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DIODX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     301DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,EO1,EPSR,EPS21,GGO(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,PO,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHOO,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,TO,T1,UIN,UINS,UO,US,U1,
     8V,VO,VS,V1,VVAR(8),W,X,XIO(6),XI1(6),XMAX,ZO,Z1
      COMMON /WON/ QRYPC(20),QRYPL(20)
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(16),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION HH(100), PRES(100)
      REAL KN,KNY
      NAMELIST /RAD1/ GEE,EPS,FHVM,FHVP,FHV,WOL,NU,ND,HVL,FF,GAMP,IS,NIH
     1VC,FHVC,AHV,AHVL,FL1,FL2,FLG,FLG1,NIC,NICN,IOPT,TB ,NY
C
C     THIS ROUTINE IS CALLED IN THE MAIN PROGRAM WHEN IPROD=1 TO
C     READ IN THE DATA FOR RADFLUX,WHEN IPROD =2 ,NAMELIST IS NOT CALLED
C
      IF (IPROD-1) 2,1,2
1     READ (5,RAD1)
      WRITE (6,RAD1)
      WRITE (6,8)
```

```
2     UINS=UIN**2
      IQ=NY
      YY(1)=0
      IF (USTAR) 3,3,4
3     HH(1)=CAPHO*UINS/4.19E7
      GO TO 5
4     HH(1)=(CAPHO-UO**2/2.)*UINS/4.19E7
5     PRES(1)=PO*RHOIN*UINS/1.01325E6
      IF (KEKONT.EQ.KETEST) WRITE (6,9)
      ETA=0
      STAENT=CAPHO-UO**2/2.
      IF (KEKONT.EQ.KETEST) WRITE (6,10) ETA,PO,STAENT,CAPHO,AUODUM,VO
      DO 6 N=2,NY
      KN=N
      KNY=NY
      ETA=(KN-1.)/(KNY-1.)
      YY(N)=ETA
      RHOAU=RHOO*AUODUM+(RHO1*AU1DUM-RHOO*AUODUM)*ETA
      RHOAUS=RHOO*AUODUM**2+(RHO1*AU1DUM**2-RHOO*AUODUM**2)*ETA
      RHOAUH=RHOO*AUODUM*CAPHO+(RHO1*AU1DUM*CAPH1-RHOO*AUODUM*CAPHO)*ETA
      RHOAUV=RHO1*AU1DUM*V1*ETA
      AUDUM=RHOAUS/RHOAU
      V=RHOAUV/RHOAU
      IF (USTAR.GT.0) USTAR=AUDUM
      SUMH=RHOAUH/RHOAU-USTAR**2/2.-V**2/2.
      STAENT=SUMH
      CAPH=RHOAUH/RHOAU
      PDUM=PO+(QD*RHOO*UO**2)*ETA+(P1-PO-QD*RHOO*UO**2)*ETA**2
      IF (KEKONT.EQ.KETEST) WRITE (6,10) ETA,PDUM,STAENT,CAPH,AUDUM,V
      HH(N)=SUMH*UINS/4.19E7
      PRES(N)=PDUM*RHOIN*UINS/1.01325E6
6     CONTINUE
      IF (KKKK.EQ.0) GO TO 7
      CALL RADFLUX (NIC,NICN,IOPT,PRES,HH,QRYO,QRY1)
      IF (KEKONT.EQ.KETEST) WRITE (6,11) QRYPC(1),QRYPC(NY),QRYPL(1),QRY
     1PL(NY),QRYO,QRY1
7     RETURN
C
C
8     FORMAT (1H1)
9     FORMAT (1HO4X31HDISTRIBUTION ACROSS SHOCK LAYER/12X3HETA14X4HPDUM1
     13X6HSTAENT11X4HCAPH13X5HAUDUM12X1HV/)
10    FORMAT (6(2XE15.8))
11    FORMAT (1HO,6X,5HQRYPC2E15.8,2X,5HQRYPL2E15.8,2X,4HQRYOE15.8,2X,4H
     1QRY1E15.8)
      END
```

RADIATION SUBPROGRAMS

The radiation package was adapted from program RATRAP (ref. 4). Reference 3 describes RATRAP as it is applied to D1250. If the input quantity KKKK is greater than zero, a radiation solution is computed. Subprogram PROD links D1250 to RATRAP by reading the input for the radiation program and by calling RADFLUX. RADFLUX serves as the main program for the radiation subprograms. A listing of the radiation subprograms follows.

```
      SUBROUTINE RADFLUX (NIC,NICN,IOPT,PRES,HH,QRY0,QRY1)
C
      DOUBLE PRECISION VVAR,CCUVAR
C
C
      COMMON /MAINP/ AA1(6),AC,A0,AOVERB,A1,BB1(6),CAPH0,CAPH1,CAPQ,CC,C
     1C1,CCI,CCUVAR(8),CII,CIMAX,COSTB,COSW,CWMTB,DAF,DDELDX,DDER(8),DD1
     2,DELL,DELS,DELTA,DELTN,DELU,DI0DX(6),DI1DW(6),DOSRB,DP1DW,DRBDX,DR
     301DW,DTBDX,DUSDW,DU1DW,DVSDW,DV1DW,DWDX,EELE1(7),EELE2(7),EELT(3),
     4EE1(6),ERRVAL(7),EMUREF,E01,EPSR,EPS21,GG0(6),GG1(6),HONE,ICOSW,IE
     5RR,IGEO,ITEXT,ITTEST,KEKONT,KETEST,KKKK,OPERA,P,PEEP,PIN,P0,PSTAG,
     6P1,QD,R,RB,RBX,RHOIN,RHON,RHO0,RHO1,R1,SINTB,SINSQW,SINW,SMALLB,SM
     7ALRB,STAENT,SSPEC,SWMTB,T,TCG,TEAN,THETAB,T0,T1,UIN,UINS,U0,US,U1,
     8V,V0,VS,V1,VVAR(8),W,X,XI0(6),XI1(6),XMAX,Z0,Z1
      COMMON /WON/ QRYPC(20),QRYPL(20)
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RB0(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(15),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      NHV=18
      C4=1.273
      G=1.
      NICN(2)=NY
      IF (IOPT.EQ.2) GO TO 1
      TB(1)=TEE(1)
1     DO 15 I=1,NY
      PRESS=PRES(I)
      IF (IOPT.EQ.2) GO TO 2
```

```
      TB(2)=TB(1)
      GO TO 3
2     TB(2)=TB(1)*1.2
      HS=HH(I)
3     I1=0
      IF (I.EQ.1) GO TO 5
4     Z=29.*PRESS/(82.057*TB(2)*RHO)
      IF (Z.LE.1.5) GO TO 6
5     CALL HTP (IZW)
      IZW=IZW
      GO TO 7
6     CALL LTP (IZW)
      IZW=IZW
7     CALL FEMP (IHELP,IOPT)
      IF (IOPT.EQ.2) GO TO 8
      TB(2)=TEE(I)
      TB(1)=TB(2)
      GO TO 9
8     TEE(I)=TB(2)
      HS=HH(I)
      TB(1)=TB(2)/1.2
9     IF (IHELP.EQ.0) GO TO 10
      WRITE (6,17) I,PRESS,HS,TB(1),TB(2)
      STOP
10    IF (I1.NE.0) GO TO 11
      I1=1
      GO TO 4
11    IF (IZW.EQ.2) GO TO 12
      XNN(1,I)=0
      XNN(2,I)=FLUT(BMT(3),W3(3),RHO)
      XNN(3,I)=FLUT(BMT(2),W3(2),RHO)
      XNN(4,I)=0.
      XNN(5,I)=0.
      XNN(6,I)=FLUT(BMT,W3,RHO)
      XNN(7,I)=FLUT(BMT(4),W3(4),RHO)
      GO TO 14
12    DO 13 L=1,4
13    XNN(L,I)=FLUT(BMT(L+2),W3(L+2),RHO)
      XNN(5,I)=FLUT(BMT,W3,RHO)
      XNN(6,I)=0.
      XNN(7,I)=FLUT(BMT(2),W3(2),RHO)
14    TB(2)=TEE(I)
      RHOND=RHO/RHOIN
```

```
      IF (KETEST.NE.KEKONT) GO TO 15
      IF (MOD(I-1,50).EQ.0) WRITE (6,18)
      WRITE (6,19) YY(I),PRES(I),TEE(I),HS,RHO,RHOND
15    CONTINUE
      C2=DELTD*FL1
      C1=DELTD*FL2
      C3=C1/3.1416
      C5=C1
      EP=.001
      DO 16 L=1,NIC
      IY=NICN(L)
      IYCON=IY
      YDELT=YY(IY)
      CALL CONTM
      CALL LINE
16    CONTINUE
      QRY0=-(1.E7*(QRYPC(1)+QRYPL(1))/(RHOIN*UIN**3))
      QRY1=1.E7*(QRYPC(NY)+QRYPL(NY))/(RHOIN*UIN**3)
      RETURN
C
C
17    FORMAT (10H1FEMP BLEW,I10,4E20.6)
18    FORMAT (14H0  PATH LENGTH,4X,8HPRESSURE,3X,11HTEMPERATURE,4X,8HENT
     1HALPY,5X,7HDENSITY,7X,11HDENSITY(ND),/,4X9H(Y/DELTA),9X,5H(ATM),7X
     2,7H(DEG K),6X,8H(CAL/GM),5X,7H(GM/CC))
19    FORMAT (6X6E13.5)
      END
```

```
      SUBROUTINE LINE
C
C
      COMMON /WON/ QRYPC(20),QRYPL(20)
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(16),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XXN(7,100)
      COMMON /RAD/ NDD,FDD(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      DIMENSION BEE(100), WWM(100), WP(100), FMU(100), T2(100), SS(100),
     1 TAU(100)
      DIMENSION FX1(20), FY1(20)
      DIMENSION WA(100), WS(100)
      DIMENSION FX(20), FY(20)
      DIMENSION IWP(100), IWM(100)
      IYCON=IY
      G=1.
      C9=2.42E14
      C11=1./2.42E14
      FIP=0.
      FIM=0.
      K2=0
      DO 21 K=1,NHV
      FX(K)=0.
      FY(K)=0.
      FX1(K)=0.
      FY1(K)=0.
      K1=K2+1
      K2=K2+NU(K)
```

```
      DO 1 I=1,NY
      T1=TEE(I)*8.62E-5
      BEE(I)=0.
      QW=FHV(K)/T1
      IF (QW.LT.85.) BEE(I)=5040.*FHV(K)**3/(EXP(QW)-1.)
      WWM(I)=0.
      WP(I)=0.
1     CALL MU (FHV(K),T1,XXN(1,I),FMU(I))
      CALL TRAP (NY,YY,FMU,C2,TAU)
      X1=FHVM(K)
      X2=FHVP(K)
      QF=FLOAT(NU(K))
      DO 16 J=K1,K2
      IJ=J-K1+1
      T2(1)=0.
      SS(1)=0.
      F2(1,IJ)=0.
      BIJ(1,IJ)=0.0
      DO 5 I=1,NY
      T1=TEE(I)*8.62E-5
      E1=1.-EXP(-FHV(K)/T1)
      J1=ND(J)
      IF (J1.EQ.7) GO TO 2
      PN=XXN(2,I)+XXN(4,I)
      FN=PN/(4.+10.*EXP(-2.384/T1)+6.*EXP(-3.576/T1))
      GO TO 3
2     PNP=XXN(1,I)+XXN(3,I)
      FN=PNP/(7.+5.*EXP(-1.9/T1))
3     FN=FN*GEE(J1)*EXP(-EPS(J1)/T1)
      S1=FN*FF(J)*.0266*E1
      GAM=(GAMP(J)*G*XXN(5,I)*(T1**.25)+1.0E-06)*C9
      IF (I.EQ.1) GO TO 4
      DY=.5*(YY(I)-YY(I-1))
      T2(I)=T2(I-1)+DY*(S1/GAM+OS1/OGAM)*C3
      SS(I)=SS(I-1)+DY*(S1+OS1)*C1
      F2(I,IJ)=F2(I-1,IJ)+DY*(S1*GAM+OS1*OGAM)*C5
      BIJ(I,IJ)=BIJ(I-1,IJ)+DY*(GAM+OGAM)*4.135E-15
4     OS1=S1
      OGAM=GAM
5     CONTINUE
      IF (IY.EQ.1) GO TO 11
      DO 8 I=1,IY
      FINT=T2(IY)-T2(I)
```

```
      IF (FINT.GT.C4) GO TO 6
      WS(I)=(SS(IY)-SS(I))*C11
      F(I,IJ)=0.
      GO TO 7
6     WS(I)=2.*SQRT(F2(IY,IJ)-F2(I,IJ))*C11
      F(I,IJ)=1.
7     WWM(I)=WWM(I)+WS(I)
      IF (I.EQ.IY) GO TO 9
8     GMIN(I,IJ)=((BIJ(IY,IJ)-BIJ(I,IJ))/(YY(IY)-YY(I)))**2
      GO TO 10
9     GMIN(I,IJ)=0
10    IF (IY.EQ.NY) GO TO 16
11    DO 15 I=IY,NY
      FINT=T2(I)-T2(IY)
      IF (FINT.GT.C4) GO TO 12
      WA(I)=(SS(I)-SS(IY))*C11
      F(I,IJ)=0.
      GO TO 13
12    WA(I)=2.*SQRT(F2(I,IJ)-F2(IY,IJ))*C11
      F(I,IJ)=1.
13    WP(I)=WP(I)+WA(I)
      IF (I.EQ.NY) GO TO 14
      GPLU(I,IJ)=((BIJ(I,IJ)-BIJ(NY,IJ))/(YY(I)-YY(NY)))**2
      GO TO 15
14    GPLU(I,IJ)=0
15    CONTINUE
16    CONTINUE
      IF (IY.EQ.1) GO TO 18
      IFL=1
      DO 17 I=1,IY
      IWM(I)=0
      IF (WWM(I)/QF.LT.WOL(K)) GO TO 17
      IWM(I)=1
      IQ1=I
      IAED=1
      CALL HAFACE (1,X1,X2)
      CALL HAFACE (2,0.,0.)
      WWM(I)=WMI
17    WWM(I)=WWM(I)*EXP(TAU(I)-TAU(IY))
      CALL TRAP1 (IY,WWM,BEE,-1.,FX(K))
      FX1(K)=WWM(1)
      FX(K)=FX(K)*AHVL(K)
      FIM=FIM+FX(K)
```

```
18    N1=NY-IY+1
      IF (N1.EQ.1) GO TO 20
      IFL=-1
      DO 19 I=IY,NY
      IWP(I)=0
      IF (WP(I)/QF.LT.WOL(K)) GO TO 19
      IWP(I)=1
      IQ1=I
      IAED=2
      CALL HAFACE (1,X1,X2)
      CALL HAFACE (2,0.,0.)
      WP(I)=WMI
19    WP(I)=WP(I)*EXP(TAU(IY)-TAU(I))
      CALL TRAP1 (N1,WP(IY),BEE(IY),1.,FY(K))
      FY1(K)=WP(NY)
      FY(K)=FY(K)*AHVL(K)
      FIP=FIP+FY(K)
20    CONTINUE
21    CONTINUE
      QRYPL(IY)=FIM+FIP
      RETURN
      END
```

```
      SUBROUTINE CONTM
C
      COMMON /WON/ QRYPC(20),QRYPL(20)
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(16),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),DUN(20),NDV,NY,C2,IY
      COMMON /RAD/ XXN(7,100)
      COMMON /RAD/ NHV,FHV(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      DIMENSION FMU(100), TAU(100), FIM(40), FIP(40), BEE(100), EM(100),
     1 EEP(100), FIIP(40), FIIM(40)
      DO 9 K=1,NHV
      DO 1 I=1,NY
      T1=TEE(I)*8.62E-5
      CALL MU (FHV(K),T1,XXN(1,I),FMU(I))
      BEE(I)=0.
      AQ=FHV(K)/T1
      IF (AQ.LT.85.) BEE(I)=5040.*FHV(K)**3/(EXP(AQ)-1.)
1     CONTINUE
      CALL TRAP (NY,YY,FMU,C2,TAU)
      IF (IY.NE.1) GO TO 2
      FIM(K)=0.
      GO TO 4
2     DO 3 I=1,IY
3     EM(I)=1.-EXP(TAU(I)-TAU(IY))
      CALL TRAP1 (IY,EM,BEE,-1.,FIM(K))
      FIM(K)=FIM(K)*AHV(K)
4     N1=NY-IY+1
      IF (N1.NE.1) GO TO 5
      FIP(K)=0.
```

```
      GO TO 7
5     DO 6 I=IY,NY
6     EEP(I)=1.-EXP(TAU(IY)-TAU(I))
      CALL TRAP1 (N1,EEP(IY),BEE(IY),1.,FIP(K))
      FIP(K)=FIP(K)*AHV(K)
7     IF (K.NE.1) GO TO 8
      FIIM(1)=0.
      FIIP(1)=0.
      GO TO 9
8     CALL TRAP (K,FHV,FIM,1.,FIIM)
      CALL TRAP (K,FHV,FIP,1.,FIIP)
9     CONTINUE
      QRYPC(IY)=FIIM(NHV)+FIIP(NHV)
      RETURN
      END
```

```
      SUBROUTINE MU (HV,XKT,XM,XAPNU)
      DIMENSION XKT(1), XNN(1), XNO(1), XNI(1), XNO2(1), XNN2(1), XAPNU(
     11,1), XM(1)
      SQA=7.25E-16
      XNN(1)=XM(4)
      XNO(1)=XM(2)
      XNI(1)=XM(1)+XM(3)
      XNO2(1)=XM(6)
      XNN2(1)=XM(7)
      L=1
      I=1
      XMOL=1.
      BQ7=0.
      CALL ZHV (HV,ZO,ZN,ZI,ZC)
      XN=14.3/XKT(I)
      XO=13.4/XKT(I)
      XI=25.5/XKT(I)
      XX=HV/XKT(I)
      EQ1=SQA*XNN(I)*XKT(I)*4.5*EXP(-XN+XX)*ZN/HV**3
      EQ2=SQA*XNO(I)*XKT(I)*0.88888889*EXP(-XO+XX)*ZO/HV**3
      EQ3=SQA*XNI(I)*XKT(I)*4.0*1.33*EXP(-XI+XX)*ZI/HV**3
      BQ5=XMOL*XNO2(I)*400.0*SQRT(TANH(0.0975/XKT(I)))*EXP(-TANH(0.195/(
     12.0*XKT(I)))*((HV-8.56)/0.805)**2)/2.687E+19
      BQ6=XMOL*XNN2(I)*1.2E-17*EXP(-ABS(HV-13.6+(1.0-0.603/XKT(I)))**1.3
     1)
      EQ4=EQ1*EXP(4.22/XKT(I)-XX)
      EQ5=EQ2*EXP(4.22/XKT(I)-XX)
      EQ7=EQ3*EXP(11.2/XKT(I)-XX)
      EQ9=EQ5+XNO(I)*3.6E-17/(9.0+5.0*EXP(-1.98/XKT(I))+EXP(-4.18/XKT(I)
     1))
      EPC=1.0-EXP(-XX)
      IF (HV-4.22) 1,1,2
1     XAPNU(L,I)=EPC*(EQ1+EQ2+EQ3)
      GO TO 17
2     IF (HV-10.8) 3,3,8
3     XAPNU(L,I)=EPC*(EQ4+EQ5+EQ3)
      IF (HV-7.0) 17,4,4
4     IF (HV-9.2) 5,5,6
5     XAPNU(L,I)=XAPNU(L,I)+BQ5+BQ7
      GO TO 17
6     IF (HV-10.0) 7,7,17
7     XAPNU(L,I)=XAPNU(L,I)+BQ7
```

```
      GO TO 17
 8    IF (HV-12.0) 9,9,11
 9    XAPNU(L,I)=EPC*(EQ4+XNN(I)*5.16E-17*EXP(-XN+10.8/XKT(I))/(4.0+10.0
     1*EXP(-2.38/XKT(I))+6.0*EXP(-3.57/XKT(I)))+EQ5+EQ7)
      IF (HV-11.0) 17,10,10
10    XAPNU(L,I)=XAPNU(L,I)+BQ6
      GO TO 17
11    IF (HV-13.4) 12,12,13
12    XAPNU(L,I)=EPC*(EQ4+(5.16E-17*XNN(I)*EXP(-XN+10.8/XKT(I))+XNN(I)*6
     1.4E-17*EXP(-XN+12.0/XKT(I)))/(4.0+10.0*EXP(-2.38/XKT(I))+6.0*EXP(-
     23.57/XKT(I)))+EQ5+EQ7)+BQ6
      GO TO 17
13    IF (HV-14.3) 14,14,16
14    XAPNU(L,I)=EPC*(EQ4+(5.16E-17*XNN(I)*EXP(-XN+10.8/XKT(I))+XNN(I)*6
     1.4E-17*EXP(-XN+12.0/XKT(I)))/(4.0+10.0*EXP(-2.38/XKT(I))+6.0*EXP(-
     23.57/XKT(I)))+EQ9+EQ7)
      IF (HV-14.2) 15,15,17
15    XAPNU(L,I)=XAPNU(L,I)+BQ6
      GO TO 17
16    XAPNU(L,I)=EPC*(EQ4+(5.16E-17*XNN(I)*EXP(-XN+10.8/XKT(I))+XNN(I)*6
     1.4E-17*EXP(-XN+12.0/XKT(I))+3.16E-17*XNN(I))/(4.0+10.0*EXP(-2.38/X
     2KT(I))+6.0*EXP(-3.57/XKT(I)))+EQ9+EQ7)
17    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE FEMP (IHELP,IOPT)
C
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(15),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      DIMENSION TGUS(15), DIG(15)
      DIMENSION FFF(3)
      IHELP=0
      W27=0.0
      DO 1 J=1,IS
1     W27=W27+ALP(J)*W26(J)
      IF (IOPT.EQ.1) GO TO 2
      HS=HS*W27
2     CONTINUE
      DO 8 I=1,N
      K=1
      DO 5 KS=1,IS
      IF (JAT(I,K)-KAT(KS)) 6,3,4
3     C(KS,I)=ALPT(I,K)
      K=K+1
      GO TO 5
4     C(KS,I)=0.0
5     CONTINUE
      GO TO 8
6     DO 7 LS=KS,IS
7     C(LS,I)=0.0
8     CONTINUE
```

```
      DO 13 I=1,N
      DO 11 J=1,2
      IF (KODE(I)-1) 9,9,10
9     CH(I,J)=RA(I,J)+RBO(I,J)
      GO TO 11
10    CH(I,J)=RA(I,J)
11    CONTINUE
      W3(I)=0.0
      DO 12 LS=1,IS
12    W3(I)=W3(I)+C(LS,I)*W26(LS)
13    CONTINUE
      IG=N
      IF (ION) 18,18,14
14    DO 15 I=1,IG
15    VNE(I)=0.0
      DO 17 I=2,IG
      DO 16 KS=2,IS
16    VNE(I)=VNE(I)+C(KS,I)*DEGI(KS)
17    VNE(I)=VNE(I)+C(1,I)*DEGI(1)
18    NP=N+1
      ISP=IS+1
      IGMS=IG-IS
      IGMSP=IGMS+1
      NG=0
      ISPNG=IS+NG
      ISPNGP=ISPNG+1
      ISPNG2=ISPNGP+1
      IGP=IG+1
      DO 19 I=1,N
19    JPH(I)=0
      DO 20 I=1,IS
      DO 20 K=1,IS
      J=IG-IS+K
20    A(K,I)=C(I,J)
      CALL INVERT (IS,A)
      DO 22 K=1,IGMS
      DO 22 J=1,IS
      VNU(K,J)=0.0
      DO 21 I=1,IS
21    VNU(K,J)=VNU(K,J)+A(I,J)*C(I,K)
22    CONTINUE
      DO 23 I=1,NP
23    VNT(I)=0.
```

```
      VN(NP)=AMAX1(VNT(NP),0.02)
      DO 24 I=1,N
      VN(I)=VNT(NP)*VNT(I)
   24 VN(I)=AMAX1(VN(I),1.0E-06)
      DO 27 I=1,IGMS
      DO 25 J=1,IS
   25 A12(I,J)=-VNU(I,J)
      DO 26 K=ISP,ISPNGP
   26 A12(I,K)=0.0
   27 CONTINUE
      DO 28 I=ISP,ISPNGP
      DO 28 J=ISP,ISPNGP
   28 A22(I,J)=0.0
      IA=1
      JA=1
      IX=1
   29 TBJA=TB(JA)
      CALL EQUIL (TBJA,PRESS,IX,N2P,.FALSE.)
      TB(JA)=TBJA
      IF (IX-1) 30,31,30
   30 WRITE (6,60) TBJA
   31 VA=0.0
      DO 32 I=1,N
   32 VA=VA+H(I)*VN(I)
      HSB=VA/VN(NP)
      GO TO (33,34), IOPT
   33 HS=HSB/W27
      FN SN 36
   34 FFF(JA)=HSB-HS
      TGUS(IA)=TBJA
      DIG(IA)=FFF(JA)
      IF (JA-2) 35,36,36
   35 JA=JA+1
      GO TO 29
   36 IF (ABS(FFF(2)/HS)-1.0E-04) 47,47,37
   37 IF (FFF(1)-FFF(2)) 38,39,38
   38 TP=TB(1)+(FFF(1)/(FFF(1)-FFF(2)))*(TB(2)-TB(1))
      GO TO 40
   39 TP=TB(1)
   40 IF (TP) 41,41,42
   41 TP=0.75*TB(1)
   42 FFF(1)=FFF(2)
      TB(1)=TB(2)
```

```
      TB(2)=TP
      IF (IA-10) 46,46,43
43    WRITE (6,61) HS,(TGUS(LK),DIG(LK),LK=1,IA)
      IMIN=1
      DO 45 IX=2,11
      IF (ABS(DIG(IX))-ABS(DIG(IMIN))) 44,44,45
44    IMIN=IX
45    CONTINUE
      TB(2)=TGUS(IMIN)
      GO TO 47
46    IA=IA+1
      GO TO 29
47    TB2=TB(2)
      CALL EQUIL (TB2,PRESS,IX,N2P,.TRUE.)
      TB(2)=TB2
      VA=0.0
      VB=0.0
      VC=0.0
      VD=0.0
      VE=0.0
      VF=1.0/TB(2)**2
      DO 57 I=1,N
      J=1
      IF (TU(I,1)-TB(2)) 48,49,49
48    J=2
49    IF (KODE(I)-1) 50,53,50
50    J=1
      IF (TU2(I,J)-TB(2)) 51,52,52
51    J=2
52    CP(I)=1.98726*(RD1(I,J)*TB(2)-2.0*RE1(I,J)*VF)
      GO TO 54
53    CP(I)=RC(I,J)+RD(I,J)*TB(2)+RE(I,J)*VF
54    VA=VA+CP(I)*VN(I)
      VC=VC+VN(I)
      IF (I-IG) 56,55,56
55    VB=VC
56    VG=VN(I)*W3(I)
57    VD=VD+VG
      WM=VD/(VB+VE/(82.0597*TB(2)))
      RHO=(PRESS*WM)/(82.0597*TB(2))
      VNT(NP)=VN(NP)
      DO 58 I=1,N
58    VNT(I)=VN(I)/VN(NP)
```

```
      SYU=0.0
      DO 59 M=1,N
      BMT(M)=(VNT(M)*W3(M))/W27
59    SYU=SYU+BMT(M)
      RETURN
C
C
60    FORMAT (21HON-R DID NOT CONVERGE,E15.5)
61    FORMAT (19HOT DID NOT CONVERGE,E15.5//(2E15.5))
      END
```

```
      SUBROUTINE DEFIOJ (N,IS,C,VN,JPH,IOJ)
      DIMENSION C(6,16), VN(17), JPH(16), IOJ(13), X(20), CT(20), V(16),
     1 TAU(7,7), P(20,20), IL(16), IPH(16)
      EQUIVALENCE (X,CT)
      LN=N
      LS=IS
      LNP=LN+1
      LSP=LS+1
      DO 1 I=1,LN
1     V(I)=VN(I)
      CALL ORDERV (LN,V,IPH)
      M=LN/2
      DO 2 J=1,M
      K=LN+1-J
      II=IPH(J)
      IPH(J)=IPH(K)
2     IPH(K)=II
      L=1
      DO 10 K=1,LN
      IND=IPH(K)
      IF (JPH(IND)) 3,3,10
3     DO 4 I=1,LS
4     TAU(L,I)=C(I,IND)
      DO 6 I=1,L
      TP=0.0
      DO 5 J=1,LS
5     TP=TP+TAU(I,J)*TAU(L,J)
      P(I,L)=TP
6     P(L,I)=TP
      DO 7 I=1,20
      CT(I)=0
7     CONTINUE
      CALL DTLNEQ (L,P,CT,X,DET)
      IF (ABS(DET)-1.0E-05) 10,10,8
8     IL(L)=IND
      IF (L-LS) 9,11,11
9     L=L+1
10    CONTINUE
11    CALL ORDERI (LS,IL)
      IOJ(LSP)=LNP
      DO 12 J=1,LS
12    IOJ(J)=IL(J)
      RETURN
      END
```

```
      SUBROUTINE ORDERI (N,IPH)
      DIMENSION IPH(16)
1     K=0
      DO 3 J=2,N
      IF (IPH(J-1)-IPH(J)) 3,3,2
2     IT=IPH(J-1)
      IPH(J-1)=IPH(J)
      IPH(J)=IT
      K=1
3     CONTINUE
      IF (K) 4,4,1
4     RETURN
      END
```

```
      SUBROUTINE ORDERV (N,V,IPH)
      DIMENSION V(16), IPH(16)
      LN=N
      DO 1 I=1,LN
1     IPH(I)=I
2     K=0
      DO 4 J=2,LN
      IF (V(J-1)-V(J)) 4,4,3
3     VT=V(J-1)
      V(J-1)=V(J)
      V(J)=VT
      IT=IPH(J-1)
      IPH(J-1)=IPH(J)
      IPH(J)=IT
      K=1
4     CONTINUE
      IF (K) 5,5,2
5     RETURN
      END
```

```
      SUBROUTINE INVERT (N,A)
      DIMENSION A(6,6), ZM(6,6), N7(6), N9(6)
      EQUIVALENCE (N9(1),N7(2))
      DO 3 I=1,N
      DO 3 J=1,N
      IF (I-J) 2,1,2
1     ZM(I,J)=1.0
      GO TO 3
2     ZM(I,J)=0.0
3     CONTINUE
      N7(1)=0
      DO 15 I=1,N
      Z3=0.0
      DO 6 J=1,N
      DO 4 K=1,I
      IF (J-N7(K)) 4,6,4
4     CONTINUE
      V=ABS(A(J,I))
      IF (V-Z3) 6,6,5
5     Z3=V
      N9(I)=J
      L=J
6     CONTINUE
      IF (Z3-1.0E-07) 7,7,8
7     Z3=1.0E-07
8     V=A(L,I)
      DO 10 J=1,N
      ZM(L,J)=ZM(L,J)/V
      IF (J-I) 10,10,9
9     A(L,J)=A(L,J)/V
10    CONTINUE
      DO 14 J=1,N
      IF (J-L) 11,14,11
11    V=-A(J,I)
      DO 13 K=1,N
      ZM(J,K)=ZM(J,K)+V*ZM(L,K)
      IF (K-I) 13,13,12
12    A(J,K)=A(J,K)+V*A(L,K)
13    CONTINUE
14    CONTINUE
15    CONTINUE
      DO 16 I=1,N
      J=N9(I)
      DO 16 K=1,N
16    A(I,K)=ZM(J,K)
      RETURN
      END
```

```
      SUBROUTINE EQUIL (TE,PR,IX,N2P,DOCB)
      LOGICAL DOCB
C
C
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(16),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      DIMENSION DMU(16), VLNK(16), STEP(17), EZ(17), AA(6), A21(7,17), A
     1T(20,20), B(20), IOJ(13), XB(20), XX(20), DY(17)
      EQUIVALENCE (XB,XX)
      KCBAL=0
      IF (DOCB) GO TO 54
      VA=ALOG(TE/3000.)
      VB=TE-3000.
      VC=(TE+3000.)/2.0
      VD=1.0/(TE*3000.)
      VE=VC*VD**2
      JC=1
      JD=1
      VF=0.0
      KERRSV=KERR
      KERR=1
      DO 1 I=1,IG
1     VF=VF+VN(I)
      IF (VF-PR) 2,4,2
2     VF=PR/VF
      DO 3 I=1,NP
```

```
3     VN(I)=VF*VN(I)
4     DO 5 I=1,IG
5     Y(I)=ALOG(VN(I))
      DO 14 I=1,N
      J=1
      IF (TE-TU(I,J)) 7,7,6
6     J=2
7     IF (KODE(I)-1) 8,8,9
8     H(I)=CH(I,J)+VB*(RC(I,J)+RD(I,J)*VC+RE(I,J)*VD)
      SD(I)=RF(I,J)+RC(I,J)*VA+VB*(RD(I,J)+RE(I,J)*VE)
      DMU(I)=H(I)-TE*SD(I)
      GO TO 14
9     J=1
      IF (TE-TU(I,J)) 11,11,10
10    J=2
11    DMU(I)=CH(I,J)-1.98726*(RC(I,J)*TE+RD(I,J)*TE**2+RE(I,J)/TE)
      J=1
      IF (TE-TU2(I,J)) 13,13,12
12    J=2
13    SD(I)=1.98726*(RC1(I,J)+RD1(I,J)*TE+RE1(I,J)/TE**2)
      H(I)=DMU(I)+TE*SD(I)
14    CONTINUE
      VA=-1.0/(1.98726*TE)
      DO 16 I=1,IGMS
      VB=0.0
      DO 15 LS=1,IS
      J=IGMS+LS
15    VB=VB+VNU(I,LS)*DMU(J)
16    VLNK(I)=VA*(DMU(I)-VB)
      CALL DEFIOJ (N,IS,C,VN,JPH,IOJ)
      CALL MASBAL (VN,IOJ,C,ALP,JC,0.9,IS,N,PR,IG)
17    EL=0.0
      ENL=0.0
      DO 18 I=1,NP
18    STEP(I)=1.0
      DO 19 I=1,IG
19    Y(I)=ALOG(VN(I))
      DO 23 I=1,IGMS
      VA=0.0
      DO 20 LS=1,IS
      J=IGMS+LS
20    VA=VA+VNU(I,LS)*Y(J)
      EZ(I)=VLNK(I)-Y(I)+VA
```

```
      A12(I,ISPNG2)=EZ(I)
      IF (VN(I)-1.0E-30) 21,21,22
21    STEP(I)=0.0
      EL=AMAX1(EL,EZ(I))
      GO TO 23
22    EL=AMAX1(EL,ABS(EZ(I)))
23    CONTINUE
      DO 24 I=1,IS
      AA(I)=0.0
      DO 24 J=1,IGMS
      A21(I,J)=C(I,J)*VN(J)
24    AA(I)=AA(I)+A21(I,J)
      DO 25 J=1,IGMS
25    A21(ISPNGP,J)=VN(J)
      DO 26 I=1,IS
      DO 26 J=1,ISPNG
      K=IGMS+J
      A22(I,J)=C(I,K)*VN(K)
26    AA(I)=AA(I)+A22(I,J)
      DO 27 J=1,IS
      K=IGMS+J
27    A22(ISPNGP,J)=VN(K)
      DO 28 I=1,IS
      A22(I,ISPNGP)=-AA(I)
      VA=(VN(NP)*ALP(I))/AA(I)
      K=IGMS+I
      EZ(K)=ALOG(VA)
      A22(I,ISPNG2)=AA(I)*EZ(K)
      ENL=AMAX1(ENL,ABS(EZ(K)))
28    CONTINUE
      PB=0.0
      DO 29 I=1,IG
29    PB=PB+VN(I)
      EZ(NP)=ALOG(PR/PB)
      A22(ISPNGP,ISPNG2)=PB*EZ(NP)
      ENL=AMAX1(ENL,ABS(EZ(NP)))
      IF (AMAX1(EL,ENL)-1.0E-05) 54,54,30
30    DO 32 I=1,ISPNGP
      DO 32 K=1,ISPNGP
      VA=0.0
      DO 31 J=1,IGMS
31    VA=VA+A21(I,J)*A12(J,K)*STEP(J)
32    AT(I,K)=A22(I,K)-VA
```

```
      DO 34 I=1,ISPNGP
      VA=0.0
      DO 33 J=1,IGMS
   33 VA=VA+A21(I,J)*A12(J,ISPNG2)
   34 B(I)=A22(I,ISPNG2)-VA
      CALL DTLNEQ (ISPNGP,AT,B,XB,VA)
      XX(ISPNG2)=-1.
      VB=0.0
      DO 37 I=1,ISPNGP
      J=IGMS+I
      DY(J)=XX(I)
      IF (I-IS) 36,36,35
   35 IF (STEP(J)) 37,37,36
   36 VB=AMAX1(VB,ABS(XX(I)))
   37 CONTINUE
      DO 41 I=1,IGMS
      VA=0.0
      DO 38 J=1,ISPNG2
   38 VA=VA+A12(I,J)*XX(J)
      DY(I)=-VA
      IF (STEP(I)) 39,39,40
   39 DY(I)=A12(I,ISPNG2)
      GO TO 41
   40 VB=AMAX1(ABS(VA),VB)
   41 CONTINUE
      IF (VB-2.3052) 44,44,42
   42 VA=2.3052/VB
      DO 43 I=1,NP
   43 DY(I)=VA*DY(I)
   44 DO 45 I=1,IG
      VN(I)=AMAX1(VN(I)*EXP(DY(I)),1.0E-30)
   45 CONTINUE
      DO 46 I=IGP,NP
   46 VN(I)=AMAX1(VN(I)*EXP(DY(I)),5.0E-10)
      IF (JC-50) 48,48,47
   47 IX=2
      RETURN
   48 IF (JD-3) 50,49,49
   49 CALL DEFIOJ (N,IS,C,VN,JPH,IOJ)
      JD=1
      GO TO 51
   50 JD=JD+1
   51 IF ((1.111*ENL)-EL) 53,52,52
```

```
52    CALL MASBAL (VN,IOJ,C,ALP,JC,0.9,IS,N,PR,IG)
53    JC=JC+1
      GO TO 17
54    IF (.NOT.DOCB) RETURN
      IF (ION.EQ.0.OR.IX.EQ.2) RETURN
      VNSAVE=0.0
      DO 55 M=2,N
55    VNSAVE=VNSAVE+VN(M)*VNE(M)
      CHGERR=VNSAVE/VN(1)-1.0
      IF (ABS(CHGERR)-1.0E-04) 56,56,57
56    RETURN
57    KCBAL=KCBAL+1
      IF (KCBAL.GT.3) RETURN
      CALL CHGBAL (TE,PR,KRAP,DMU)
      IF (KRAP.EQ.2) RETURN
      JC=1
      GO TO 17
      END
```

```
      SUBROUTINE CHGBAL (TE,PR,KRAP,DMU)
      REAL KSUBP,LOGKP
      DIMENSION ALPTC(16,7), JATC(16,7), DMUCI(16), VNECB(16), VNMN(16),
     1 DMUCN(16), KSUBP(16), AK(10), INDEX(16), VNOLD(16), DMU(16)
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(16),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      PB=0.0
      DO 1 I=1,IG
    1 PB=PB+VN(I)
      J=1
      DO 4 I=2,IG
      IF (ABS(VNE(I))-1.0E-20) 4,4,2
    2 DO 3 K=1,5
      ALPTC(J,K)=ALPT(I,K)
    3 JATC(J,K)=JAT(I,K)
      DMUCI(J)=DMU(I)
      VNECB(J)=VNE(I)
      INDEX(J)=I
      J=J+1
    4 CONTINUE
      NOION=J-1
      DO 5 J=1,NOION
    5 DMUCN(J)=0.0
      DO 9 I=2,IG
      IF (ABS(VNE(I))-1.0E-20) 6,6,9
    6 DO 8 J=1,NOION
```

```
      JIN=1
      JNU=1
      IF (JAT(I,1).EQ.0) JNU=2
      IF (JATC(J,1).EQ.0) JIN=2
7     DIFF=ABS(ALPT(I,JNU)-ALPTC(J,JIN))
      IF ((JAT(I,JNU).NE.JATC(J,JIN)).OR.(DIFF.GT.1.0E-20)) GO TO 8
      JNU=JNU+1
      JIN=JIN+1
      IF (MAX0(JNU,JIN).LT.6) GO TO 7
      VNMN(J)=VN(I)
      DMUCN(J)=DMU(I)
8     CONTINUE
9     CONTINUE
      MISING=0
      DO 10 J=1,NOION
      IF (ABS(DMUCN(J)).GT.1.0E-10) GO TO 10
      MISING=MISING+1
      I=INDEX(J)
10    CONTINUE
      IF (MISING.EQ.0) GO TO 11
      CALL DUMP
11    RTR=-1.0/(TE*1.98726)
      DO 12 J=1,NOION
      LOGKP=RTR*(DMUCI(J)-DMUCN(J)+VNECB(J)*DMU(1))
      KSUBP(J)=EXP(LOGKP)
12    I=INDEX(J)
      DO 15 KK=1,5
      AK(KK)=0.0
      DO 14 J=1,NOION
      KVNECB=IFIX(VNECB(J)+0.001)
      IF (VNECB(J).LT.0.0) KVNECB=IFIX(VNECB(J)-0.001)
      IF ((KK-3)+KVNECB) 14,13,14
13    AK(KK)=AK(KK)+VNECB(J)*KSUBP(J)*VNMN(J)
14    CONTINUE
15    CONTINUE
      AK(4)=AK(4)-1.0
      XNEW=ABS(VN(1))
      KRUDD=1
16    DO 18 LL=1,50
      L=LL
      FOFX=0.0
      FPOFX=0.0
      X=XNEW
```

```
      DO 17 KK=1,5
      VKK=KK-3
      TEST1=VKK*ALOG(X)
      TEST2=(VKK-1.0)*ALOG(X)
      TERM1=1.0E+36
      TERM2=1.0E+36
      IF (TEST1.LT.83.0) TERM1=X**VKK
      IF (TEST2.LT.83.0) TERM2=X**(VKK-1.0)
      FOFX=FOFX+AK(KK)*TERM1
17    FPOFX=FPOFX+VKK*AK(KK)*TERM2
      XNEW=X-(FOFX/FPOFX)
      IF (XNEW.LT.0.0) XNEW=X/2.0
      ERROR=1.0-XNEW/X
      IF (ABS(ERROR)-1.0E-06) 20,20,18
18    CONTINUE
19    KRAP=2
      RETURN
20    IF (XNEW) 21,22,22
21    XNEW=ABS(XNEW)
      KRUDD=KRUDD+1
      IF (KRUDD.GT.2) GO TO 19
      GO TO 16
22    X=XNEW
      VN(1)=X
      DO 23 J=1,NOION
      I=INDEX(J)
      VNOLD(I)=VN(I)
      VN(I)=KSUBP(J)*VNMN(J)*X**(-VNECB(J))
23    VN(I)=AMAX1(VN(I),9.999E-30)
      KRAP=1
      RETURN
      END
```

```
      SUBROUTINE ZHV (HV,ZO,ZN,ZI,ZC)
      X=HV
      IF (HV-9.82) 1,1,2
1     ZO=0.99997956-0.31554804*X+2.8245479E-02*X**2+6.6773283E-03*X**3-3
     1.6445854E-03*X**4+8.0580698E-04*X**5-7.7086374E-05*X**6+2.668133E-
     206*X**7
      GO TO 3
2     ZO=(X/9.82)**3
3     IF (HV-8.35) 4,4,5
4     ZN=1.000148-0.41835346*X+0.16803591*X**2-9.7794579E-02*X**3+3.3546
     1351E-02*X**4-5.6093534E-03*X**5+4.515535E-04*X**6-1.4035845E-05*X*
     2*7
      GO TO 6
5     ZN=(X/8.35)**3
6     X=HV/4.0
      IF (X-6.6) 7,7,8
7     ZI=1.0003794-0.29647668*X+7.5052416E-02*X**2-1.7029481E-02*X**3+3.
     12795539E-03*X**4-2.1284692E-04*X**5
      GO TO 9
8     ZI=(X/7.37)**3
9     X=HV
      IF (X-7.37) 10,10,11
10    ZC=0.99743674-0.43418122*X+8.5313141E-02*X**2-1.3939168E-02*X**3+4
     1.0385449E-03*X**4-5.4264246E-04*X**5+2.8121261E-05*X**6-3.8835298E
     2-07*X**7
      GO TO 12
11    ZC=(X/7.37)**3
12    RETURN
      END
```

```
      SUBROUTINE LTP (ITSW)
C
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(16),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      ALP(1)=5.5
      ALP(2)=1.4375
      ITSW=1
      ION=0
      IS=2
      N=4
      W26(1)=14.008
      W26(2)=16.0
      KAT(1)=7
      KAT(2)=8
      DEGI(1)=0.0
      DEGI(2)=0.0
      KODE(1)=1
      DO 1 J=2,4
1     KODE(J)=2
      DO 2 J=1,4
      DO 2 K=1,5
      ALPT(J,K)=0.0
2     JAT(J,K)=0
      ALPT(1,1)=2.0
      JAT(1,1)=8
      ALPT(2,1)=1.0
```

```
JAT(2,1)=7
ALPT(3,1)=1.0
JAT(3,1)=8
ALPT(4,1)=2.0
JAT(4,1)=7
RA(1,1)=0.0
RBO(1,1)=2.55197E+04
RC(1,1)=8.12927
RD(1,1)=4.85368E-04
RE(1,1)=-2.75743E+05
RF(1,1)=67.9798
TU(1,1)=3000.
RA(1,2)=0.0
RBO(1,2)=2.55239E+04
RC(1,2)=10.2348
RD(1,2)=4.5738E-05
RE(1,2)=-7.73465E+06
RF(1,2)=67.9813
TU(1,2)=6000.
RA(2,1)=0.1125E+06
RC(2,1)=19.8515
RD(2,1)=0.650822E-03
RE(2,1)=-0.156336E+07
TU(2,1)=5000.
RA(2,2)=0.1125E+06
RC(2,2)=23.2779
RD(2,2)=0.190986E-03
RE(2,2)=-0.331003E+08
TU(2,2)=24000.
RC1(2,1)=22.4633
RD1(2,1)=0.622485E-03
RE1(2,1)=-0.165345E+07
TU2(2,1)=6000.
RC1(2,2)=26.0356
RD1(2,2)=0.229541E-03
RE1(2,2)=-0.501696E+08
TU2(2,2)=24000.
RA(3,1)=0.58985E+05
RC(3,1)=20.8169
RD(3,1)=0.655447E-03
RE(3,1)=-0.162744E+07
TU(3,1)=5000.
RA(3,2)=0.58985E+05
```

```
      RC(3,2)=24.5103
      RD(3,2)=0.158277E-03
      RE(3,2)=-0.351471E+08
      TU(3,2)=24000.
      RC1(3,1)=23.3381
      RD1(3,1)=0.659562E-03
      RE1(3,1)=-0.155587E+07
      TU2(3,1)=5000.
      RC1(3,2)=26.8167
      RD1(3,2)=0.186999E-03
      RE1(3,2)=-0.322302E+08
      TU2(3,2)=24000.
      RA(4,1)=0.0
      RC(4,1)=24.9173
      RD(4,1)=1.08123E-03
      RE(4,1)=-2.21576E+06
      TU(4,1)=5000.
      RA(4,2)=0.0
      RC(4,2)=30.6229
      RD(4,2)=3.01129E-04
      RE(4,2)=-5.19808E+07
      TU(4,2)=24000.
      RC1(4,1)=28.2374
      RD1(4,1)=1.32899E-03
      RE1(4,1)=-2.1492E+06
      TU2(4,1)=4000.
      RC1(4,2)=33.5174
      RD1(4,2)=4.39119E-04
      RE1(4,2)=-3.14737E+07
      TU2(4,2)=24000.
      RETURN
      END
```

```
      SUBROUTINE HAFACE (IFL,D1,D2)
      DIMENSION ALOWER(40), TABLE(1), ALINIT(40), X1STEP(40), XNU(40), X
     1NUBAR(40), SAVE(40), XSTAR(40), DX(40), DELT(40)
      IF (IFL.EQ.2) GO TO 1
      ARG5=D1
      TF=D2
      NORD=1
      NRTAB=0
      DTP=(TF-ARG5)*.1
      HMIN=DTP*.02
      ARG4=DTP*.1
      HMAX=DTP
      RMAX=1.E-5
      TP=ARG5
      ALINIT(1)=0.
      RETURN
1     CALL INOCAL (XNU,ALINIT,-1.,ARG5,NTAB)
      NTAB=1
      SENS=0.
      GO TO 36
2     SENSR=0.
3     IF (TF-ARG5) 44,4,4
4     DO 5 I=1,NORD
      ALOWER(I)=ALINIT(I)
      SAVE(I)=ALINIT(I)
5     XNUBAR(I)=ALINIT(I)
      ARG7=ARG4/2.0
      ARG8=ARG7/2.0
      ARG6=ARG4
      SW3=-1.
      ARG9=ARG5
      ARG10=ARG6
      ARG11=ARG7
6     CALL INOCAL (XSTAR,XNUBAR,0.0,ARG9,NTAB)
      DO 7 I=1,NORD
      DX(I)=XSTAR(I)*ARG10
7     XNUBAR(I)=XNUBAR(I)+(DX(I)/2.0)
      ARG9=ARG9+ARG11
      CALL INOCAL (XSTAR,XNUBAR,0.0,ARG9,NTAB)
      DO 8 I=1,NORD
      TEMP=XSTAR(I)*ARG10
      DX(I)=DX(I)+(TEMP*2.0)
```

```
8     XNUBAR(I)=SAVE(I)+(TEMP/2.0)
      CALL INOCAL (XSTAR,XNUBAR,0.0,ARG9,NTAB)
      DO 9 I=1,NORD
      TEMP=XSTAR(I)*ARG10
      DX(I)=DX(I)+(TEMP*2.0)
9     XNUBAR(I)=TEMP+SAVE(I)
      ARG9=ARG9+ARG11
      CALL INOCAL (XSTAR,XNUBAR,0.0,ARG9,NTAB)
      DO 10 I=1,NORD
10    XSTAR(I)=(((XSTAR(I)*ARG10)+DX(I))/6.0)+SAVE(I)
      IF (SW3) 11,13,15
11    SW3=0.0
      ARG9=ARG5
      ARG10=ARG7
      ARG11=ARG8
      DO 12 I=1,NORD
      XNUBAR(I)=SAVE(I)
12    X1STEP(I)=XSTAR(I)
      GO TO 6
13    SW3=1.0
      ARG9=ARG5+ARG7
      DO 14 I=1,NORD
      XNUBAR(I)=XSTAR(I)
14    SAVE(I)=XNUBAR(I)
      GO TO 6
15    DO 16 I=1,NORD
      DELT(I)=(XSTAR(I)-X1STEP(I))/15.0
      XNU(I)=XSTAR(I)+DELT(I)
16    ALOWER(I)=XNU(I)
      QMAX=0.
      DO 25 I=1,NORD
      IF (ABS(XNU(I))-1.0) 17,18,18
17    QUO=ABS(DELT(I))
      GO TO 19
18    QUO=ABS(DELT(I)/XNU(I))
19    IF (QMAX-QUO) 20,20,21
20    QMAX=QUO
21    IF (RMAX-QUO) 22,22,25
22    IF (SENS) 24,23,24
23    ARG4=ARG4/2.0
      IF (ARG4-HMIN) 43,43,2
24    QMAX=RMAX
25    CONTINUE
```

```
      DO 26 I=1,NORD
26    ALINIT(I)=ALOWER(I)
      ARG5=ARG5+ARG4
      IF (TP-ARG5) 31,31,27
27    IF (SENSR) 28,40,28
28    IF (TABLE(NTAB)+DTP-TP) 30,30,29
29    TP=TABLE(NTAB)+DTP
30    GO TO 32
31    TP=TP+DTP
32    CALL INOCAL (XSTAR,XNU,0.0,ARG9,NTAB)
      SUB=1.0
      CALL INOCAL (XSTAR,XNU,SUB,ARG9,NTAB)
      IF (SUB-15.0) 40,44,40
33    ARG4=HMAX
34    IF (SENSR) 35,36,35
35    NTAB=NTAB+1
36    IF (NTAB-NRTAB) 37,37,2
37    IF (TABLE(NTAB)-ARG5-ARG4) 38,39,2
38    ARG4=TABLE(NTAB)-ARG5
39    SENSR=1.
      GO TO 3
40    IF (QMAX) 33,33,41
41    ARG4=SQRT(SQRT(RMAX/QMAX))*ARG4
      IF (HMAX-ARG4) 33,42,42
42    SENS=0.
      GO TO 34
43    ARG4=HMIN
      SENS=1.
      GO TO 3
44    RETURN
      END
```

```
      SUBROUTINE DTLNEQ (N,A,C,X,DET)
      DIMENSION A(20,20), C(20), X(20), AL(20,20), CL(20), M(20)
      DET=0.0
      DO 2 I=1,N
      CL(I)=C(I)
      DO 1 J=1,N
1     AL(I,J)=A(I,J)
2     CONTINUE
      IR=0
      PRD=1.0
      ALT=1.0
      DO 15 J=1,N
      ALTA=-ALT
      BIG=0.0
      DO 8 I=1,N
      IRHO=1
      IF (IR) 21,6,4
3     IRHO=IRHO+1
4     IF (I-M(IRHO)) 5,8,5
5     IF (IR-IRHO) 21,6,3
6     ALTA=-ALTA
      V=ABS(AL(I,J))
      IF (V-BIG) 8,8,7
7     BIG=V
      ALT=ALTA
      M(IR+1)=I
8     CONTINUE
      IF (BIG) 21,21,9
9     I=M(IR+1)
      PRD=PRD*AL(I,J)
      CL(I)=CL(I)/AL(I,J)
      IF (J-N) 10,16,21
10    L=J+1
      DO 11 K=L,N
11    AL(I,K)=AL(I,K)/AL(I,J)
      IR=IR+1
      DO 14 IU=1,N
      DO 12 IRHO=1,IR
      IF (IU-M(IRHO)) 12,14,12
12    CONTINUE
      DO 13 K=L,N
13    AL(IU,K)=AL(IU,K)-AL(IU,J)*AL(I,K)
```

```
      CL(IU)=CL(IU)-AL(IU,J)*CL(I)
14    CONTINUE
15    CONTINUE
      GO TO 21
16    DET=ALT*PRD
      I=M(N)
      X(N)=CL(I)
17    IF (J-1) 20,21,18
18    L=J
      J=J-1
      I=M(J)
      X(J)=CL(I)
      DO 19 K=L,N
19    X(J)=X(J)-AL(I,K)*X(K)
      GO TO 17
20    DET=0.0
21    RETURN
      END
```

```
      SUBROUTINE HTP (ITSW)
C
C
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(15),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      ALP(1)=6.9375
      ALP(2)=5.5
      ALP(3)=1.4375
      ITSW=2
      ION=1
      IS=3
      N=6
      W26(1)=0.54862E-03
      W26(2)=14.007451
      W26(3)=15.999451
      KAT(1)=0
      KAT(2)=7
      KAT(3)=8
      DEGI(1)=-1.0
      DEGI(2)=1.0
      DEGI(3)=1.0
      DO 1 J=1,6
1     KODE(J)=2
      DO 2 J=1,6
      DO 2 K=1,5
      ALPT(J,K)=0.0
```

```
2     JAT(J,K)=0
      ALPT(1,1)=1.0
      ALPT(2,1)=2.0
      ALPT(2,2)=2.0
      JAT(2,2)=7
      ALPT(3,1)=1.0
      JAT(3,1)=8
      ALPT(4,1)=1.0
      ALPT(4,2)=1.0
      JAT(4,2)=8
      ALPT(5,1)=1.0
      JAT(5,1)=7
      ALPT(6,1)=1.0
      ALPT(6,2)=1.0
      JAT(6,2)=7
      RA(1,1)=0.0
      RC(1,1)=3.9483
      RD(1,1)=6.46872E-04
      RE(1,1)=-1.57124E+06
      TU(1,1)=5000.
      RA(1,2)=0.0
      RC(1,2)=7.71015
      RD(1,2)=1.42221E-04
      RE(1,2)=-3.59273E+07
      TU(1,2)=24000.
      RC1(1,1)=6.4483
      RD1(1,1)=6.46871E-04
      RE1(1,1)=-1.57124E+06
      TU2(1,1)=5000.
      RC1(1,2)=10.2102
      RD1(1,2)=1.42221E-04
      RE1(1,2)=-3.59274E+07
      TU2(1,2)=24000.
      RA(2,1)=0.0
      RC(2,1)=24.9173
      RD(2,1)=1.08123E-03
      RE(2,1)=-2.21576E+06
      TU(2,1)=5000.
      RA(2,2)=0.0
      RC(2,2)=30.6229
      RD(2,2)=3.01129E-04
      RE(2,2)=-5.19808E+07
      TU(2,2)=24000.
```

```
      RC1(2,1)=28.2374                                                  AF   86
      RD1(2,1)=1.32899E-03                                              AF   87
      RE1(2,1)=-2.1492E+06                                              AF   88
      TU2(2,1)=4000.                                                    AF   89
      RC1(2,2)=33.5174                                                  AF   90
      RD1(2,2)=4.39119E-04                                              AF   91
      RE1(2,2)=-3.14737E+07                                             AF   92
      TU2(2,2)=24000.                                                   AF   93
      RA(3,1)=3.73033E+05                                               AF   94
      RC(3,1)=20.0611                                                   AF   95
      RD(3,1)=6.47307E-04                                               AF   96
      RE(3,1)=-1.57026E+06                                              AF   97
      TU(3,1)=5000.                                                     AF   98
      RA(3,2)=3.73033E+05                                               AF   99
      RC(3,2)=23.5272                                                   AF  100
      RD(3,2)=1.7478E-04                                                AF  101
      RE(3,2)=-3.23627E+07                                              AF  102
      TU(3,2)=24000.                                                    AF  103
      RC1(3,1)=22.7653                                                  AF  104
      RD1(3,1)=5.88991E-04                                              AF  105
      RE1(3,1)=-1.72548E+06                                             AF  106
      TU2(3,1)=6000.                                                    AF  107
      RC1(3,2)=26.3126                                                  AF  108
      RD1(3,2)=1.93706E-04                                              AF  109
      RE1(3,2)=-5.03986E+07                                             AF  110
      TU2(3,2)=24000.                                                   AF  111
      RA(4,1)=0.58985E+05                                               AF  112
      RC(4,1)=20.8169                                                   AF  113
      RD(4,1)=0.655447E-03                                              AF  114
      RE(4,1)=-0.162744E+07                                             AF  115
      TU(4,1)=5000.                                                     AF  116
      RA(4,2)=0.58985E+05                                               AF  117
      RC(4,2)=24.5103                                                   AF  118
      RD(4,2)=0.158277E-03                                              AF  119
      RE(4,2)=-0.351471E+08                                             AF  120
      TU(4,2)=24000.                                                    AF  121
      RC1(4,1)=23.3381                                                  AF  122
      RD1(4,1)=0.659562E-03                                             AF  123
      RE1(4,1)=-0.155587E+07                                            AF  124
      TU2(4,1)=5000.                                                    AF  125
      RC1(4,2)=26.8167                                                  AF  126
      RD1(4,2)=0.186999E-03                                             AF  127
      RE1(4,2)=-0.322302E+08                                            AF  128
```

```
      TU2(4,2)=24000.
      RA(5,1)=4.48051E+05
      RC(5,1)=20.609
      RD(5,1)=6.56764E-04
      RE(5,1)=-1.64226E+06
      TU(5,1)=5000.
      RA(5,2)=4.48051E+05
      RC(5,2)=24.346
      RD(5,2)=1.56145E-04
      RE(5,2)=-3.5928E+07
      TU(5,2)=24000.
      RC1(5,1)=23.3481
      RD1(5,1)=5.99657E-04
      RE1(5,1)=-1.70972E+06
      TU2(5,1)=6000.
      RC1(5,2)=27.2144
      RD1(5,2)=1.53048E-04
      RE1(5,2)=-4.98219E+07
      TU2(5,2)=24000.
      RA(6,1)=0.1125E+06
      RC(6,1)=19.8515
      RD(6,1)=0.650822E-03
      RE(6,1)=-0.156336E+07
      TU(6,1)=5000.
      RA(6,2)=0.1125E+06
      RC(6,2)=23.2779
      RD(6,2)=0.190986E-03
      RE(6,2)=-0.331003E+08
      TU(6,2)=24000.
      RC1(6,1)=22.4633
      RD1(6,1)=0.622485E-03
      RE1(6,1)=-0.165345E+07
      TU2(6,1)=6000.
      RC1(6,2)=26.0356
      RD1(6,2)=0.229541E-03
      RE1(6,2)=-0.501696E+08
      TU2(6,2)=24000.
      RETURN
      END
```

```
      SUBROUTINE TRAP1 (N,X,Y,C,ANS)
      DIMENSION X(1), Y(1)
      ANS=0.
      DO 1 I=2,N
      DX=X(I)-X(I-1)
1     ANS=ANS+.5*DX*(Y(I)+Y(I-1))
      ANS=C*ANS
      RETURN
      END
```

```
FUNCTION FLUT (A,B,C)
XN=A/B
R=(C/.00129)*29.
FLUT=2.69E19*XN*R
RETURN
END
```

```
      SUBROUTINE INOCAL (DX,X,S,T,L)
      DIMENSION DX(1), X(1)
C
C
      COMMON /AAA/ A(6,6),A12(16,12),A22(7,7),ALP(6),ALPT(16,5),BMT(16),
     1C(6,16),CH(16,2),CP(16),DEGI(6),H(16),JAT(16,5),JPH(16),KAT(6),KOD
     2E(16),RA(16,2),RBO(16,2),RC(16,2),RD(16,2),RD1(16,2),RE(16,2),RE1(
     316,2),SD(16),TB(3),TU(16,2),TU2(16,2),VN(17),VNE(16),VNT(17),VNU(1
     46,6),W26(6),W3(16),Y(16),RF(16,2),RC1(16,2),HS,IG,IGMS,IGMSP,IGP,I
     5ON,IS,ISP,ISPNGP,ISPNG2,N,NG,NP,PRESS,W27,RHO,WM,SYU,ISPNG
      COMMON /RAD/ YY(100),TEE(100),FHV(20),NHV,NY,C2,IY
      COMMON /RAD/ XNN(7,100)
      COMMON /RAD/ NIHVC,FHVC(50),AHV(50),AHVL(20)
      COMMON /RAD/ C1,C3,C4,FLG,C5,FLG1
      COMMON /RAD/ YDELT,DELTD,FL1,FL2
      COMMON /RAD/ GEE(8),EPS(8),NU(20),ND(70),FF(70),GAMP(70),WOL(20),F
     1HVM(20),FHVP(20)
      COMMON /CIONCL/ F(100,10),F2(100,10),HVL(70),EP,K2,K1,IFL,IYCON,IQ
     11,WMI,BIJ(100,10),GMIN(100,10),GPLU(100,10),IAED
      DIMENSION NICN(100)
      DIMENSION PRES(100)
      DIMENSION HH(100)
      IF (S) 10,1,9
1     SUM=0.
      DO 5 I=K1,K2
      J=I-K1+1
      IF (F(IQ1,J).EQ.0.) GO TO 5
      GO TO (2,3), IAED
2     EP=GMIN(IQ1,J)
      GO TO 4
3     EP=GPLU(IQ1,J)
4     CONTINUE
      E=1./((T-HVL(I))**2+EP*EP)
      E=E*1.17E-29
      SUM=SUM+E*(F2(IQ1,J)-F2(IY,J))*FLOAT(IFL)/3.14159
5     CONTINUE
      IF (SUM-88.0) 6,6,7
6     DX=1.0-EXP(SUM)
      GO TO 8
7     DX=1.0
8     WMI=X
      RETURN
9     CONTINUE
10    RETURN
      END
```

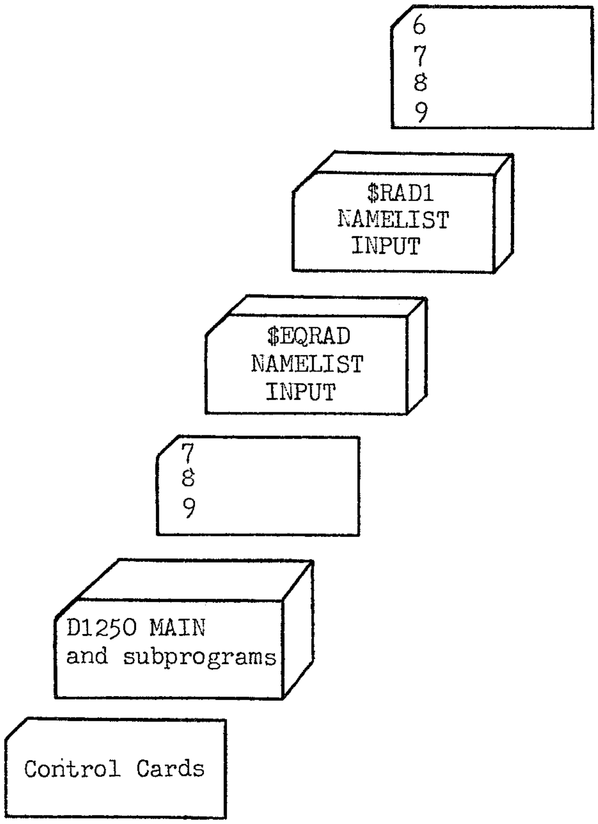
```
      SUBROUTINE TRAP (N,X,Y,C,ANS)
      DIMENSION ANS(1), X(1), Y(1)
      ANS(1)=0.
      DO 1 I=2,N
      DX=X(I)-X(I-1)
1     ANS(I)=ANS(I-1)+.5*DX*(Y(I)+Y(I-1))*C
      RETURN
      END
```

```
      SUBROUTINE MASBAL (VN,IB,C,ALP,IRHO,BD,IS,N,PR,IG)
      DIMENSION VN(17), IB(13), C(6,16), ALP(6), A(20,20), B(20), X(20)
      NP=N+1
      ISP=IS+1
      DO 2 LS=1,IS
      B(LS)=VN(NP)*ALP(LS)
      J=1
      DO 2 I=1,N
      B(LS)=B(LS)-C(LS,I)*VN(I)
      IF (I-IB(J)) 2,1,2
1     A(LS,J)=C(LS,I)
      J=J+1
2     CONTINUE
      DO 3 J=1,ISP
3     A(ISP,J)=0.0
      DO 4 LS=1,IS
4     A(LS,ISP)=-ALP(LS)
      B(ISP)=PR
      DO 5 I=1,IG
5     B(ISP)=B(ISP)-VN(I)
      J=0
      DO 7 I=1,IS
      IF (IB(I)-IG) 6,6,7
6     J=J+1
7     CONTINUE
      DO 8 I=1,J
8     A(ISP,I)=1.0
      CALL DTLNEQ (ISP,A,B,X,V)
      J=1
      G=1.0
      DO 13 I=1,NP
      IF (I-IB(J)) 13,9,13
9     V=BD*VN(I)
      W=ABS(X(J))
      IF (W-V) 12,12,10
10    IF (V/W-G) 11,12,12
11    G=V/W
12    J=J+1
13    CONTINUE
      J=1
      DO 15 I=1,NP
      IF (I-IB(J)) 15,14,15
14    VN(I)=VN(I)+G*X(J)
      J=J+1
15    CONTINUE
      RETURN
      END
```

USAGE

Program Information and Deck Configuration

The program D1250 was written in the FORTRAN IV language for the Control Data 6600 computer system under the Scope 3.2 operating system. The program requires a field length of 110 000 octal locations; the computing time depends primarily on the accuracy of the initial δ_o and the number of iterations desired, KETEST. The following sketch shows the deck configuration needed for execution:



For the sample case ($U'_\infty = 15.24 \times 10^5$ cm/sec (50 000 ft/sec), and altitude of 60.96 km (200 000 ft), and KETEST = 12), the run time was 18.21 minutes. The results of a similar case are discussed in reference 3.

Input Description

The input is loaded by using the FORTRAN IV NAMELIST. The input symbols are as follows with typical values given in parentheses:

$EQRAD

ALT altitude for AT62

AOVERB ratio of semiminor axis to semimajor axis of an ellipse

CCI initial computing interval for INT1 (0.05)

CII initial linear integration step away from singular point of stagnation streamline; used in FIRST (0.05)

CIMAX absolute value of maximum computing interval in INT1

DELTX an increment used in ITR1 so that $\frac{f(x + DELTX) - f(x)}{DELTX}$ is a reasonable approximation to derivative of f(x) (-1.E-3)

DUMBTIM initial guess for standoff distance = $\frac{DUMBTIM}{RHO1}$ (0.78 for sphere)

EELE1 array of relative error for dependent variables used by INT1 (1.E-3)

EELE2 array of relative zero for dependent variables used by INT1 (1.E-4)

EELT array of NT values to return to the program from INT1 at specific values (NT is computed in CONT)

EITR1 relative error criterion for ITR1 (1.E-4)

EITR2 absolute error criterion for ITR1 (1.E-4)

EMUREF molecular weight of cold air, g/mole (28.967)

EPSR accuracy criterion for R_1 iteration in MAIN (0.01)

EPS21 accuracy criterion used in PROPIT for RHO iteration (1.E-3)

IALT option for atmosphere routine:

= 1 call AT62 and input ALT

≠ 1 input PIN, RHOIN

IGEO test in GEO:

1 sphere geometry

2 ellipsoid geometry

3 hyperboloid geometry

ITEXT	time history print option for INT1; if equal to 0, no printout is requested; if equal to 1, a printout is requested
ITTEST	iteration limit in PROPIT (500)
KETEST	number of iterations desired on DELTN (10)
KKKK	radiation option: 0 do not compute radiation; 1 adiabatic radiation; 2 nonadiabatic radiation
PEEP	coefficient in equation describing pressure variation in stagnation region (see ref. 3, eq. (36)) (-2.5 for sphere)
PIN	free-stream pressure, dyn/cm^2
QI1, QI2, QO1, QO2	curve-fit coefficients to radiation distribution around body, used for all but the final δ_0 iteration (see discussion on p. 42)
R	gas constant, ergs/mole-$^{\circ}$K
RB	body radius at axis of symmetry $x = 0$, cm
RHOIN	free-stream density, g/cm^3
RHON	initial guess for RHO, nondimensionalized
R1	initial guess for weighted heat flux, nondimensionalized (if value not known, use R1 = 0)
SSPEC	print control option for INT1
TEAN	initial guess for T', $^{\circ}$K

TCG accuracy criterion for iteration in RANH (0.001)

UIN free-stream velocity, cm/sec

XMAX limiting value in x-direction

$

The input for the radiation portion of the program was supplied with the RATRAP code. Part of the data is permanent and, therefore, is not normally modified. The input is loaded by using FORTRAN IV NAMELIST. The input symbols are as follows:

$RAD1

GEE
EPS
FHVM
FHVP
FHV
WOL
NU
ND
HVL
FF
GAMP
IS

permanent data supplied with code for occupation number, density calculation, and line absorption coefficient

NIHVC total number of continuum spectral points

FHVC	spectral points for continuum calculation	
AHV	transmission factors for continuum calculation	
AHVL	transmission factors for line calculation	
FL1	1	intensity calculation
	2	flux calculation
FL2	1	intensity calculation
	2	flux calculation
FLG	0	normal output
	$\neq 0$	diagnostic output
FLG1	0	intensity calculation
	$\neq 0$	flux calculation
NIC	number of y/δ points where transport evaluated	
NICN	an array of NIC values of index location of y/δ points where transport is evaluated	
IOPT	option in subprogram FEMP:	
	1	temperatures supplied
	2	enthalpies supplied
NY	number of values of YY, PRES, TEE, and HH (maximum is 100)	
TB	initial temperature estimate	

A listing of the NAMELIST input data appears in the output for the sample case.

Discussion of Output

The output of program D1250 consists of printing only. The NAMELIST input EQRAD is printed from MAIN and the NAMELIST RAD1 from PROD. If PIN and RHOIN are found by the atmosphere routine, they are printed in MAIN. Also printed in MAIN are the initial DELTA for each δ_0 iteration and the maximum x from the previous iterations. The remainder of the output is printed only during the final δ_0 iteration. The results from the integration routine are printed by CONT. The frequency of the output in CONT is controlled by a print option in INT1. If SSPEC is zero, control is returned to the program after every acceptable integration step. The distribution across the shock layer is written by PROD and the radiation results are written by RADFLUX. The output symbols are as follows:

AT62:

RHOIN	ρ_∞
PIN	p_∞
DELTN	δ_0
X	x

Stagnation-point conditions:

UO	u_0
RHOO	ρ_0
AO	a_0
RHOOAO	$\rho_0 a_0$
HO	H_0
PO	p_0
DWDX	$\frac{d\omega}{dx}$

Shock standoff distance:

DELTD	dimensional δ, cm
DELTA/RB	δ/R_B

Distribution across shock layer:

ETA	η	
PDUM	p	
STAENT	h	
CAPH	H	
AUDUM	u	velocity gradient when PROD is called by MAIN
	u	velocity when PROD is called by CONT
V	v	

Radiation output:

PATH LENGTH

PRESSURE

TEMPERATURE

ENTHALPY

DENSITY

DENSITY (ND)

QRYPC	body and shock continuum radiation heat flux, watts/cm^2
QRYPL	body and shock line radiation heat flux, watts/cm^2
QRYO	total radiation heat flux at body, dimensionless
QRY1	total radiation heat flux at shock, dimensionless

Properties at first step off stagnation line:

X	x

DELTA	δ	
W	ω	
IO(2) to IO(5)	$I_{j,0}$	(j = 2,3,4,5)
SMALRB	r_b	

Body and shock properties:

X	x	
DELTA	δ	
W	ω	
IO(2) to IO(5)	$I_{j,0}$	(j = 2,3,4,5)
SMALRB	r_b	
I1(2) to I1(5)	$I_{j,1}$	(j = 2,3,4,5)
RBX	R_B at any x-coordinate	
THETAB	θ_b	
Q	Q	
DDELDX	$\frac{d\delta}{dx}$	
DWDX	$\frac{d\omega}{dx}$	
DIODX(2) to DIODX(5)	$\frac{dI_{j,0}}{dx}$	(j = 2,3,4,5)
DSMALRBDX	$\frac{dr_b}{dx}$	
PRATIO	$\frac{PO}{PSTAG}$	
QRATIO	ratio of heat flux at body to stagnation heat flux	

Output for Sample Case

```
$EQRAD
ALT      =  0.2E+06,
AOVERB   =  0.1E+01,
CCI      =  0.5E-02,
CII      =  0.5E-02,
CIMAX    =  0.0,
DELTX    = -0.1E-02,
DUMBTIM  =  0.78E+00,
EELE1    =  0.1E-02,  0.1E-02,  0.1E-02,  0.1E-02,  0.1E-02,  0.1E-02,  0.1E-02,
EELE2    =  0.1E-03,  0.1E-03,  0.1E-03,  0.1E-03,  0.1E-03,  0.1E-03,  0.1E-03,
EELT     =  0.1E+04,  0.2E+04,  0.3E+04,
EITR1    =  0.1E-03,
EITR2    =  0.1E-03,
EMUREF   =  0.28967E+02,
EPSR     =  0.1E-01,
EPS21    =  0.1E-02,
IALT     =  1,
IGEO     =  1,
ITEXT    =  0,
ITTEST   =  500,
KETEST   =  12,
KKKK     =  1,
PEEP     = -0.25E+01,
PIN      =  0.16212E+03,
QI1      = -0.302E+01,
```

```
QI2     =  0.204E+01,
QO1     = -0.19875E+01,
QO2     =  0.125E+01,
R       =  0.8314395E+08,
RB      =  0.3048E+03,
RHOV    =  0.14E+02,
RHOIN   =  0.23773E-06,
R1      =  0.134661176E+00,
SSPEC   =  0.0,
TEAN    =  0.5E+04,
TCG     =  0.1E-02,
UIN     =  0.1524E+07,
XMAX    =  0.15708E+01,
$END
      AT62      RHOIN 2.71626956E-07      PIN 1.97961862E+02
      DELTN 4.43919683E-02      X 0.
```

```
$RAD1

GEE    =  0.4E+01,  0.1E+02,  0.6E+01,  0.18E+02,  0.54E+02,  0.9E+02,
          0.9E+01,  0.0,

EPS    =  0.0,  0.2384E+01,  0.3576E+01,  0.10452E+02,  0.11877E+02,
          0.13002E+02,  0.0,  0.0,

FHVM   =  0.6E+00,  0.85E+00,  0.97E+00,  0.12E+01,  0.14E+01,  0.162E+01,
          0.24E+01,  0.34E+01,  0.62E+01,  0.8E+01,  0.86E+01,  0.9E+01,
          0.97E+01,  0.108E+02,  0.12E+02,  0.128E+02,  0.134E+02,  0.138E+02,
          0.0,  0.0,

FHVP   =  0.8E+00,  0.95E+00,  0.12E+01,  0.14E+01,  0.155E+01,  0.24E+01,
          0.33E+01,  0.4E+01,  0.8E+01,  0.86E+01,  0.9E+01,  0.97E+01,
          0.108E+02,  0.12E+02,  0.128E+02,  0.134E+02,  0.138E+02,
          0.145E+02,  0.0,  0.0,

FHV    =  0.69E+00,  0.89E+00,  0.105E+01,  0.129E+01,  0.146E+01,  0.185E+01,
          0.285E+01,  0.37E+01,  0.711E+01,  0.8302E+01,  0.8781E+01,
          0.94E+01,  0.104E+02,  0.115E+02,  0.1241E+02,  0.1304E+02,
          0.1358E+02,  0.142E+02,  0.0,  0.0,

WOL    =  0.2E-01,  0.3E-01,  0.5E-01,  0.45E-01,  0.8E-01,  0.1E+00,
          0.25E-01,  0.17E+00,  0.18E+01,  0.6E+00,  0.4E+00,  0.8E-01,
          0.5E-01,  0.5E-01,  0.5E-01,  0.75E-01,  0.8E-01,  0.1E+00,  0.0,
          0.0,

NU     =  4,  2,  4,  4,  2,  4,  3,  4,  1,  1,  1,  3,  9,  10,  3,  3,  3,
          4,  0,  0,

ND     =  6,  6,  6,  6,  5,  5,  5,  5,  5,  5,  5,  5,  4,  5,  4,  4,  4,
          5,  5,  5,  4,  4,  4,  4,  4,  4,  4,  3,  2,  3,  3,  3,  3,  2,
          3,  1,  3,  2,  3,  2,  3,  3,  1,  3,  2,  3,  7,  2,  2,  2,  2,
          3,  3,  2,  2,  1,  1,  2,  2,  7,  1,  1,  1,  1,  1,  0,  0,  0,
          0,  0,

HVL    =  0.657E+00,  0.674E+00,  0.69E+00,  0.71E+00,  0.877E+00,  0.911E+00,
          0.998E+00,  0.1033E+01,  0.1119E+01,  0.117E+01,  0.1225E+01,
          0.1268E+01,  0.1319E+01,  0.1368E+01,  0.143E+01,  0.1509E+01,
          0.1663E+01,  0.1836E+01,  0.1919E+01,  0.2075E+01,  0.2571E+01,
          0.2925E+01,  0.3107E+01,  0.3466E+01,  0.3541E+01,  0.3849E+01,
          0.3926E+01,  0.7111E+01,  0.8302E+01,  0.8781E+01,  0.9301E+01,
          0.9374E+01,  0.946E+01,  0.9973E+01,  0.10102E+02,  0.10332E+02,
          0.10418E+02,  0.10493E+02,  0.10585E+02,  0.10619E+02,  0.10682E+02,
          0.10757E+02,  0.10927E+02,  0.112E+02,  0.11293E+02,  0.1131E+02,
          0.11424E+02,  0.11609E+02,  0.11776E+02,  0.11874E+02,  0.11948E+02,
          0.12E+02,  0.12316E+02,  0.12414E+02,  0.12511E+02,  0.12877E+02,
          0.13004E+02,  0.1319E+02,  0.13508E+02,  0.13543E+02,  0.13677E+02,
          0.13993E+02,  0.1416E+02,  0.14257E+02,  0.14332E+02,  0.0,  0.0,
```

```
          0.0,  0.0,  0.0,

FF     =  0.102E+00,  0.208E+00,  0.276E+00,  0.307E+00,  0.406E-01,
          0.584E-01,  0.202E+00,  0.633E-01,  0.744E-01,  0.201E+00,
          0.293E+00,  0.625E-01,  0.183E+00,  0.389E-01,  0.516E+00,
          0.225E+00,  0.927E-01,  0.742E-02,  0.127E-01,  0.134E-02,
          0.463E-02,  0.106E-01,  0.585E-02,  0.172E-01,  0.38E-02,  0.14E-01,
          0.32E-02,  0.634E-01,  0.74E-01,  0.435E-01,  0.166E-01,  0.119E-01,
          0.36E-01,  0.89E-01,  0.374E-01,  0.184E+00,  0.225E-01,  0.187E-01,
          0.131E-01,  0.533E-01,  0.819E-02,  0.518E-02,  0.454E+00,  0.2E-01,
          0.418E-01,  0.254E-01,  0.226E+00,  0.25E-01,  0.22E-01,  0.91E-02,
          0.575E-02,  0.269E-01,  0.156E-01,  0.574E-01,  0.279E-01,
          0.23E-01,  0.132E+00,  0.489E-01,  0.291E-01,  0.161E+00,
          0.957E-01,  0.584E-01,  0.342E-01,  0.212E-01,  0.138E-01,  0.0,
          0.0,  0.0,  0.0,  0.0,

GAMP   =  0.187E-19,  0.187E-19,  0.187E-19,  0.187E-19,  0.466E-20,
          0.366E-20,  0.312E-20,  0.336E-20,  0.446E-20,  0.24E-20,
          0.304E-20,  0.32E-20,  0.984E-21,  0.229E-20,  0.95E-21,  0.839E-21,
          0.958E-21,  0.293E-19,  0.293E-19,  0.293E-19,  0.551E-20,
          0.551E-20,  0.209E-19,  0.39E-19,  0.573E-19,  0.573E-19,
          0.573E-19,  0.912E-21,  0.912E-21,  0.661E-21,  0.446E-20,
          0.229E-20,  0.336E-20,  0.661E-21,  0.293E-19,  0.621E-21,
          0.532E-19,  0.446E-19,  0.796E-19,  0.312E-20,  0.268E-18,
          0.437E-18,  0.161E-22,  0.446E-20,  0.293E-19,  0.323E-20,
          0.143E-22,  0.532E-19,  0.796E-19,  0.268E-18,  0.437E-18,
          0.299E-19,  0.696E-19,  0.39E-20,  0.337E-20,  0.446E-20,
          0.294E-20,  0.299E-19,  0.696E-18,  0.95E-23,  0.293E-19,
          0.532E-19,  0.796E-19,  0.268E-18,  0.437E-18,  0.0,  0.0,  0.0,
          0.0,  0.0,

IS     =  65,

NIHVC  =  31,

FHVC   =  0.1E-01,  0.2E-01,  0.5E-01,  0.1E+00,  0.2E+00,  0.5E+00,
          0.692E+00,  0.853E+00,  0.1215E+01,  0.1729E+01,  0.211E+01,
          0.2594E+01,  0.2964E+01,  0.3209E+01,  0.3807E+01,  0.4446E+01,
          0.5E+01,  0.7E+01,  0.825E+01,  0.92E+01,  0.1097E+02,  0.1081E+02,
          0.1199E+02,  0.1201E+02,  0.1339E+02,  0.1341E+02,  0.1429E+02,
          0.1431E+02,  0.16E+02,  0.18E+02,  0.2E+02,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
          0.0,  0.0,  0.0,  0.0,

AHV    =  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
          0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
          0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
          0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
          0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
          0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
          0.31416E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
```

```
         0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,

AHVL   = 0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
         0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
         0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,  0.31416E+01,
         0.31416E+01,  0.31416E+01,  0.31416E+01,  0.0,  0.0,

FL1    = 0.2E+01,

FL2    = 0.2E+01,

FLG    = 0.0,

FLG1   = 0.1E+01,

NIC    = 2,

NICV   = 1,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
         0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
         0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
         0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
         0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
         0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,

IOPT   = 2,

TB     = 0.15E+05,  0.0,  0.0,

NY     = 11,

$END
```

```
DELTN 4.08873392E-02      X 3.95000000E-01

DELTN 3.91350247E-02      X 4.25000000E-01

DELTN 3.82588674E-02      X 4.65000000E-01
   RHO IS SMALLER THAN ALLOWED

DELTN 3.86969461E-02      X 4.85000000E-01

DELTN 3.84779068E-02      X 4.85000000E-01

DELTN 3.83683871E-02      X 5.25000000E-01

DELTN 3.83136273E-02      X 5.65000000E-01
   RHO IS SMALLER THAN ALLOWED

DELTN 3.83410072E-02      X 5.05000000E-01
   H IS ZERO OR NEGATIVE

DELTN 3.83546971E-02      X 5.45000000E-01

DELTN 3.83478522E-02      X 5.65000000E-01
   RHO IS SMALLER THAN ALLOWED

DELTN 3.83512747E-02      X 5.45000000E-01
```

```
STAGNATION POINT CONDITIONS       UO 0.                  RHOO 4.72682601E+01      AO 2.25838184E-01
                               RHOOAO 1.06749780E+01       HO 1.76326038E-01      PO 9.64327061E-01     DWDX-1.01135076E+00
SHOCK STAND-OFF DISTANCE        DELTD 1.16894685E+01 DELTA/RB 3.83512747E-02


 DISTRIBUTION ACROSS SHOCK LAYER
      ETA               PDUM             STAENT            CAPH             AUDUM            V

0.               9.64327061E-01   1.76326038E-01   1.76326038E-01   2.25838184E-01   0.
1.00000000E-01   9.64087950E-01   2.24796404E-01   2.24836441E-01   3.43066632E-01  -8.94833413E-03
2.00000000E-01   9.63370615E-01   2.68157802E-01   2.68301725E-01   4.48103235E-01  -1.69660349E-02
3.00000000E-01   9.62175058E-01   3.07177428E-01   3.07470033E-01   5.42755920E-01  -2.41911058E-02
4.00000000E-01   9.60501278E-01   3.42476211E-01   3.42948548E-01   6.28491991E-01  -3.07355497E-02
5.00000000E-01   9.58349275E-01   3.74562082E-01   3.75235205E-01   7.06514734E-01  -3.66912165E-02
6.00000000E-01   9.55719048E-01   4.03854557E-01   4.04742199E-01   7.77820247E-01  -4.21341407E-02
7.00000000E-01   9.52610599E-01   4.30703167E-01   4.31813682E-01   8.43240193E-01  -4.71278051E-02
8.00000000E-01   9.49023927E-01   4.55401473E-01   4.56739243E-01   9.03474383E-01  -5.17256281E-02
9.00000000E-01   9.44959032E-01   4.78197829E-01   4.79764311E-01   9.59115913E-01  -5.59728821E-02
1.00000000E+00   9.40415914E-01   4.99303768E-01   5.01098264E-01   1.01067076E+00  -5.99081894E-02

PATH LENGTH     PRESSURE    TEMPERATURE    ENTHALPY     DENSITY        DENSITY(ND)
 (Y/DELTA)        (ATM)        (DEG K)      (CAL/GM)     (GM/CC)
     0.          6.00414E-01  8.16031E+03  9.77400E+03  1.32420E-05  4.87506E+01
     1.00000E-01  6.00265E-01  1.04720E+04  1.24608E+04  9.63634E-06  3.54764E+01
     2.00000E-01  5.99818E-01  1.16447E+04  1.48644E+04  8.12868E-06  2.99259E+01
     3.00000E-01  5.99074E-01  1.23573E+04  1.70273E+04  7.21803E-06  2.65733E+01
     4.00000E-01  5.98032E-01  1.28722E+04  1.89839E+04  6.57105E-06  2.41914E+01
     5.00000E-01  5.96692E-01  1.32780E+04  2.07625E+04  6.07585E-06  2.23684E+01
     6.00000E-01  5.95054E-01  1.36157E+04  2.23862E+04  5.67859E-06  2.09058E+01
     7.00000E-01  5.93119E-01  1.39065E+04  2.38745E+04  5.35018E-06  1.96968E+01
     8.00000E-01  5.90886E-01  1.41636E+04  2.52435E+04  5.07197E-06  1.86726E+01
     9.00000E-01  5.88355E-01  1.43952E+04  2.65072E+04  4.83188E-06  1.77887E+01
     1.00000E+00  5.85526E-01  1.46079E+04  2.76771E+04  4.62057E-06  1.70107E+01

  QRYPC 3.00159291E+03 6.59064604E+03  QRYPL 2.07189299E+03 4.45971229E+03  QRYO-5.27689789E-02  QRY1 1.14934019E-01

       PROPERTIES AT FIRST STEP OFF STAGNATION LINE
   X 5.00000000D-03      DELTA 3.83509801D-02        W 1.56573960D+00      IO(2) 5.33748901D-02      IO(3) 9.64387332D-01
 IO(4) 0.                 IO(5) 9.41141692D-03     SMALRB 0.
```

```
      BODY AND SHOCK PROPERTIES
     X 5.00000000D-03      DELTA 3.83509801D-02         W 1.56573960D+00      IO(2) 5.33748901D-02      IO(3) 9.64387332D-01
  IO(4) 0.                 IO(5) 9.41141692D-03    SMALRB 0.                  I1(2) 8.43508003E-02      I1(3) 9.40818045E-01
  I1(4)-5.05327013E-03     I1(5) 4.22680396E-02       RBX 1.00000000E+00     THETAB 1.56579633E+00          Q 1.00000000E+00
 DDELDX-5.89044012E-05      DWDX-1.00948451E+00  DIODX(2) 1.07048948E+01   DIODX(3) 1.20878701E-02   DIODX(4) 0.
DIODX(5) 1.89715195E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.64327061E-01	1.76326038E-01	1.76326675E-01	1.12919092E-03	0.
1.00000000E-01	9.64087917E-01	2.24795068E-01	2.24836574E-01	1.71532177E-03	-8.94819925E-03
2.00000000E-01	9.63370020E-01	2.68155100E-01	2.68301529E-01	2.24049604E-03	-1.69658016E-02
3.00000000E-01	9.62173373E-01	3.07173359E-01	3.07469638E-01	2.71375279E-03	-2.41908021E-02
4.00000000E-01	9.60497973E-01	3.42470791E-01	3.42948055E-01	3.14242806E-03	-3.07351971E-02
5.00000000E-01	9.58343822E-01	3.74555340E-01	3.75234688E-01	3.53253797E-03	-3.66908317E-02
6.00000000E-01	9.55710920E-01	4.03846529E-01	4.04741717E-01	3.88906272E-03	-4.21337368E-02
7.00000000E-01	9.52599266E-01	4.30693895E-01	4.31813278E-01	4.21616044E-03	-4.71273923E-02
8.00000000E-01	9.49008860E-01	4.55390999E-01	4.56738951E-01	4.51733001E-03	-5.17252143E-02
9.00000000E-01	9.44939703E-01	4.78186198E-01	4.79764156E-01	4.79553679E-03	-5.59724737E-02
1.00000000E+00	9.40391794E-01	4.99291024E-01	5.01098264E-01	5.05331055E-03	-5.99077912E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	6.00414E-01	8.16031E+03	9.77400E+03	1.32420E-05	4.87506E+01
1.00000E-01	6.00265E-01	1.04719E+04	1.24607E+04	9.63640E-06	3.54766E+01
2.00000E-01	5.99818E-01	1.16446E+04	1.48642E+04	8.12875E-06	2.99261E+01
3.00000E-01	5.99073E-01	1.23573E+04	1.70271E+04	7.21810E-06	2.65736E+01
4.00000E-01	5.98030E-01	1.28721E+04	1.89836E+04	6.57112E-06	2.41917E+01
5.00000E-01	5.96688E-01	1.32779E+04	2.07621E+04	6.07591E-06	2.23686E+01
6.00000E-01	5.95049E-01	1.36156E+04	2.23858E+04	5.67864E-06	2.09060E+01
7.00000E-01	5.93112E-01	1.39064E+04	2.38740E+04	5.35022E-06	1.96969E+01
8.00000E-01	5.90876E-01	1.41635E+04	2.52430E+04	5.07200E-06	1.86727E+01
9.00000E-01	5.88343E-01	1.43951E+04	2.65065E+04	4.83189E-06	1.77887E+01
1.00000E+00	5.85511E-01	1.46078E+04	2.76764E+04	4.62057E-06	1.70107E+01

```
QRYPC 3.00140163E+03 6.59012703E+03   QRYPL 2.06121076E+03 4.46000428E+03   QRY0-5.26558842E-02   QRY1 1.14931658E-01

PRATIO 1.00000000E+00   QRATIO 0.
```

```
      BODY AND SHOCK PROPERTIES
       X 2.50000000D-02       DELTA 3.83478404D-02          W 1.54555863D+00      IO(2) 2.67600596D-01      IO(3) 9.65117515D-01
   IO(4) 0.                   IO(5) 4.74085075D-02     SMALRB 0.                  I1(2) 4.20976327E-01      I1(3) 9.50432569E-01
   I1(4)-2.52152719E-02       I1(5) 2.10950506E-01        RBX 1.00000000E+00     THETAB 1.54579632E+00          Q 1.00000000E+00
  DDELDX-2.46807887E-04        DWDX-1.00756351E+00  DIODX(2) 1.07339990E+01   DIODX(3) 6.11161198E-02  DIODX(4) 0.
DIODX(5) 1.91043466E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.63593765E-01	1.77145233E-01	1.77161442E-01	5.69369531E-03	0.
1.00000000E-01	9.63361238E-01	2.25282474E-01	2.25359157E-01	8.59907922E-03	-8.91193718E-03
2.00000000E-01	9.62651972E-01	2.68394431E-01	2.68600144E-01	1.12056689E-02	-1.69073567E-02
3.00000000E-01	9.61465966E-01	3.07228838E-01	3.07611643E-01	1.35573028E-02	-2.41207283E-02
4.00000000E-01	9.59803220E-01	3.42392119E-01	3.42985263E-01	1.56896434E-02	-3.06614426E-02
5.00000000E-01	9.57663735E-01	3.74381258E-01	3.75207192E-01	1.76319985E-02	-3.66193973E-02
6.00000000E-01	9.55047511E-01	4.03607421E-01	4.04680676E-01	1.94086757E-02	-4.20691544E-02
7.00000000E-01	9.51954547E-01	4.30413706E-01	4.31742984E-01	2.10400060E-02	-4.70730759E-02
8.00000000E-01	9.48384843E-01	4.55088670E-01	4.56678369E-01	2.25431243E-02	-5.16837216E-02
9.00000000E-01	9.44338400E-01	4.77876750E-01	4.79728095E-01	2.39325740E-02	-5.59457018E-02
1.00000000E+00	9.39815218E-01	4.98986387E-01	5.01098264E-01	2.52207792E-02	-5.98971256E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.99957E-01	8.19355E+03	9.81941E+03	1.31560E-05	4.84340E+01
1.00000E-01	5.99812E-01	1.04889E+04	1.24877E+04	9.60705E-06	3.53685E+01
2.00000E-01	5.99371E-01	1.16493E+04	1.48775E+04	8.11649E-06	2.98810E+01
3.00000E-01	5.98632E-01	1.23577E+04	1.70301E+04	7.21192E-06	2.65508E+01
4.00000E-01	5.97597E-01	1.28705E+04	1.89793E+04	6.56786E-06	2.41797E+01
5.00000E-01	5.96265E-01	1.32752E+04	2.07525E+04	6.07422E-06	2.23624E+01
6.00000E-01	5.94636E-01	1.36123E+04	2.23725E+04	5.67781E-06	2.09030E+01
7.00000E-01	5.92710E-01	1.39028E+04	2.38584E+04	5.34985E-06	1.96956E+01
8.00000E-01	5.90488E-01	1.41598E+04	2.52262E+04	5.07186E-06	1.86722E+01
9.00000E-01	5.87968E-01	1.43913E+04	2.64894E+04	4.83185E-06	1.77886E+01
1.00000E+00	5.85152E-01	1.46041E+04	2.76595E+04	4.62052E-06	1.70105E+01

```
QRYPC 2.99787128E+03 6.57564746E+03  QRYPL 2.06196097E+03 4.45251997E+03  QRYO-5.26269682E-02  QRY1 1.14703213E-01

PRATIO 9.99239578E-01  QRATIO 0.
```

```
BODY AND SHOCK PROPERTIES
    X 4.50000000D-02      DELTA 3.83416634D-02          W 1.52545553D+00       IO(2) 4.82994894D-01       IO(3) 9.66843149D-01
IO(4) 0.                  IO(5) 8.59501166D-02     SMALRB 0.                   I1(2) 7.56155994E-01       I1(3) 9.72735574E-01
I1(4)-4.52699809E-02      I1(5) 3.78908456E-01        RBX 1.00000000E+00      THETAB 1.52579633E+00           Q 1.00000000E+00
DDELDX-3.53862846E-04      DWDX-1.00270656E+00   DIODX(2) 1.08047489E+01    DIODX(3) 1.11739121E-01    DIODX(4) 0.
DIODX(5) 1.94322511E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.61857293E-01	1.77898958E-01	1.77952433E-01	1.03416676E-02	0.
1.00000000E-01	9.61640737E-01	2.25674916E-01	2.25834735E-01	1.55223575E-02	-8.87105716E-03
2.00000000E-01	9.60952765E-01	2.68506015E-01	2.68851367E-01	2.01765996E-02	-1.68406614E-02
3.00000000E-01	9.59793378E-01	3.07121961E-01	3.07708122E-01	2.43807583E-02	-2.40395737E-02
4.00000000E-01	9.58162575E-01	3.42115648E-01	3.42980584E-01	2.81971097E-02	-3.05744313E-02
5.00000000E-01	9.56060356E-01	3.73973784E-01	3.75142831E-01	3.16769471E-02	-3.65330657E-02
6.00000000E-01	9.53486722E-01	4.03099639E-01	4.04588866E-01	3.48629003E-02	-4.19884729E-02
7.00000000E-01	9.50441672E-01	4.29830184E-01	4.31648837E-01	3.77906902E-02	-4.70018190E-02
8.00000000E-01	9.46925207E-01	4.54449176E-01	4.56601472E-01	4.04904740E-02	-5.16247432E-02
9.00000000E-01	9.42937326E-01	4.77197265E-01	4.79683713E-01	4.29878880E-02	-5.59011432E-02
1.00000000E+00	9.38478030E-01	4.98279876E-01	5.01098264E-01	4.53048640E-02	-5.98685737E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.98876E-01	8.22459E+03	9.86119E+03	1.30627E-05	4.80905E+01
1.00000E-01	5.98741E-01	1.05020E+04	1.25095E+04	9.57262E-06	3.52418E+01
2.00000E-01	5.98313E-01	1.16506E+04	1.48837E+04	8.09973E-06	2.98193E+01
3.00000E-01	5.97591E-01	1.23548E+04	1.70242E+04	7.20205E-06	2.65145E+01
4.00000E-01	5.96575E-01	1.28655E+04	1.89640E+04	6.56163E-06	2.41568E+01
5.00000E-01	5.95267E-01	1.32690E+04	2.07299E+04	6.07018E-06	2.23475E+01
6.00000E-01	5.93664E-01	1.36053E+04	2.23444E+04	5.67519E-06	2.08933E+01
7.00000E-01	5.91768E-01	1.38952E+04	2.38261E+04	5.34818E-06	1.96894E+01
8.00000E-01	5.89579E-01	1.41517E+04	2.51908E+04	5.07087E-06	1.86685E+01
9.00000E-01	5.87096E-01	1.43829E+04	2.64517E+04	4.83137E-06	1.77868E+01
1.00000E+00	5.84319E-01	1.45954E+04	2.76204E+04	4.62041E-06	1.70101E+01

QRYPC 2.98617631E+03 6.54094413E+03   QRYPL 2.06120834E+03 4.42816779E+03   QRYO-5.24975014E-02   QRY1 1.14088981E-01

PRATIO 9.97438869E-01   QRATIO 0.

BODY AND SHOCK PROPERTIES

```
      X 6.50000000D-02      DELTA 3.83342394D-02          W 1.50543498D+00      IO(2) 6.99479998D-01      IO(3) 9.69593650D-01
  IO(4) 0.                  IO(5) 1.24977254D-01     SMALRB 0.                  I1(2) 1.08964146E+00      I1(3) 1.00753800E+00
  I1(4)-6.51795024E-02      I1(5) 5.46017445E-01        RBX 1.00000000E+00     THETAB 1.50579632E+00          Q 1.00000000E+00
 DDELDX-3.75199063E-04       DWDX-9.99175063E-01   DIODX(2) 1.08445144E+01   DIODX(3) 1.63528336E-01   DIODX(4) 0.
DIODX(5) 1.95979713E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.59052058E-01	1.78557969E-01	1.78671663E-01	1.50793600E-02	0.
1.00000000E-01	9.58861846E-01	2.25953477E-01	2.26245289E-01	2.24883483E-02	-8.82597735E-03
2.00000000E-01	9.58210342E-01	2.68478832E-01	2.69044355E-01	2.91537594E-02	-1.67661665E-02
3.00000000E-01	9.57097547E-01	3.06847653E-01	3.07753288E-01	3.51821844E-02	-2.39475441E-02
4.00000000E-01	9.55523459E-01	3.41640688E-01	3.42931668E-01	4.06607704E-02	-3.04739244E-02
5.00000000E-01	9.53488081E-01	3.73335352E-01	3.75041446E-01	4.56614607E-02	-3.64310103E-02
6.00000000E-01	9.50991410E-01	4.02327722E-01	4.04467354E-01	5.02441723E-02	-4.18901779E-02
7.00000000E-01	9.48033448E-01	4.28949146E-01	4.31532386E-01	5.44592075E-02	-4.69113500E-02
8.00000000E-01	9.44614193E-01	4.53478945E-01	4.56509709E-01	5.83491083E-02	-5.15452049E-02
9.00000000E-01	9.40733648E-01	4.76154234E-01	4.79631909E-01	6.19500976E-02	-5.58348931E-02
1.00000000E+00	9.36391810E-01	4.97177603E-01	5.01098264E-01	6.52932098E-02	-5.98173846E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.97129E-01	8.25194E+03	9.89772E+03	1.29642E-05	4.77280E+01
1.00000E-01	5.97011E-01	1.05105E+04	1.25249E+04	9.53329E-06	3.50970E+01
2.00000E-01	5.96605E-01	1.16484E+04	1.48822E+04	8.07824E-06	2.97402E+01
3.00000E-01	5.95912E-01	1.23485E+04	1.70090E+04	7.18815E-06	2.64633E+01
4.00000E-01	5.94932E-01	1.28571E+04	1.89376E+04	6.55209E-06	2.41216E+01
5.00000E-01	5.93665E-01	1.32591E+04	2.06945E+04	6.06348E-06	2.23228E+01
6.00000E-01	5.92111E-01	1.35944E+04	2.23016E+04	5.67049E-06	2.08760E+01
7.00000E-01	5.90269E-01	1.38835E+04	2.37773E+04	5.34499E-06	1.96777E+01
8.00000E-01	5.88140E-01	1.41394E+04	2.51370E+04	5.06886E-06	1.86611E+01
9.00000E-01	5.85724E-01	1.43700E+04	2.63939E+04	4.83035E-06	1.77830E+01
1.00000E+00	5.83020E-01	1.45820E+04	2.75593E+04	4.62024E-06	1.70095E+01

```
QRYPC 2.96624698E+03 6.48620144E+03  QRYPL 2.04162353E+03 4.39567654E+03  QRYD-5.20865176E-02  QRY1 1.13181666E-01

PRATIO 9.94529861E-01  QRATIO 0.
```

```
      BODY AND SHOCK PROPERTIES
        X 8.50000000D-02       DELTA 3.83270261D-02          W 1.48547001D+00      IO(2) 9.16395790D-01      IO(3) 9.73384243D-01
    IO(4) 0.                   IO(5) 1.64149678D-01     SMALRB 0.                  I1(2) 1.42168339E+00      I1(3) 1.05469704E+00
    I1(4)-8.49328790E-02       I1(5) 7.12403081E-01        RBX 1.00000000E+00     THETAB 1.48579633E+00          Q 1.00000000E+00
   DDELDX-3.38818567E-04        DWDX-9.97283485E-01   DIODX(2) 1.08453938E+01   DIODX(3) 2.15579969E-01   DIODX(4) 0.
 DIODX(5) 1.95657445E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.55173380E-01	1.78927749E-01	1.79125307E-01	1.98775603E-02	0.
1.00000000E-01	9.55020129E-01	2.25992278E-01	2.26465465E-01	2.94825035E-02	-8.78381658E-03
2.00000000E-01	9.54420745E-01	2.68237165E-01	2.69103609E-01	3.81334454E-02	-1.66951895E-02
3.00000000E-01	9.53375228E-01	3.06366103E-01	3.07707131E-01	4.59657943E-02	-2.38579508E-02
4.00000000E-01	9.51883579E-01	3.40952245E-01	3.42822821E-01	5.30904899E-02	-3.03735562E-02
5.00000000E-01	9.49945796E-01	3.72467115E-01	3.74902939E-01	5.95992919E-02	-3.63259207E-02
6.00000000E-01	9.47561881E-01	4.01302165E-01	4.04324791E-01	6.55687528E-02	-4.17850523E-02
7.00000000E-01	9.44731833E-01	4.27785070E-01	4.31405642E-01	7.10632429E-02	-4.68098185E-02
8.00000000E-01	9.41455652E-01	4.52192201E-01	4.56414199E-01	7.61372812E-02	-5.14500772E-02
9.00000000E-01	9.37733338E-01	4.74758286E-01	4.79579563E-01	8.08373503E-02	-5.57483373E-02
1.00000000E+00	9.33564891E-01	4.95683963E-01	5.01098264E-01	8.52033243E-02	-5.97410642E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.94714E-01	8.26677E+03	9.91822E+03	1.28789E-05	4.74139E+01
1.00000E-01	5.94619E-01	1.05102E+04	1.25271E+04	9.49455E-06	3.49544E+01
2.00000E-01	5.94246E-01	1.16410E+04	1.48688E+04	8.05397E-06	2.96509E+01
3.00000E-01	5.93595E-01	1.23382E+04	1.69823E+04	7.17097E-06	2.64001E+01
4.00000E-01	5.92666E-01	1.28449E+04	1.88995E+04	6.53943E-06	2.40750E+01
5.00000E-01	5.91460E-01	1.32456E+04	2.06464E+04	6.05406E-06	2.22881E+01
6.00000E-01	5.89975E-01	1.35798E+04	2.22447E+04	5.66356E-06	2.08505E+01
7.00000E-01	5.88213E-01	1.38680E+04	2.37127E+04	5.34009E-06	1.96597E+01
8.00000E-01	5.86173E-01	1.41229E+04	2.50657E+04	5.06569E-06	1.86494E+01
9.00000E-01	5.83856E-01	1.43526E+04	2.63165E+04	4.82872E-06	1.77770E+01
1.00000E+00	5.81260E-01	1.45637E+04	2.74765E+04	4.61998E-06	1.70086E+01

```
QRYPC 2.93764008E+03 6.41170279E+03   QRYPL 2.05716229E+03 4.[illegible]4448566E+03   QRYO-5.19505968E-02   QRY1 1.11874378E-01

PRATIO 9.90507700E-01   QRATIO 0.
```

```
      BODY AND SHOCK PROPERTIES
        X 1.05000000D-01      DELTA 3.83208388D-02          W 1.46552958D+00      IO(2) 1.13298319D+00     IO(3) 9.78211322D-01
    IO(4) 0.                  IO(5) 2.03081994D-01     SMALRB 0.                  I1(2) 1.75259612E+00     I1(3) 1.11412357E+00
    I1(4)-1.04524123E-01      I1(5) 8.78222874E-01        RBX 1.00000000E+00     THETAB 1.46579632E+00         Q 1.00000000E+00
   DDELDX-2.76967246E-04       DWDX-9.96662369E-01   DIODX(2) 1.08126279E+01   DIODX(3) 2.67081057E-01  DIODX(4) 0.
 DIODX(5) 1.93626233E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.50229681E-01	1.78940307E-01	1.79245373E-01	2.47008461E-02	0.
1.00000000E-01	9.50123922E-01	2.25746871E-01	2.26450757E-01	3.64864208E-02	-8.74719488E-03
2.00000000E-01	9.49592158E-01	2.67754014E-01	2.69002002E-01	4.71100159E-02	-1.66319743E-02
3.00000000E-01	9.48634390E-01	3.05662974E-01	3.07555074E-01	5.67354032E-02	-2.37758888E-02
4.00000000E-01	9.47250618E-01	3.40044871E-01	3.42648195E-01	6.54969590E-02	-3.02786720E-02
5.00000000E-01	9.45440841E-01	3.71369521E-01	3.74727135E-01	7.35059765E-02	-3.62229249E-02
6.00000000E-01	9.43205059E-01	4.00026927E-01	4.04164239E-01	8.08554176E-02	-4.16776435E-02
7.00000000E-01	9.40543273E-01	4.26343520E-01	4.31272950E-01	8.76235383E-02	-4.67009090E-02
8.00000000E-01	9.37455482E-01	4.50594597E-01	4.56319012E-01	9.38766859E-02	-5.13419640E-02
9.00000000E-01	9.33941686E-01	4.73013947E-01	4.79529212E-01	9.96714813E-02	-5.56428323E-02
1.00000000E+00	9.30001886E-01	4.93801385E-01	5.01098264E-01	1.05056538E-01	-5.96395948E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.91636E-01	8.26562E+03	9.91891E+03	1.28131E-05	4.71716E+01
1.00000E-01	5.91570E-01	1.04996E+04	1.25135E+04	9.45831E-06	3.48210E+01
2.00000E-01	5.91239E-01	1.16279E+04	1.48420E+04	8.02766E-06	2.95540E+01
3.00000E-01	5.90643E-01	1.23235E+04	1.69433E+04	7.15080E-06	2.63258E+01
4.00000E-01	5.89781E-01	1.28290E+04	1.88492E+04	6.52375E-06	2.40173E+01
5.00000E-01	5.88655E-01	1.32285E+04	2.05855E+04	6.04192E-06	2.22435E+01
6.00000E-01	5.87263E-01	1.35616E+04	2.21741E+04	5.65437E-06	2.08167E+01
7.00000E-01	5.85605E-01	1.38486E+04	2.36328E+04	5.33344E-06	1.96352E+01
8.00000E-01	5.83683E-01	1.41024E+04	2.49771E+04	5.06131E-06	1.86333E+01
9.00000E-01	5.81495E-01	1.43309E+04	2.62198E+04	4.82644E-06	1.77686E+01
1.00000E+00	5.79042E-01	1.45408E+04	2.73721E+04	4.61963E-06	1.70073E+01

QRYPC 2.90033140E+03 6.31793138E+03   QRYPL 1.99781535E+03 4.28207326E+03   QRYO-5.09452883E-02   QRY1 1.10249921E-01

PRATIO 9.85381121E-01   QRATIO 0.

```
BODY AND SHOCK PROPERTIES
       X 1.25000000D-01      DELTA 3.83159731D-02         W 1.44559565D+00     IO(2) 1.34868951D+00     IO(3) 9.84059513D-01
   IO(4) 0.                  IO(5) 2.41492217D-01    SMALRB 0.                 I1(2) 2.08248875E+00     I1(3) 1.18573050E+00
   I1(4)-1.23936746E-01      I1(5) 1.04353150E+00       RBX 1.00000000E+00    THETAB 1.44579633E+00         Q 1.00000000E+00
  DDELDX-2.08366330E-04       DWDX-9.96601154E-01  DIODX(2) 1.07578414E+01  DIODX(3) 3.17640042E-01  DIODX(4) 0.
DIODX(5) 1.90463643E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.44240951E-01	1.78621036E-01	1.79056940E-01	2.95263735E-02	0.
1.00000000E-01	9.44192935E-01	2.25233350E-01	2.26216904E-01	4.34873773E-02	-8.71523872E-03
2.00000000E-01	9.43743723E-01	2.67038946E-01	2.68748701E-01	5.60782814E-02	-1.65751846E-02
3.00000000E-01	9.42893316E-01	3.04743379E-01	3.07301761E-01	6.74913396E-02	-2.36998533E-02
4.00000000E-01	9.41641713E-01	3.38920791E-01	3.42400436E-01	7.78844433E-02	-3.01878093E-02
5.00000000E-01	9.39988915E-01	3.70043104E-01	3.74513831E-01	8.73884703E-02	-3.61207540E-02
6.00000000E-01	9.37934921E-01	3.98501764E-01	4.03984509E-01	9.61128250E-02	-4.15669838E-02
7.00000000E-01	9.35479732E-01	4.24624178E-01	4.31132791E-01	1.04149669E-01	-4.65840309E-02
8.00000000E-01	9.32623347E-01	4.48686276E-01	4.56222790E-01	1.11577189E-01	-5.12207039E-02
9.00000000E-01	9.29365767E-01	4.70922232E-01	4.79480035E-01	1.18462149E-01	-5.55186807E-02
1.00000000E+00	9.25706991E-01	4.91532072E-01	5.01098264E-01	1.24861904E-01	-5.95137650E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.87908E-01	8.24956E+03	9.90122E+03	1.27643E-05	4.69920E+01
1.00000E-01	5.87878E-01	1.04790E+04	1.24850E+04	9.42396E-06	3.46945E+01
2.00000E-01	5.87598E-01	1.16092E+04	1.48023E+04	7.99914E-06	2.94490E+01
3.00000E-01	5.87068E-01	1.23046E+04	1.68924E+04	7.12763E-06	2.62405E+01
4.00000E-01	5.86289E-01	1.28093E+04	1.87869E+04	6.50508E-06	2.39486E+01
5.00000E-01	5.85260E-01	1.32078E+04	2.05120E+04	6.02712E-06	2.21890E+01
6.00000E-01	5.83981E-01	1.35397E+04	2.20895E+04	5.64295E-06	2.07746E+01
7.00000E-01	5.82453E-01	1.38255E+04	2.35375E+04	5.32507E-06	1.96043E+01
8.00000E-01	5.80674E-01	1.40778E+04	2.48713E+04	5.05573E-06	1.86128E+01
9.00000E-01	5.78646E-01	1.43048E+04	2.61039E+04	4.82351E-06	1.77578E+01
1.00000E+00	5.76368E-01	1.45131E+04	2.72463E+04	4.61916E-06	1.70055E+01

```
QRYPC 2.85462755E+03 6.20560099E+03  QRYPL 1.99287465E+03 4.20834463E+03  QRYD-5.04185379E-02  QRY1 1.08314734E-01
```

```
PRATIO 9.79170853E-01  QRATIO 0.
```

```
      BODY AND SHOCK PROPERTIES
        X 1.45000000D-01      DELTA 3.83124836D-02          W 1.42566200D+00       IO(2) 1.56315710D+00       IO(3) 9.90908112D-01
    IO(4) 0.                  IO(5) 2.79194999D-01     SMALRB 0.                   I1(2) 2.41128508E+00       I1(3) 1.26939981E+00
    I1(4)-1.43143778E-01      I1(5) 1.20829077E+00        RBX 1.00000000E+00      THETAB 1.42579633E+00           Q 1.00000000E+00
   DDELDX-1.39471072E-04       DWDX-9.96656631E-01   DIODX(2) 1.06883807E+01    DIODX(3) 3.67075703E-01    DIODX(4) 0.
 DIODX(5) 1.86533189E+00 DSMALRBDX 0.

    DISTRIBUTION ACROSS SHOCK LAYER
         ETA                PDUM             STAENT             CAPH               AUDUM               V

  0.                9.37226776E-01   1.78019951E-01   1.78609687E-01   3.43434346E-02   0.
  1.00000000E-01    9.37246479E-01   2.24483970E-01   2.25795736E-01   5.04785534E-02  -8.68506754E-03
  2.00000000E-01    9.36894233E-01   2.66111441E-01   2.68362648E-01   6.50341729E-02  -1.65218384E-02
  3.00000000E-01    9.36170038E-01   3.03617861E-01   3.06957039E-01   7.82314012E-02  -2.36263424E-02
  4.00000000E-01    9.35073893E-01   3.37584583E-01   3.42110214E-01   9.02519170E-02  -3.00973832E-02
  5.00000000E-01    9.33605800E-01   3.68488783E-01   3.74262777E-01   1.01246383E-01  -3.60160676E-02
  6.00000000E-01    9.31765758E-01   3.96725747E-01   4.03783194E-01   1.11340795E-01  -4.14502232E-02
  7.00000000E-01    9.29553767E-01   4.22625680E-01   4.30981972E-01   1.20641331E-01  -4.64570085E-02
  8.00000000E-01    9.26969826E-01   4.46466550E-01   4.56122628E-01   1.29238097E-01  -5.10849322E-02
  9.00000000E-01    9.24013937E-01   4.68484006E-01   4.79430251E-01   1.37208065E-01  -5.53754289E-02
  1.00000000E+00    9.20686099E-01   4.88879123E-01   5.01098264E-01   1.44617373E-01  -5.93641040E-02

  PATH LENGTH     PRESSURE   TEMPERATURE    ENTHALPY      DENSITY        DENSITY(ND)
   (Y/DELTA)        (ATM)      (DEG K)      (CAL/GM)      (GM/CC)
       0.         5.83540E-01  8.22113E+03  9.86790E+03  1.27274E-05  4.68563E+01
       1.00000E-01  5.83553E-01  1.04496E+04  1.24435E+04  9.39022E-06  3.45703E+01
       2.00000E-01  5.83333E-01  1.15852E+04  1.47509E+04  7.96799E-06  2.93343E+01
       3.00000E-01  5.82882E-01  1.22816E+04  1.68300E+04  7.10131E-06  2.61436E+01
       4.00000E-01  5.82200E-01  1.27859E+04  1.87128E+04  6.48340E-06  2.38688E+01
       5.00000E-01  5.81286E-01  1.31835E+04  2.04259E+04  6.00967E-06  2.21247E+01
       6.00000E-01  5.80140E-01  1.35141E+04  2.19911E+04  5.62935E-06  2.07245E+01
       7.00000E-01  5.78763E-01  1.37984E+04  2.34267E+04  5.31501E-06  1.95673E+01
       8.00000E-01  5.77154E-01  1.40492E+04  2.47483E+04  5.04899E-06  1.85879E+01
       9.00000E-01  5.75314E-01  1.42743E+04  2.59687E+04  4.81993E-06  1.77447E+01
       1.00000E+00  5.73242E-01  1.44807E+04  2.70993E+04  4.61856E-06  1.70033E+01

      QRYPC 2.80095142E+03 6.07558117E+03  QRYPL 1.93600196E+03 4.15143070E+03  QRYD-4.92687272E-02  QRY1 1.06370449E-01

      PRATIO 9.71897205E-01  QRATIO 0.
```

BODY AND SHOCK PROPERTIES

```
       X 1.65000000D-01      DELTA 3.83103639D-02          W 1.40572838D+00      IO(2) 1.77612638D+00      IO(3) 9.98733286D-01
   IO(4) 0.                  IO(5) 3.16053580D-01     SMALRB 0.                  I1(2) 2.73881616E+00      I1(3) 1.36497667E+00
   I1(4)-1.62112407E-01      I1(5) 1.37241602E+00        RBX 1.00000000E+00     THETAB 1.40579632E+00          Q 1.00000000E+00
  DDELDX-7.05505447E-05       DWDX-9.96643946E-01   DIODX(2) 1.06071802E+01   DIODX(3) 4.15245035E-01   DIODX(4) 0.
DIODX(5) 1.81981323E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.29204776E-01	1.77179169E-01	1.77945434E-01	3.91475422E-02	0.
1.00000000E-01	9.29301938E-01	2.23526002E-01	2.25214094E-01	5.74562596E-02	-8.65802228E-03
2.00000000E-01	9.29060673E-01	2.64988095E-01	2.67859817E-01	7.39743604E-02	-1.64692786E-02
3.00000000E-01	9.28480981E-01	3.02295571E-01	3.06529178E-01	8.89522849E-02	-2.35521999E-02
4.00000000E-01	9.27562862E-01	3.36040473E-01	3.41753551E-01	1.02595851E-01	-3.00041154E-02
5.00000000E-01	9.26306315E-01	3.66707836E-01	3.73973663E-01	1.15075768E-01	-3.59057521E-02
6.00000000E-01	9.24711342E-01	3.94698751E-01	4.03558144E-01	1.26534817E-01	-4.13246299E-02
7.00000000E-01	9.22777941E-01	4.20347725E-01	4.30817680E-01	1.37093338E-01	-4.63176563E-02
8.00000000E-01	9.20506114E-01	4.43935911E-01	4.56015974E-01	1.46853471E-01	-5.09331329E-02
9.00000000E-01	9.17895859E-01	4.65701310E-01	4.79378301E-01	1.55902475E-01	-5.52123224E-02
1.00000000E+00	9.14947177E-01	4.85846731E-01	5.01098264E-01	1.64315336E-01	-5.91906861E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.78546E-01	8.18275E+03	9.82129E+03	1.26980E-05	4.67481E+01
1.00000E-01	5.78606E-01	1.04119E+04	1.23904E+04	9.35608E-06	3.44446E+01
2.00000E-01	5.78456E-01	1.15562E+04	1.46887E+04	7.93383E-06	2.92086E+01
3.00000E-01	5.78095E-01	1.22545E+04	1.67567E+04	7.07170E-06	2.60346E+01
4.00000E-01	5.77523E-01	1.27588E+04	1.86272E+04	6.45868E-06	2.37777E+01
5.00000E-01	5.76741E-01	1.31555E+04	2.03271E+04	5.98959E-06	2.20508E+01
6.00000E-01	5.75748E-01	1.34848E+04	2.18787E+04	5.61358E-06	2.06665E+01
7.00000E-01	5.74544E-01	1.37675E+04	2.33005E+04	5.30329E-06	1.95242E+01
8.00000E-01	5.73130E-01	1.40164E+04	2.46080E+04	5.04108E-06	1.85588E+01
9.00000E-01	5.71504E-01	1.42395E+04	2.58145E+04	4.81569E-06	1.77291E+01
1.00000E+00	5.69669E-01	1.44437E+04	2.69312E+04	4.61780E-06	1.70005E+01

```
QRYPC 2.73974577E+03 5.92886635E+03   QRYPL 1.93599573E+03 4.05422260E+03   QRYO-4.86320666E-02   QRY1 1.03833423E-01

PRATIO 9.63578451E-01   QRATIO 0.
```

```
BODY AND SHOCK PROPERTIES
  X 1.85000000D-01      DELTA 3.83096382D-02          W 1.38579687D+00      IO(2) 1.98737110D+00      IO(3) 1.00750825D+00
IO(4) 0.                IO(5) 3.51948290D-01     SMALRB 0.                  I1(2) 3.06487734E+00      I1(3) 1.47227213E+00
I1(4)-1.80806933E-01    I1(5) 1.53580472E+00        RBX 1.00000000E+00     THETAB 1.38579633E+00          Q 1.00000000E+00
DDELDX 5.66455166E-07    DWDX-9.96497235E-01   DIODX(2) 1.05149688E+01   DIODX(3) 4.61990177E-01   DIODX(4) 0.
DIODX(5) 1.76848160E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.20192453E-01	1.76127181E-01	1.77092386E-01	4.39364289E-02	0.
1.00000000E-01	9.20376591E-01	2.22377955E-01	2.24490027E-01	6.44179242E-02	-8.62990113E-03
2.00000000E-01	9.20259979E-01	2.63680291E-01	2.67250881E-01	8.28957684E-02	-1.64155616E-02
3.00000000E-01	9.19842617E-01	3.00782997E-01	3.06023625E-01	9.96502684E-02	-2.34750890E-02
4.00000000E-01	9.19124507E-01	3.34291802E-01	3.41341330E-01	1.14911775E-01	-2.99055421E-02
5.00000000E-01	9.18105647E-01	3.64701835E-01	3.73646116E-01	1.28871337E-01	-3.57874193E-02
6.00000000E-01	9.16786037E-01	3.92421676E-01	4.03307753E-01	1.41688741E-01	-4.11880466E-02
7.00000000E-01	9.15165678E-01	4.17791400E-01	4.30637883E-01	1.53498652E-01	-4.61641660E-02
8.00000000E-01	9.13244570E-01	4.41096312E-01	4.55901007E-01	1.64415367E-01	-5.07639363E-02
9.00000000E-01	9.11022712E-01	4.62577509E-01	4.79323076E-01	1.74536525E-01	-5.50284974E-02
1.00000000E+00	9.08500106E-01	4.82440094E-01	5.01098264E-01	1.83946031E-01	-5.89932036E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.72934E-01	8.13634E+03	9.76298E+03	1.26728E-05	4.66550E+01
1.00000E-01	5.73049E-01	1.03664E+04	1.23267E+04	9.32094E-06	3.43152E+01
2.00000E-01	5.72976E-01	1.15223E+04	1.46162E+04	7.89643E-06	2.90709E+01
3.00000E-01	5.72717E-01	1.22235E+04	1.66728E+04	7.03872E-06	2.59132E+01
4.00000E-01	5.72269E-01	1.27280E+04	1.85303E+04	6.43088E-06	2.36754E+01
5.00000E-01	5.71635E-01	1.31238E+04	2.02159E+04	5.96687E-06	2.19672E+01
6.00000E-01	5.70813E-01	1.34517E+04	2.17525E+04	5.59566E-06	2.06005E+01
7.00000E-01	5.69805E-01	1.37326E+04	2.31588E+04	5.28991E-06	1.94749E+01
8.00000E-01	5.68608E-01	1.39796E+04	2.44506E+04	5.03200E-06	1.85254E+01
9.00000E-01	5.67225E-01	1.42009E+04	2.56413E+04	4.81030E-06	1.77092E+01
1.00000E+00	5.65654E-01	1.44022E+04	2.67423E+04	4.61684E-06	1.69970E+01

```
QRYPC 2.67153002E+03 5.76702806E+03  QRYPL 1.87854596E+03 3.94663699E+03  QRYD-4.73250281E-02  QRY1 1.01031164E-01

PRATIO 9.54232739E-01  QRATIO 0.
```

```
       BODY AND SHOCK PROPERTIES
         X 2.05000000D-01       DELTA 3.83103801D-02          W 1.36587043D+00       IO(2) 2.19666995D+00       IO(3) 1.01720284D+00
     IO(4) 0.                   IO(5) 3.86762992D-01     SMALRB 0.                   I1(2) 3.38925195E+00       I1(3) 1.59106576E+00
     I1(4)-1.99189851E-01       I1(5) 1.69834827E+00        RBX 1.00000000E+00      THETAB 1.36579632E+00           Q 1.00000000E+00
    DDELDX 7.69460658E-05        DWDX-9.96182482E-01   DIODX(2) 1.04116964E+01    DIODX(3) 5.07135685E-01    DIODX(4) 0.
  DIODX(5) 1.71138488E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	9.10208829E-01	1.74881619E-01	1.76067867E-01	4.87082668E-02	0.
1.00000000E-01	9.10489221E-01	2.21051342E-01	2.23634537E-01	7.13611572E-02	-8.60086490E-03
2.00000000E-01	9.10510585E-01	2.62195248E-01	2.66542250E-01	9.17952909E-02	-1.63593108E-02
3.00000000E-01	9.10272922E-01	2.99084503E-01	3.05443536E-01	1.10321426E-01	-2.33933265E-02
4.00000000E-01	9.09776231E-01	3.32341222E-01	3.40874506E-01	1.27194877E-01	-2.97998499E-02
5.00000000E-01	9.09020513E-01	3.62472630E-01	3.73279702E-01	1.42627350E-01	-3.56592618E-02
6.00000000E-01	9.08005767E-01	3.89896286E-01	4.03030850E-01	1.56795874E-01	-4.10387765E-02
7.00000000E-01	9.06731994E-01	4.14958961E-01	4.30441179E-01	1.69849619E-01	-4.59950314E-02
8.00000000E-01	9.05199193E-01	4.37950962E-01	4.55776498E-01	1.81915172E-01	-5.05760888E-02
9.00000000E-01	9.03407365E-01	4.59117122E-01	4.79263834E-01	1.93100652E-01	-5.48229996E-02
1.00000000E+00	9.01356509E-01	4.78665333E-01	5.01098264E-01	2.03498962E-01	-5.87710368E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.66718E-01	8.08342E+03	9.69393E+03	1.26492E-05	4.65683E+01
1.00000E-01	5.66893E-01	1.03127E+04	1.22532E+04	9.28497E-06	3.41828E+01
2.00000E-01	5.66906E-01	1.14837E+04	1.45339E+04	7.85568E-06	2.89208E+01
3.00000E-01	5.66758E-01	1.21885E+04	1.65787E+04	7.00231E-06	2.57791E+01
4.00000E-01	5.66449E-01	1.26935E+04	1.84221E+04	6.39999E-06	2.35617E+01
5.00000E-01	5.65978E-01	1.30885E+04	2.00924E+04	5.94152E-06	2.18738E+01
6.00000E-01	5.65347E-01	1.34149E+04	2.16125E+04	5.57559E-06	2.05266E+01
7.00000E-01	5.64554E-01	1.36939E+04	2.30018E+04	5.27486E-06	1.94195E+01
8.00000E-01	5.63599E-01	1.39387E+04	2.42762E+04	5.02174E-06	1.84876E+01
9.00000E-01	5.62484E-01	1.41575E+04	2.54495E+04	4.80464E-06	1.76884E+01
1.00000E+00	5.61207E-01	1.43562E+04	2.65331E+04	4.61565E-06	1.69926E+01

```
QRYPC 2.59661584E+03 5.59033428E+03  QRYPL 1.82792075E+03 3.84873570E+03  QRYD-4.60193016E-02  QRY1 9.81751193E-02

PRATIO 9.43879795E-01  QRATIO 0.
```

```
      BODY AND SHOCK PROPERTIES
       X 2.25000000D-01      DELTA 3.83127312D-02        W 1.34595266D+00      IO(2) 2.40379719D+00      IO(3) 1.02778317D+00
   IO(4) 0.                  IO(5) 4.20381189D-01   SMALRB 0.                   I1(2) 3.71171511E+00      I1(3) 1.72110535E+00
   I1(4)-2.17221524E-01      I1(5) 1.85993400E+00      RBX 1.00000000E+00      THETAB 1.34579633E+00          Q 1.00000000E+00
  DDELDX 1.62329519E-04       DWDX-9.95667413E-01 DIODX(2) 1.02969798E+01  DIODX(3) 5.50487991E-01  DIODX(4) 0.
DIODX(5) 1.64844638E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	8.99275317E-01	1.73453092E-01	1.74882137E-01	5.34611120E-02	0.
1.00000000E-01	8.99660982E-01	2.19553167E-01	2.22654037E-01	7.82834065E-02	-8.57028597E-03
2.00000000E-01	8.99833265E-01	2.60537526E-01	2.65737548E-01	1.00669612E-01	-1.62994741E-02
3.00000000E-01	8.99792166E-01	2.97203144E-01	3.04790570E-01	1.20961575E-01	-2.33055921E-02
4.00000000E-01	8.99537686E-01	3.30191035E-01	3.40353414E-01	1.39440040E-01	-2.96855715E-02
5.00000000E-01	8.99069824E-01	3.60022376E-01	3.72873943E-01	1.56337717E-01	-3.55197592E-02
6.00000000E-01	8.98388581E-01	3.87125080E-01	4.02726538E-01	1.71849135E-01	-4.08753191E-02
7.00000000E-01	8.97493956E-01	4.11853640E-01	4.30226572E-01	1.86138161E-01	-4.58088292E-02
8.00000000E-01	8.96385949E-01	4.34504136E-01	4.55641596E-01	1.99343816E-01	-5.03682883E-02
9.00000000E-01	8.95064561E-01	4.55325718E-01	4.79200074E-01	2.11584808E-01	-5.45946825E-02
1.00000000E+00	8.93529791E-01	4.74529505E-01	5.01098264E-01	2.22963114E-01	-5.85232211E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.59911E-01	8.02519E+03	9.61475E+03	1.26256E-05	4.64815E+01
1.00000E-01	5.60151E-01	1.02518E+04	1.21701E+04	9.24691E-06	3.40427E+01
2.00000E-01	5.60258E-01	1.14401E+04	1.44420E+04	7.81153E-06	2.87583E+01
3.00000E-01	5.60233E-01	1.21494E+04	1.64744E+04	6.96247E-06	2.56325E+01
4.00000E-01	5.60074E-01	1.26552E+04	1.83030E+04	6.36602E-06	2.34366E+01
5.00000E-01	5.59783E-01	1.30494E+04	1.99565E+04	5.91352E-06	2.17707E+01
6.00000E-01	5.59359E-01	1.33743E+04	2.14589E+04	5.55334E-06	2.04447E+01
7.00000E-01	5.58802E-01	1.36513E+04	2.28296E+04	5.25812E-06	1.93579E+01
8.00000E-01	5.58112E-01	1.38937E+04	2.40852E+04	5.01027E-06	1.84454E+01
9.00000E-01	5.57289E-01	1.41100E+04	2.52393E+04	4.79824E-06	1.76648E+01
1.00000E+00	5.56334E-01	1.43057E+04	2.63038E+04	4.61421E-06	1.69873E+01

```
QRYPC 2.51559784E+03 5.40053278E+03  QRYPL 1.76663843E+03 3.72301277E+03  QRYO-4.45392456E-02  QRY1 9.48933713E-02

PRATIO 9.32541824E-01  QRATIO 0.
```

```
      BODY AND SHOCK PROPERTIES
        X 2.45000000D-01      DELTA 3.83169157D-02         W 1.32604795D+00      IO(2) 2.60851799D+00      IO(3) 1.03921132D+00
    IO(4) 0.                  IO(5) 4.52684640D-01    SMALRB 0.                  I1(2) 4.03203233E+00      I1(3) 1.86210503E+00
    I1(4)-2.34859275E-01      I1(5) 2.02044440E+00       RBX 1.00000000E+00     THETAB 1.32579632E+00          Q 1.00000000E+00
   DDELDX 2.61268753E-04       DWDX-9.94907365E-01  DIODX(2) 1.01702586E+01  DIODX(3) 5.91834296E-01  DIODX(4) 0.
 DI3DX(5) 1.57955385E+00 DSMALRBDX 0.


  DISTRIBUTION ACROSS SHOCK LAYER
         ETA                PDUM             STAENT            CAPH              AUDUM              V

0.                8.87416455E-01  1.71847739E-01  1.73540931E-01  5.81926496E-02   0.
1.00000000E-01    8.87916117E-01  2.17887586E-01  2.21551998E-01  8.51817581E-02  -8.53763806E-03
2.00000000E-01    8.88251828E-01  2.58710048E-01  2.64838611E-01  1.09515046E-01  -1.62351432E-02
3.00000000E-01    8.88423587E-01  2.95141228E-01  3.04065422E-01  1.31566142E-01  -2.32107081E-02
4.00000000E-01    8.88431394E-01  3.27843449E-01  3.39777993E-01  1.51641731E-01  -2.95513482E-02
5.00000000E-01    8.88275250E-01  3.57353595E-01  3.72428326E-01  1.69995903E-01  -3.53674415E-02
6.00000000E-01    8.87955155E-01  3.84111234E-01  4.02394096E-01  1.86840965E-01  -4.06961482E-02
7.00000000E-01    8.87471108E-01  4.08479545E-01  4.29993321E-01  2.02355690E-01  -4.56040206E-02
8.00000000E-01    8.86823109E-01  4.30761094E-01  4.55495698E-01  2.16691685E-01  -5.01390181E-02
9.00000000E-01    8.86011159E-01  4.51209889E-01  4.79131444E-01  2.29978366E-01  -5.43420792E-02
1.00000000E+00    8.85035258E-01  4.70040672E-01  5.01098264E-01  2.42326870E-01  -5.82483610E-02

PATH LENGTH     PRESSURE   TEMPERATURE     ENTHALPY     DENSITY       DENSITY(ND)
 (Y/DELTA)        (ATM)        (DEG K)     (CAL/GM)     (GM/CC)
     0.          5.52527E-01  7.96200E+03  9.52576E+03  1.26024E-05  4.63958E+01
     1.00000E-01 5.52838E-01  1.01822E+04  1.20778E+04  9.20839E-06  3.39009E+01
     2.00000E-01 5.53047E-01  1.13916E+04  1.43407E+04  7.76401E-06  2.85834E+01
     3.00000E-01 5.53154E-01  1.21063E+04  1.63601E+04  6.91921E-06  2.54732E+01
     4.00000E-01 5.53159E-01  1.26131E+04  1.81728E+04  6.32896E-06  2.33002E+01
     5.00000E-01 5.53062E-01  1.30066E+04  1.98086E+04  5.88289E-06  2.16580E+01
     6.00000E-01 5.52863E-01  1.33299E+04  2.12918E+04  5.52892E-06  2.03548E+01
     7.00000E-01 5.52561E-01  1.36048E+04  2.26426E+04  5.23968E-06  1.92900E+01
     8.00000E-01 5.52158E-01  1.38447E+04  2.38777E+04  4.99758E-06  1.83987E+01
     9.00000E-01 5.51652E-01  1.40582E+04  2.50112E+04  4.79108E-06  1.76385E+01
     1.00000E+00 5.51045E-01  1.42509E+04  2.60550E+04  4.61247E-06  1.69809E+01

    QRYPC 2.42895748E+03 5.19897229E+03  QRYPL 1.73237704E+03 3.58917941E+03  QRYO-4.32817548E-02  QRY1 9.14049630E-02

    PRATIO 9.20244273E-01  QRATIO 0.
```

BODY AND SHOCK PROPERTIES

```
     X 2.65000000D-01      DELTA 3.83232593D-02          W 1.30616179D+00      IO(2) 2.81058505D+00      IO(3) 1.05144491D+00
 IO(4) 0.                  IO(5) 4.83552913D-01     SMALRB 0.                  I1(2) 4.34995541E+00      I1(3) 2.01374188E+00
 I1(4)-2.52055917E-01      I1(5) 2.17975511E+00        RBX 1.00000000E+00     THETAB 1.30579633E+00          Q 1.00000000E+00
DDELDX 3.79465737E-04       DWDX-9.93837718E-01   DIODX(2) 1.00308012E+01   DIODX(3) 6.30937633E-01   DIODX(4) 0.
DIODX(5) 1.50458006E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	8.74660672E-01	1.70068860E-01	1.72047066E-01	6.29000234E-02	0.
1.00000000E-01	8.75282720E-01	2.16056993E-01	2.20329994E-01	9.20527569E-02	-8.50241317E-03
2.00000000E-01	8.75793862E-01	2.56714783E-01	2.63846124E-01	1.18327348E-01	-1.61654142E-02
3.00000000E-01	8.76194096E-01	2.92900721E-01	3.03268163E-01	1.42129968E-01	-2.31074635E-02
4.00000000E-01	8.76483425E-01	3.25300783E-01	3.39147924E-01	1.63793798E-01	-2.94257332E-02
5.00000000E-01	8.76661846E-01	3.54469264E-01	3.71942318E-01	1.83594715E-01	-3.52006832E-02
6.00000000E-01	8.76729362E-01	3.80858633E-01	4.02032914E-01	2.01763107E-01	-4.04995061E-02
7.00000000E-01	8.76685970E-01	4.04841669E-01	4.29740853E-01	2.18492874E-01	-4.53787534E-02
8.00000000E-01	8.76531673E-01	4.26728107E-01	4.55338355E-01	2.33948382E-01	-4.98863621E-02
9.00000000E-01	8.76266468E-01	4.46777312E-01	4.79057694E-01	2.48269874E-01	-5.40632344E-02
1.00000000E+00	8.75890358E-01	4.65208025E-01	5.01098264E-01	2.61577743E-01	-5.79444828E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.44585E-01	7.89595E+03	9.42716E+03	1.25754E-05	4.62967E+01
1.00000E-01	5.44972E-01	1.01034E+04	1.19763E+04	9.16984E-06	3.37590E+01
2.00000E-01	5.45291E-01	1.13380E+04	1.42301E+04	7.71323E-06	2.83964E+01
3.00000E-01	5.45540E-01	1.20590E+04	1.62359E+04	6.87257E-06	2.53015E+01
4.0000QE-01	5.45720E-01	1.25672E+04	1.80319E+04	6.28885E-06	2.31525E+01
5.00000E-01	5.45831E-01	1.29600E+04	1.96487E+04	5.84962E-06	2.15355E+01
6.00000E-01	5.45873E-01	1.32818E+04	2.11115E+04	5.50233E-06	2.02569E+01
7.00000E-01	5.45846E-01	1.35544E+04	2.24409E+04	5.21952E-06	1.92158E+01
8.00000E-01	5.45750E-01	1.37917E+04	2.36541E+04	4.98362E-06	1.83473E+01
9.00000E-01	5.45585E-01	1.40023E+04	2.47655E+04	4.78313E-06	1.76092E+01
1.00000E+00	5.45351E-01	1.41918E+04	2.57871E+04	4.61039E-06	1.69732E+01

QRYPC 2.33727532E+03 4.98710880E+03   QRYPL 1.68195499E+03 3.44851300E+03   QRYO-4.18037388E-02   QRY1 8.77383237E-02

PRATIO 9.07016621E-01   QRATIO 0.

```
BODY AND SHOCK PROPERTIES
     X 2.85000000D-01      DELTA 3.83322171D-02        W 1.28630124D+00      IO(2) 3.00973490D+00      IO(3) 1.06443651D+00
 IO(4) 0.                  IO(5) 5.12863153D-01    SMALRB 0.                 I1(2) 4.66521638E+00      I1(3) 2.17565058E+00
 I1(4)-2.68757589E-01      I1(5) 2.33773183E+00       RBX 1.00000000E+00    THETAB 1.28579632E+00          Q 1.00000000E+00
DDELDX 5.24266711E-04       DWDX-9.92366022E-01  DIODX(2) 9.87756111E+00  DIODX(3) 6.67528732E-01  DI3DX(4) 0.
DI3DX(5) 1.42338700E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	8.61041314E-01	1.68117934E-01	1.70401437E-01	6.75796349E-02	0.
1.00000000E-01	8.61793750E-01	2.14062706E-01	2.18988358E-01	9.88921797E-02	-8.46405137E-03
2.00000000E-01	8.62491727E-01	2.54553201E-01	2.62760025E-01	1.27101465E-01	-1.60892648E-02
3.00000000E-01	8.63135245E-01	2.90483541E-01	3.02398472E-01	1.52647036E-01	-2.29944534E-02
4.00000000E-01	8.63724305E-01	3.22565663E-01	3.38462735E-01	1.75889173E-01	-2.92770039E-02
5.00000000E-01	8.64258907E-01	3.51372945E-01	3.71415385E-01	1.97125985E-01	-3.50174976E-02
6.00000000E-01	8.64739050E-01	3.77371964E-01	4.01642469E-01	2.16606268E-01	-4.02831863E-02
7.00000000E-01	8.65164734E-01	4.00945986E-01	4.29468713E-01	2.34539294E-01	-4.51306382E-02
8.00000000E-01	8.65535960E-01	4.22412564E-01	4.55169228E-01	2.51102363E-01	-4.96077789E-02
9.00000000E-01	8.65852727E-01	4.42036895E-01	4.78978638E-01	2.66446682E-01	-5.37554809E-02
1.00000000E+00	8.66115035E-01	4.60042071E-01	5.01098264E-01	2.80701995E-01	-5.76088152E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.36105E-01	7.82778E+03	9.31901E+03	1.25440E-05	4.61810E+01
1.00000E-01	5.36574E-01	1.00167E+04	1.18658E+04	9.12953E-06	3.36105E+01
2.00000E-01	5.37008E-01	1.12790E+04	1.41102E+04	7.65932E-06	2.81980E+01
3.00000E-01	5.37409E-01	1.20075E+04	1.61019E+04	6.82264E-06	2.51177E+01
4.00000E-01	5.37776E-01	1.25174E+04	1.78803E+04	6.24572E-06	2.29937E+01
5.00000E-01	5.38109E-01	1.29097E+04	1.94771E+04	5.81374E-06	2.14034E+01
6.00000E-01	5.38408E-01	1.32298E+04	2.09183E+04	5.47356E-06	2.01510E+01
7.00000E-01	5.38673E-01	1.35002E+04	2.22250E+04	5.19764E-06	1.91352E+01
8.00000E-01	5.38904E-01	1.37347E+04	2.34149E+04	4.96839E-06	1.82912E+01
9.00000E-01	5.39101E-01	1.39423E+04	2.45027E+04	4.77434E-06	1.75768E+01
1.00000E+00	5.39264E-01	1.41285E+04	2.55008E+04	4.60793E-06	1.69642E+01

```
QRYPC 2.24121519E+03 4.76650570E+03  QRYPL 1.58952427E+03 3.29917698E+03  QRY0-3.98432583E-02  QRY1 8.38906122E-02

PRATIO 8.92893447E-01  QRATIO 0.
```

```
       BODY AND SHOCK PROPERTIES
         X 3.05000000D-01      DELTA 3.83444130D-02         W 1.26647563D+00      IO(2) 3.20568291D+00      IO(3) 1.07813296D+00
     IO(4) 0.                  IO(5) 5.40489908D-01    SMALRB 0.                  I1(2) 4.97751913E+00      I1(3) 2.34741564E+00
     I1(4)-2.84900603E-01      I1(5) 2.49422619E+00       RBX 1.00000000E+00     THETAB 1.26579633E+00          Q 1.00000000E+00
    DDELDX 7.05349136E-04       DWDX-9.90361191E-01  DIODX(2) 9.70960478E+00   DIODX(3) 7.01294246E-01   DIODX(4) 0.
  DIODX(5) 1.33582778E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	8.46598132E-01	1.65995312E-01	1.68603671E-01	7.22268580E-02	0.
1.00000000E-01	8.47488505E-01	2.11905474E-01	2.17526624E-01	1.05694712E-01	-8.42186945E-03
2.00000000E-01	8.48383998E-01	2.52226647E-01	2.61579788E-01	1.35831176E-01	-1.60054264E-02
3.00000000E-01	8.49284610E-01	2.87891834E-01	3.01455799E-01	1.63110079E-01	-2.28699049E-02
4.00000000E-01	8.50190343E-01	3.19641242E-01	3.37721885E-01	1.87919458E-01	-2.91129508E-02
5.00000000E-01	8.51101196E-01	3.48068972E-01	3.7084[illegible]021E-01	2.10580135E-01	-3.48152962E-02
6.00000000E-01	8.52017169E-01	3.73656901E-01	4.01222321E-01	2.31359667E-01	-4.00442693E-02
7.00000000E-01	8.52938262E-01	3.96799639E-01	4.29176547E-01	2.50482960E-01	-4.48564655E-02
8.00000000E-01	8.53864475E-01	4.17823183E-01	4.54988066E-01	2.68140441E-01	-4.92998041E-02
9.00000000E-01	8.54795807E-01	4.36999018E-01	4.78894145E-01	2.84494424E-01	-5.34151295E-02
1.00000000E+00	8.55732260E-01	4.54554918E-01	5.01098264E-01	2.99684109E-01	-5.72374703E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.27113E-01	7.75693E+03	9.20135E+03	1.25106E-05	4.60579E+01
1.00000E-01	5.27667E-01	9.91918E+03	1.17462E+04	9.09083E-06	3.34681E+01
2.00000E-01	5.28225E-01	1.12145E+04	1.39813E+04	7.60250E-06	2.79888E+01
3.00000E-01	5.28785E-01	1.19517E+04	1.59582E+04	6.76951E-06	2.49221E+01
4.00000E-01	5.29349E-01	1.24637E+04	1.77182E+04	6.19965E-06	2.28241E+01
5.00000E-01	5.29916E-01	1.28556E+04	1.92940E+04	5.77530E-06	2.12619E+01
6.00000E-01	5.30487E-01	1.31740E+04	2.07123E+04	5.44264E-06	2.00372E+01
7.00000E-01	5.31060E-01	1.34421E+04	2.19952E+04	5.17403E-06	1.90483E+01
8.00000E-01	5.31637E-01	1.36739E+04	2.31605E+04	4.95186E-06	1.82304E+01
9.00000E-01	5.32217E-01	1.38784E+04	2.42235E+04	4.76469E-06	1.75413E+01
1.00000E+00	5.32800E-01	1.40612E+04	2.51966E+04	4.60505E-06	1.69536E+01

```
QRYPC 2.14137542E+03 4.53871746E+03   QRYPL 1.53431179E+03 3.15038950E+03   QRYO-3.82305706E-02   QRY1 7.99738740E-02

PRATIO 8.77915975E-01   QRATIO 0.
```

```
        BODY AND SHOCK PROPERTIES
          X 3.25000000D-01       DELTA 3.83606954D-02           W 1.24669744D+00        IO(2) 3.39811676D+00        IO(3) 1.09247430D+00
      IO(4) 0.                   IO(5) 5.66305055D-01      SMALRB 0.                    I1(2) 5.28652790E+00        I1(3) 2.52855991E+00
      I1(4)-3.00406843E-01       I1(5) 2.64906995E+00         RBX 1.00000000E+00       THETAB 1.24579633E+00            Q 1.00000000E+00
     DDELDX 9.35683578E-04        DWDX-9.87637842E-01    DIODX(2) 9.52501224E+00     DIODX(3) 7.31860214E-01     DIODX(4) 0.
   DIODX(5) 1.24175159E+00 DSMALRBDX 0.

    DISTRIBUTION ACROSS SHOCK LAYER
           ETA                PDUM              STAENT            CAPH              AUDUM              V

   0.                 8.31379482E-01   1.63700762E-01   1.66652618E-01   7.68356193E-02   0.
   1.00000000E-01     8.32414801E-01   2.09585902E-01   2.15943864E-01   1.12453475E-01  -8.37497551E-03
   2.00000000E-01     8.33517589E-01   2.49736686E-01   2.60304650E-01   1.44508580E-01  -1.59122265E-02
   3.00000000E-01     8.34687846E-01   2.85128284E-01   3.00439509E-01   1.73510029E-01  -2.27314588E-02
   4.00000000E-01     8.35925573E-01   3.16531480E-01   3.36924845E-01   1.99874334E-01  -2.89306081E-02
   5.00000000E-01     8.37230770E-01   3.44562737E-01   3.70236795E-01   2.23945550E-01  -3.45905740E-02
   6.00000000E-01     8.38603436E-01   3.69720395E-01   4.00772123E-01   2.46010379E-01  -3.97787695E-02
   7.00000000E-01     8.40043571E-01   3.92411251E-01   4.28864095E-01   2.66309638E-01  -4.45518194E-02
   8.00000000E-01     8.41551176E-01   4.12970349E-01   4.54794696E-01   2.85047091E-01  -4.89576350E-02
   9.00000000E-01     8.43126250E-01   4.31675900E-01   4.78804126E-01   3.02396305E-01  -5.30370285E-02
   1.00000000E+00     8.44768794E-01   4.48760673E-01   5.01098264E-01   3.18506050E-01  -5.68249802E-02

   PATH LENGTH     PRESSURE   TEMPERATURE    ENTHALPY      DENSITY        DENSITY(ND)
    (Y/DELTA)        (ATM)       (DEG K)      (CAL/GM)      (GM/CC)
       0.          5.17637E-01  7.68485E+03  9.07416E+03  1.24725E-05  4.59177E+01
       1.00000E-01 5.18282E-01  9.81079E+03  1.16176E+04  9.05377E-06  3.33316E+01
       2.00000E-01 5.18968E-01  1.11441E+04  1.38433E+04  7.54306E-06  2.77699E+01
       3.00000E-01 5.19697E-01  1.18914E+04  1.58051E+04  6.71337E-06  2.47154E+01
       4.00000E-01 5.20468E-01  1.24060E+04  1.75458E+04  6.15075E-06  2.26441E+01
       5.00000E-01 5.21280E-01  1.27981E+04  1.90996E+04  5.73387E-06  2.11094E+01
       6.00000E-01 5.22135E-01  1.31145E+04  2.04941E+04  5.40960E-06  1.99155E+01
       7.00000E-01 5.23032E-01  1.33802E+04  2.17519E+04  5.14871E-06  1.89551E+01
       8.00000E-01 5.23970E-01  1.36091E+04  2.28915E+04  4.93403E-06  1.81647E+01
       9.00000E-01 5.24951E-01  1.38105E+04  2.39284E+04  4.75416E-06  1.75025E+01
       1.00000E+00 5.25974E-01  1.39903E+04  2.48754E+04  4.60126E-06  1.69396E+01

      QRYPC 2.03861193E+03 4.30579718E+03  QRYPL 1.49462160E+03 2.99531896E+03  QRY0-3.67489196E-02  QRY1 7.59384081E-02

      PRATIO 8.62134348E-01  QRATIO 0.
```

BODY AND SHOCK PROPERTIES

```
      X 3.45000000D-01      DELTA 3.83822177D-02          W 1.22698359D+00      IO(2) 3.58668624D+00      IO(3) 1.10739226D+00
  IO(4) 0.                  IO(5) 5.90177295D-01     SMALRB 0.                  I1(2) 5.59185196E+00      I1(3) 2.71852841E+00
  I1(4)-3.15177143E-01      I1(5) 2.80206731E+00        RBX 1.00000000E+00     THETAB 1.22579633E+00          Q 1.00000000E+00
 DDELDX 1.23283963E-03       DWDX-9.83923341E-01   DIODX(2) 9.32191547E+00   DIODX(3) 7.58782010E-01   DIODX(4) 0.
DIODX(5) 1.14110085E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	8.15446080E-01	1.61233886E-01	1.64546675E-01	8.13976497E-02	0.
1.00000000E-01	8.16632686E-01	2.07104842E-01	2.14238935E-01	1.19159254E-01	-8.32216173E-03
2.00000000E-01	8.17951385E-01	2.47085484E-01	2.58933791E-01	1.53123285E-01	-1.58073883E-02
3.00000000E-01	8.19402175E-01	2.82196490E-01	2.99349013E-01	1.83835182E-01	-2.25758873E-02
4.00000000E-01	8.20985057E-01	3.13241542E-01	3.36071194E-01	2.11740704E-01	-2.87258979E-02
5.00000000E-01	8.22700031E-01	3.40861095E-01	3.69584408E-01	2.37207702E-01	-3.43384901E-02
6.00000000E-01	8.24547096E-01	3.65571109E-01	4.00291670E-01	2.60542432E-01	-3.94811582E-02
7.00000000E-01	8.26526254E-01	3.87791390E-01	4.28531219E-01	2.82001925E-01	-4.42105486E-02
8.00000000E-01	8.28637503E-01	4.07866614E-01	4.54589033E-01	3.01803497E-01	-4.85745551E-02
9.00000000E-01	8.30880845E-01	4.26082138E-01	4.78708543E-01	3.20132133E-01	-5.26139459E-02
1.00000000E+00	8.33256278E-01	4.42676024E-01	5.01098264E-01	3.37146288E-01	-5.63636422E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	5.07717E-01	7.61197E+03	8.93742E+03	1.24296E-05	4.57599E+01
1.00000E-01	5.08455E-01	9.69062E+03	1.14801E+04	9.01957E-06	3.32057E+01
2.00000E-01	5.09277E-01	1.10677E+04	1.36963E+04	7.48139E-06	2.75429E+01
3.00000E-01	5.10180E-01	1.18265E+04	1.56425E+04	6.65443E-06	2.44984E+01
4.00000E-01	5.11165E-01	1.23443E+04	1.73634E+04	6.09919E-06	2.24543E+01
5.00000E-01	5.12233E-01	1.27363E+04	1.88944E+04	5.69053E-06	2.09498E+01
6.00000E-01	5.13383E-01	1.30512E+04	2.02641E+04	5.37453E-06	1.97864E+01
7.00000E-01	5.14615E-01	1.33146E+04	2.14958E+04	5.12171E-06	1.88557E+01
8.00000E-01	5.15930E-01	1.35406E+04	2.26086E+04	4.91492E-06	1.80944E+01
9.00000E-01	5.17327E-01	1.37388E+04	2.36183E+04	4.74273E-06	1.74605E+01
1.00000E+00	5.18806E-01	1.39152E+04	2.45382E+04	4.59737E-06	1.69253E+01

QRYPC 1.93347694E+03 4.06878736E+03 QRYPL 1.43729404E+03 2.89813865E+03 QRYD-3.50591578E-02 QRY1 7.24625195E-02

PRATIO 8.45611528E-01 QRATIO 0.

```
     BODY AND SHOCK PROPERTIES
    X 3.65000000D-01      DELTA 3.84105437D-02         W 1.20735754D+00      IO(2) 3.77099655D+00      IO(3) 1.12280875D+00
 IO(4) 0.                 IO(5) 6.11975065D-01     SMALRB 0.                 I1(2) 5.89301938E+00      I1(3) 2.91666171E+00
 I1(4)-3.29080709E-01     I1(5) 2.95298178E+00        RBX 1.00000000E+00    THETAB 1.20579633E+00          Q 1.00000000E+00
 DDELDX 1.62117929E-03     DWDX-9.78860316E-01   DIODX(2) 9.09717958E+00  DIODX(3) 7.81466146E-01   DIODX(4) 0.
DIODX(5) 1.03362350E+00 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	7.98874265E-01	1.58595126E-01	1.62284705E-01	8.59020248E-02	0.
1.00000000E-01	8.00217684E-01	2.04464204E-01	2.12411123E-01	1.25799767E-01	-8.26171935E-03
2.00000000E-01	8.01759426E-01	2.44276510E-01	2.57466778E-01	1.61661475E-01	-1.56876875E-02
3.00000000E-01	8.03499491E-01	2.79101612E-01	2.98184061E-01	1.94070088E-01	-2.23986152E-02
4.00000000E-01	8.05437880E-01	3.09778423E-01	3.35160796E-01	2.23501441E-01	-2.84930347E-02
5.00000000E-01	8.07574593E-01	3.36973013E-01	3.68889794E-01	2.50347781E-01	-3.40521695E-02
6.00000000E-01	8.09909628E-01	3.61220102E-01	3.99780936E-01	2.74935352E-01	-3.91435756E-02
7.00000000E-01	8.12442988E-01	3.82953304E-01	4.28177917E-01	2.97537714E-01	-4.38238998E-02
8.00000000E-01	8.15174671E-01	4.02527494E-01	4.54371083E-01	3.18385967E-01	-4.81409966E-02
9.00000000E-01	8.18104677E-01	4.20235572E-01	4.78607402E-01	3.37676681E-01	-5.21355701E-02
1.00000000E+00	8.21233007E-01	4.36321177E-01	5.01098264E-01	3.55578113E-01	-5.58424617E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	4.97399E-01	7.53863E+03	8.79115E+03	1.23822E-05	4.55854E+01
1.00000E-01	4.98235E-01	9.55776E+03	1.13337E+04	8.98969E-06	3.30957E+01
2.00000E-01	4.99195E-01	1.09848E+04	1.35406E+04	7.41803E-06	2.73096E+01
3.00000E-01	5.00278E-01	1.17571E+04	1.54710E+04	6.59305E-06	2.42724E+01
4.00000E-01	5.01485E-01	1.22786E+04	1.71715E+04	6.04520E-06	2.22555E+01
5.00000E-01	5.02816E-01	1.26709E+04	1.86789E+04	5.64499E-06	2.07821E+01
6.00000E-01	5.04270E-01	1.29843E+04	2.00229E+04	5.33754E-06	1.96503E+01
7.00000E-01	5.05847E-01	1.32453E+04	2.12276E+04	5.09313E-06	1.87505E+01
8.00000E-01	5.07548E-01	1.34685E+04	2.23127E+04	4.89455E-06	1.80194E+01
9.00000E-01	5.09372E-01	1.36634E+04	2.32942E+04	4.73041E-06	1.74151E+01
1.00000E+00	5.11320E-01	1.38363E+04	2.41859E+04	4.59294E-06	1.69090E+01

```
QRYPC 1.82689583E+03 3.82984654E+03  QRYPL 1.36652744E+03 2.73399377E+03  QRYO-3.32145764E-02  QRY1 6.82700528E-02

PRATIO 8.28426680E-01  QRATIO 0.
```

BODY AND SHOCK PROPERTIES

```
       X 3.85000000D-01      DELTA 3.84478132D-02          W 1.18785164D+00      IO(2) 3.95058555D+00      IO(3) 1.13863267D+00
   IO(4) 0.                  IO(5) 6.31564632D-01     SMALRB 0.                  I1(2) 6.18944904E+00      I1(3) 3.12216303E+00
   I1(4)-3.41941134E-01      I1(5) 3.10152217E+00        RBX 1.00000000E+00     THETAB 1.18579632E+00          Q 1.00000000E+00
  DDELDX 2.13433967E-03       DWDX-9.71905056E-01   DIODX(2) 8.84717003E+00   DIODX(3) 7.99192737E-01   DIODX(4) 0.
DIODX(5) 9.19365929E-01 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	7.81765758E-01	1.55786043E-01	1.59866082E-01	9.03331500E-02	0.
1.00000000E-01	7.83270436E-01	2.01667414E-01	2.10460247E-01	1.32357734E-01	-8.19124293E-03
2.00000000E-01	7.85040306E-01	2.41315129E-01	2.55903698E-01	1.70104026E-01	-1.55485804E-02
3.00000000E-01	7.87075367E-01	2.75851082E-01	2.96944886E-01	2.04193705E-01	-2.21931873E-02
4.00000000E-01	7.89375618E-01	3.06151761E-01	3.34193951E-01	2.35133567E-01	-2.82238460E-02
5.00000000E-01	7.91941061E-01	3.32910466E-01	3.68153261E-01	2.63340889E-01	-3.37218903E-02
6.00000000E-01	7.94771696E-01	3.56681795E-01	3.99240201E-01	2.89162359E-01	-3.87548951E-02
7.00000000E-01	7.97867521E-01	3.77913949E-01	4.27804413E-01	3.12888398E-01	-4.33794679E-02
8.00000000E-01	8.01228538E-01	3.96972548E-01	4.54141005E-01	3.34764128E-01	-4.76433869E-02
9.00000000E-01	8.04854745E-01	4.14158414E-01	4.78500783E-01	3.54997875E-01	-5.15872579E-02
1.00000000E+00	8.08746144E-01	4.29721022E-01	5.01098264E-01	3.73767821E-01	-5.52458114E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	4.86746E-01	7.46508E+03	8.63544E+03	1.23311E-05	4.53972E+01
1.00000E-01	4.87683E-01	9.41176E+03	1.11787E+04	8.96551E-06	3.30067E+01
2.00000E-01	4.88785E-01	1.08958E+04	1.33764E+04	7.35304E-06	2.70704E+01
3.00000E-01	4.90052E-01	1.16829E+04	1.52908E+04	6.52970E-06	2.40392E+01
4.00000E-01	4.91485E-01	1.22089E+04	1.69704E+04	5.98917E-06	2.20492E+01
5.00000E-01	4.93082E-01	1.26017E+04	1.84537E+04	5.59754E-06	2.06074E+01
6.00000E-01	4.94844E-01	1.29138E+04	1.97714E+04	5.29887E-06	1.95079E+01
7.00000E-01	4.96772E-01	1.31725E+04	2.09483E+04	5.06311E-06	1.86399E+01
8.00000E-01	4.98864E-01	1.33928E+04	2.20047E+04	4.87303E-06	1.79401E+01
9.00000E-01	5.01122E-01	1.35844E+04	2.29574E+04	4.71721E-06	1.73665E+01
1.00000E+00	5.03545E-01	1.37539E+04	2.38200E+04	4.58795E-06	1.68906E+01

```
QRYPC 1.71978072E+03 3.59092753E+03  QRYPL 1.24597723E+03 2.57890352E+03  QRYO-3.08466449E-02  QRY1 6.41719895E-02

PRATIO 8.10685285E-01  QRATIO 0.
```

BODY AND SHOCK PROPERTIES

```
      X 4.05000000D-01      DELTA 3.84969668D-02         W 1.16851140D+00     IO(2) 4.12490716D+00     IO(3) 1.15475665D+00
   IO(4) 0.                 IO(5) 6.48815079D-01    SMALRB 0.                 I1(2) 6.48039992E+00     I1(3) 3.33404295E+00
   I1(4)-3.53513781E-01     I1(5) 3.24731715E+00       RBX 1.00000000E+00    THETAB 1.16579633E+00         Q 1.00000000E+00
  DDELDX 2.81960229E-03      DWDX-9.62284164E-01  DIODX(2) 8.56689142E+00  DIODX(3) 8.11019931E-01  DIODX(4) 0.
DIODX(5) 7.98494991E-01 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	7.64257570E-01	1.52810924E-01	1.57292044E-01	9.46691036E-02	0.
1.00000000E-01	7.65926529E-01	1.98720843E-01	2.08387654E-01	1.38808838E-01	-8.10726551E-03
2.00000000E-01	7.67926781E-01	2.38209956E-01	2.54245875E-01	1.78424173E-01	-1.53835223E-02
3.00000000E-01	7.70258329E-01	2.72455945E-01	2.95632711E-01	2.14176833E-01	-2.19503109E-02
4.00000000E-01	7.72921170E-01	3.02375208E-01	3.33171733E-01	2.46605499E-01	-2.79065725E-02
5.00000000E-01	7.75915307E-01	3.28689867E-01	3.67375711E-01	2.76153136E-01	-3.33336676E-02
6.00000000E-01	7.79240737E-01	3.51975486E-01	3.98670181E-01	3.03187349E-01	-3.82991154E-02
7.00000000E-01	7.82897462E-01	3.72695605E-01	4.27411238E-01	3.28015757E-01	-4.28594167E-02
8.00000000E-01	7.86885481E-01	3.91227103E-01	4.53899142E-01	3.50897743E-01	-4.70522136E-02
9.00000000E-01	7.91204794E-01	4.07879081E-01	4.78388854E-01	3.72053561E-01	-5.09479603E-02
1.00000000E+00	7.95855402E-01	4.22907089E-01	5.01098264E-01	3.91671436E-01	-5.45512291E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	4.75845E-01	7.39147E+03	8.47052E+03	1.22778E-05	4.52009E+01
1.00000E-01	4.76885E-01	9.25095E+03	1.10154E+04	8.95059E-06	3.29518E+01
2.00000E-01	4.78130E-01	1.07987E+04	1.32043E+04	7.28932E-06	2.68358E+01
3.00000E-01	4.79582E-01	1.16041E+04	1.51026E+04	6.46509E-06	2.38013E+01
4.00000E-01	4.81240E-01	1.21353E+04	1.67611E+04	5.93163E-06	2.18374E+01
5.00000E-01	4.83104E-01	1.25290E+04	1.82197E+04	5.54861E-06	2.04273E+01
6.00000E-01	4.85174E-01	1.28399E+04	1.95105E+04	5.25884E-06	1.93605E+01
7.00000E-01	4.87451E-01	1.30964E+04	2.06590E+04	5.03190E-06	1.85250E+01
8.00000E-01	4.89934E-01	1.33138E+04	2.16863E+04	4.85049E-06	1.78572E+01
9.00000E-01	4.92623E-01	1.35023E+04	2.26093E+04	4.70321E-06	1.73150E+01
1.00000E+00	4.95519E-01	1.36683E+04	2.34423E+04	4.58237E-06	1.68701E+01

QRYPC 1.61294972E+03 3.35399937E+03   QRYPL 1.19247283E+03 2.45743993E+03   QRYO-2.91790074E-02   QRY1 6.04443814E-02

PRATIO 7.92529424E-01   QRATIO 0.

BODY AND SHOCK PROPERTIES

```
        X 4.25000000D-01      DELTA 3.85620747D-02          W 1.14940119D+00      IO(2) 4.29330288D+00      IO(3) 1.17105211D+00
    IO(4) 0.                  IO(5) 6.63603402D-01     SMALRB 0.                  I1(2) 6.76490294E+00      I1(3) 3.55104133E+00
    I1(4)-3.63453128E-01      I1(5) 3.38988112E+00        RBX 1.00000000E+00     THETAB 1.14579632E+00          Q 1.00000000E+00
   DDELDX 3.74389426E-03       DWDX-9.48876301E-01   DIODX(2) 8.24974069E+00   DIODX(3) 8.15721967E-01   DIODX(4) 0.
 DIODX(5) 6.71532352E-01 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	7.46539364E-01	1.49678628E-01	1.54567106E-01	9.88784978E-02	0.
1.00000000E-01	7.48373671E-01	1.95635603E-01	2.06197297E-01	1.45118269E-01	-8.00475937E-03
2.00000000E-01	7.50602551E-01	2.34974673E-01	2.52496693E-01	1.86583803E-01	-1.51830308E-02
3.00000000E-01	7.53226005E-01	2.68932746E-01	2.94250367E-01	2.23978210E-01	-2.16565323E-02
4.00000000E-01	7.56244033E-01	2.98468419E-01	3.32096450E-01	2.57872995E-01	-2.75241997E-02
5.00000000E-01	7.59656636E-01	3.24334175E-01	3.66558969E-01	2.88737474E-01	-3.28672783E-02
6.00000000E-01	7.63463812E-01	3.47127588E-01	3.98072260E-01	3.16960638E-01	-3.77531078E-02
7.00000000E-01	7.67665562E-01	3.67328242E-01	4.26999372E-01	3.42867632E-01	-4.22379755E-02
8.00000000E-01	7.72261886E-01	3.85324755E-01	4.53646114E-01	3.66732336E-01	-4.63592939E-02
9.00000000E-01	7.77252785E-01	4.01434826E-01	4.78271908E-01	3.88787089E-01	-5.01872839E-02
1.00000000E+00	7.82638257E-01	4.15920299E-01	5.01098264E-01	4.09230273E-01	-5.37262886E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	4.64814E-01	7.31815E+03	8.29690E+03	1.22241E-05	4.50031E+01
1.00000E-01	4.65956E-01	9.07777E+03	1.08444E+04	8.94486E-06	3.29307E+01
2.00000E-01	4.67344E-01	1.06941E+04	1.30250E+04	7.22746E-06	2.66080E+01
3.00000E-01	4.68977E-01	1.15208E+04	1.49073E+04	6.40026E-06	2.35627E+01
4.00000E-01	4.70856E-01	1.20582E+04	1.65445E+04	5.87345E-06	2.16232E+01
5.00000E-01	4.72981E-01	1.24531E+04	1.79783E+04	5.49889E-06	2.02443E+01
6.00000E-01	4.75351E-01	1.27630E+04	1.92418E+04	5.21798E-06	1.92101E+01
7.00000E-01	4.77967E-01	1.30173E+04	2.03615E+04	4.99988E-06	1.84072E+01
8.00000E-01	4.80829E-01	1.32320E+04	2.13591E+04	4.82720E-06	1.77714E+01
9.00000E-01	4.83937E-01	1.34172E+04	2.22521E+04	4.68853F-06	1.72609E+01
1.00000E+00	4.87290E-01	1.35798E+04	2.30550E+04	4.57621E-06	1.68474E+01

QRYPC 1.50745626E+03 3.12133637E+03   QRYPL 1.12544247E+03 2.29537486E+03   QRY0-2.73845991E-02   QRY1 5.63388419E-02

PRATIO 7.74155776E-01   QRATIO 0.

```
     BODY AND SHOCK PROPERTIES
       X 4.45000000D-01      DELTA 3.86488130D-02           W 1.13061277D+00      IO(2) 4.45496519D+00      IO(3) 1.18736282D+00
   IO(4) 0.                  IO(5) 6.75824310D-01      SMALRB 0.                     I1(2) 7.04166109E+00      I1(3) 3.77151139E+00
   I1(4)-3.71264459E-01      I1(5) 3.52856415E+00         RBX 1.00000000E+00      THETAB 1.12579633E+00          Q 1.00000000E+00
  DDELDX 5.00263317E-03      DWDX-9.30046259E-01    DIODX(2) 7.88711962E+00    DIODX(3) 8.11710373E-01    DIODX(4) 0.
DIODX(5) 5.39678756E-01 DSMALRBDX 0.

   DISTRIBUTION ACROSS SHOCK LAYER
          ETA                PDUM             STAENT            CAPH              AUDUM             V

 0.               7.28879141E-01   1.46405521E-01   1.51701367E-01   1.02915945E-01   0.
 1.00000000E-01   7.30877124E-01   1.92430359E-01   2.03897489E-01   1.51235653E-01  -7.87639427E-03
 2.00000000E-01   7.33327078E-01   2.31630841E-01   2.50662909E-01   1.94527977E-01  -1.49332958E-02
 3.00000000E-01   7.36229002E-01   2.65306418E-01   2.92803266E-01   2.33538725E-01  -2.12922753E-02
 4.00000000E-01   7.39582898E-01   2.94460067E-01   3.30972354E-01   2.68873134E-01  -2.70519903E-02
 5.00000000E-01   7.43388764E-01   3.19876074E-01   3.65706283E-01   3.01027502E-01  -3.22933398E-02
 6.00000000E-01   7.47646600E-01   3.42174981E-01   3.97448823E-01   3.30412640E-01  -3.70832888E-02
 7.00000000E-01   7.52356408E-01   3.61853057E-01   4.26570461E-01   3.57371521E-01  -4.14777438E-02
 8.00000000E-01   7.57518186E-01   3.79311084E-01   4.53382930E-01   3.82192726E-01  -4.55237451E-02
 9.00000000E-01   7.63131935E-01   3.94875641E-01   4.78150410E-01   4.05120817E-01  -4.92611576E-02
 1.00000000E+00   7.69197655E-01   4.08815046E-01   5.01098264E-01   4.26364418E-01  -5.27239886E-02

 PATH LENGTH    PRESSURE   TEMPERATURE    ENTHALPY     DENSITY       DENSITY(ND)
  (Y/DELTA)       (ATM)      (DEG K)      (CAL/GM)     (GM/CC)
     0.         4.53818E-01  7.24558E+03  8.11546E+03  1.21726E-05  4.48136E+01
     1.00000E-01  4.55062E-01  8.89247E+03  1.06667E+04  8.95254E-06  3.29590E+01
     2.00000E-01  4.56587E-01  1.05837E+04  1.28396E+04  7.16777E-06  2.63883E+01
     3.00000E-01  4.58394E-01  1.14333E+04  1.47063E+04  6.33676E-06  2.33289E+01
     4.00000E-01  4.60482E-01  1.19779E+04  1.63223E+04  5.81587E-06  2.14112E+01
     5.00000E-01  4.62852E-01  1.23745E+04  1.77312E+04  5.44940E-06  2.00621E+01
     6.00000E-01  4.65503E-01  1.26836E+04  1.89672E+04  5.17713E-06  1.90597E+01
     7.00000E-01  4.68436E-01  1.29359E+04  2.00580E+04  4.96768E-06  1.82886E+01
     8.00000E-01  4.71649E-01  1.31478E+04  2.10257E+04  4.80358E-06  1.76845E+01
     9.00000E-01  4.75145E-01  1.33298E+04  2.18885E+04  4.67340E-06  1.72052E+01
     1.00000E+00  4.78921E-01  1.34890E+04  2.26612E+04  4.56948E-06  1.68226E+01

   QRYPC 1.40448454E+03 2.89544386E+03   QRYPL 1.07954983E+03 2.13901709E+03   QRYO-2.58362710E-02   QRY1 5.23630830E-02

   PRATIO 7.55842256E-01   QRATIO 0.
```

```
BODY AND SHOCK PROPERTIES
     X 4.65000000D-01       DELTA 3.87651554D-02          W 1.11227749D+00      IO(2) 4.60888871D+00      IO(3) 1.20349638D+00
 IO(4) 0.                   IO(5) 6.85406289D-01     SMALRB 0.                  I1(2) 7.30890622E+00      I1(3) 3.99325074E+00
 I1(4)-3.76234022E-01       I1(5) 3.66248022E+00        RBX 1.00000000E+00     THETAB 1.10579633E+00          Q 1.00000000E+00
DDELDX 6.73250402E-03        DWDX-9.03395525E-01   DIODX(2) 7.46825194E+00   DIODX(3) 7.96977235E-01   DIODX(4) 0.
DIODX(5) 4.05452401E-01 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	7.11661651E-01	1.43019918E-01	1.48714003E-01	1.06715365E-01	0.
1.00000000E-01	7.13817727E-01	1.89135550E-01	2.01503537E-01	1.57087576E-01	-7.71146688E-03
2.00000000E-01	7.16472709E-01	2.28212100E-01	2.48756630E-01	2.02176869E-01	-1.46141735E-02
3.00000000E-01	7.19626597E-01	2.61614589E-01	2.91300859E-01	2.42772925E-01	-2.08290118E-02
4.00000000E-01	7.23279391E-01	2.90392325E-01	3.29806689E-01	2.79515506E-01	-2.64539229E-02
5.00000000E-01	7.27431092E-01	3.15362664E-01	3.64823068E-01	3.12928425E-01	-3.15690968E-02
6.00000000E-01	7.32081699E-01	3.37169944E-01	3.96803763E-01	3.43444669E-01	-3.62408196E-02
7.00000000E-01	7.37231212E-01	3.56327655E-01	4.26127134E-01	3.71425272E-01	-4.05243620E-02
8.00000000E-01	7.42879631E-01	3.73249091E-01	4.53111170E-01	3.97173663E-01	-4.44661757E-02
9.00000000E-01	7.49026957E-01	3.88269931E-01	4.78025073E-01	4.20946716E-01	-4.81055853E-02
1.00000000E+00	7.55673189E-01	4.01665107E-01	5.01098264E-01	4.42963346E-01	-5.14761047E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	4.43098E-01	7.17448E+03	7.92780E+03	1.21271E-05	4.46463E+01
1.00000E-01	4.44440E-01	8.70132E+03	1.04840E+04	8.97317E-06	3.30349E+01
2.00000E-01	4.46093E-01	1.04654E+04	1.26501E+04	7.11575E-06	2.61968E+01
3.00000E-01	4.48057E-01	1.13425E+04	1.45017E+04	6.27687E-06	2.31084E+01
4.00000E-01	4.50331E-01	1.18952E+04	1.60969E+04	5.76080E-06	2.12085E+01
5.00000E-01	4.52916E-01	1.22939E+04	1.74810E+04	5.40174E-06	1.98866E+01
6.00000E-01	4.55812E-01	1.26025E+04	1.86898E+04	5.13755E-06	1.89140E+01
7.00000E-01	4.59018E-01	1.28529E+04	1.97517E+04	4.93628E-06	1.81730E+01
8.00000E-01	4.62535E-01	1.30621E+04	2.06897E+04	4.78032E-06	1.75988E+01
9.00000E-01	4.66363E-01	1.32410E+04	2.15223E+04	4.65819E-06	1.71492E+01
1.00000E+00	4.70501E-01	1.33967E+04	2.22649E+04	4.5[illegible]23E-06	1.67960E+01

```
QRYPC 1.30513097E+03 2.67905321E+03   QRYPL 9.87257146E+02 1.98451536E+03   QRYD-2.38429715E-02   QRY1 4.85054568E-02

PRATIO 7.37987847E-01   QRATIO 0.
```

BODY AND SHOCK PROPERTIES

```
      X 4.85000000D-01     DELTA 3.89223753D-02          W 1.09458348D+00      IO(2) 4.75380202D+00      IO(3) 1.21921299D+00
  IO(4) 0.                 IO(5) 6.92335272D-01     SMALRB 0.                  I1(2) 7.56419870E+00      I1(3) 4.21326137E+00
  I1(4)-3.77332056E-01     I1(5) 3.79040684E+00        RBX 1.00000000E+00     THETAB 1.08579633E+00          Q 1.00000000E+00
 DDELDX 9.12940781E-03      DWDX-8.65653706E-01   DIODX(2) 6.97639634E+00   DIODX(3) 7.68681739E-01   DIODX(4) 0.
DIODX(5) 2.71769150E-01 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	6.95423757E-01	1.39568052E-01	1.45638222E-01	1.10183209E-01	0.
1.00000000E-01	6.97726928E-01	1.85799025E-01	1.99041497E-01	1.62569302E-01	-7.49441750E-03
2.00000000E-01	7.00559019E-01	2.24769768E-01	2.46798131E-01	2.09416306E-01	-1.41964062E-02
3.00000000E-01	7.03920029E-01	2.57913329E-01	2.89758732E-01	2.51558628E-01	-2.02253375E-02
4.00000000E-01	7.07809958E-01	2.86326886E-01	3.28611231E-01	2.89671095E-01	-2.56777530E-02
5.00000000E-01	7.12228806E-01	3.10861832E-01	3.63917994E-01	3.24305363E-01	-3.06325730E-02
6.00000000E-01	7.17176574E-01	3.32186906E-01	3.96143223E-01	3.55916792E-01	-3.51549420E-02
7.00000000E-01	7.22653260E-01	3.50833198E-01	4.25673478E-01	3.84884578E-01	-3.92991084E-02
8.00000000E-01	7.28658866E-01	3.67226743E-01	4.52833258E-01	4.11527041E-01	-4.31106111E-02
9.00000000E-01	7.35193391E-01	3.81712459E-01	4.77896977E-01	4.36113366E-01	-4.66279604E-02
1.00000000E+00	7.42256835E-01	3.94571967E-01	5.01098264E-01	4.58872734E-01	-4.98839429E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	4.32988E-01	7.10502E+03	7.73645E+03	1.20967E-05	4.45344E+01
1.00000E-01	4.34422E-01	8.51144E+03	1.02991E+04	9.00787E-06	3.31626E+01
2.00000E-01	4.36185E-01	1.03430E+04	1.24593E+04	7.07306E-06	2.60396E+01
3.00000E-01	4.38278E-01	1.12495E+04	1.42965E+04	6.22384E-06	2.29132E+01
4.00000E-01	4.40700E-01	1.18115E+04	1.58715E+04	5.71099E-06	2.10251E+01
5.00000E-01	4.43451E-01	1.22128E+04	1.72315E+04	5.35820E-06	1.97263E+01
6.00000E-01	4.46532E-01	1.25210E+04	1.84136E+04	5.10112E-06	1.87799E+01
7.00000E-01	4.49942E-01	1.27696E+04	1.94472E+04	4.90712E-06	1.80657E+01
8.00000E-01	4.53681E-01	1.29761E+04	2.03559E+04	4.75840E-06	1.75182E+01
9.00000E-01	4.57749E-01	1.31518E+04	2.11589E+04	4.6434[illegible]-06	1.70949E+01
1.00000E+00	4.62147E-01	1.33040E+04	2.18717E+04	4.55458E-06	1.67678E+01

QRYPC 1.21090712E+03 2.47546848E+03   QRYPL 9.18319258E+02 1.85042460E+03   QRYO-2.21459375E-02   QRY1 4.49933172E-02

PRATIO 7.21149271E-01   QRATIO 0.

```
      BODY AND SHOCK PROPERTIES
        X 5.05000000D-01      DELTA 3.91364632D-02         W 1.07779909D+00      IO(2) 4.88808253D+00      IO(3) 1.23421220D+00
   IO(4) O.                   IO(5) 6.96691581D-01    SMALRB O.                  I1(2) 7.80415126E+00      I1(3) 4.42741643E+00
   I1(4)-3.73085561E-01       I1(5) 3.91064665E+00       RBX 1.00000000E+00     THETAB 1.06579633E+00          Q 1.00000000E+00
  DDELDX 1.24731112E-02        DWDX-8.11474025E-01  DIODX(2) 6.40215275E+00   DIODX(3) 7.24589699E-01  DIODX(4) O.
DIODX(5) 1.49827530E-01 DSMALRBDX O.


   DISTRIBUTION ACROSS SHOCK LAYER
         ETA                PDUM            STAENT            CAPH              AUDUM              V

O.                  6.80983442E-01  1.36123853E-01  1.42528604E-01  1.13179071E-01  O.
1.00000000E-01      6.83414379E-01  1.82495489E-01  1.96553694E-01  1.67524711E-01  -7.20285583E-03
2.00000000E-01      6.86376909E-01  2.21382260E-01  2.44819971E-01  2.16077369E-01  -1.36379220E-02
3.00000000E-01      6.89871030E-01  2.54286719E-01  2.88201633E-01  2.59716431E-01  -1.94217507E-02
4.00000000E-01      6.93896744E-01  2.82354772E-01  3.27404464E-01  2.99151866E-01  -2.46484395E-02
5.00000000E-01      6.98454050E-01  3.06472337E-01  3.63004520E-01  3.34963150E-01  -2.93947911E-02
6.00000000E-01      7.03542948E-01  3.27332824E-01  3.95476629E-01  3.67627928E-01  -3.37241115E-02
7.00000000E-01      7.09163438E-01  3.45485065E-01  4.25215693E-01  3.97543445E-01  -3.76890505E-02
8.00000000E-01      7.15315520E-01  3.61367901E-01  4.52552820E-01  4.25042773E-01  -4.13337531E-02
9.00000000E-01      7.21999195E-01  3.75335511E-01  4.77767712E-01  4.50407274E-01  -4.46955102E-02
1.00000000E+00      7.29214461E-01  3.87676203E-01  5.01098264E-01  4.73876255E-01  -4.78060391E-02

PATH LENGTH     PRESSURE   TEMPERATURE     ENTHALPY      DENSITY        DENSITY(ND)
 (Y/DELTA)          (ATM)         (DEG K)         (CAL/GM)       (GM/CC)
     O.            4.23997E-01  7.03909E+03  7.54554E+03  1.20893E-05  4.45072E+01
     1.00000E-01   4.25511E-01  8.33245E+03  1.01160E+04  9.05819E-06  3.33479E+01
     2.00000E-01   4.27355E-01  1.02170E+04  1.22715E+04  7.04753E-06  2.59456E+01
     3.00000E-01   4.29531E-01  1.11561E+04  1.40955E+04  6.18336E-06  2.27641E+01
     4.00000E-01   4.32037E-01  1.17289E+04  1.56513E+04  5.67078E-06  2.08771E+01
     5.00000E-01   4.34875E-01  1.21332E+04  1.69882E+04  5.32242E-06  1.95946E+01
     6.00000E-01   4.38043E-01  1.24412E+04  1.81445E+04  5.07081E-06  1.86683E+01
     7.00000E-01   4.41543E-01  1.26879E+04  1.91507E+04  4.88250E-06  1.79750E+01
     8.00000E-01   4.45373E-01  1.28918E+04  2.00311E+04  4.73947E-06  1.74484E+01
     9.00000E-01   4.49534E-01  1.30642E+04  2.08054E+04  4.63009F-06  1.70458E+01
     1.00000E+00   4.54027E-01  1.32129E+04  2.14894E+04  4.54668E-06  1.67387E+01

     QRYPC 1.12357610E+03 2.28858892E+03  QRYPL 8.64145351E+02 1.74991564E+03  QRYO-2.06741544E-02  QRY1 4.20042089E-02

     PRATIO 7.06174772E-01  QRATIO O.
```

```
    BODY AND SHOCK PROPERTIES
     X 5.25000000D-01      DELTA 3.94301327D-02          W 1.06229841D+00      IO(2) 5.00956305D+00      IO(3) 1.24810969D+00
 IO(4) 0.                  IO(5) 6.98659106D-01     SMALRB 0.                   I1(2) 8.02412690E+00      I1(3) 4.63007942E+00
 I1(4)-3.61449890E-01      I1(5) 4.02087606E+00        RBX 1.00000000E+00      THETAB 1.04579633E+00          Q 1.00000000E+00
DDELDX 1.71543230E-02       DWDX-7.33344428E-01  DIODX(2) 5.74032168E+00    DIODX(3) 6.63026725E-01   DIODX(4) 0.
DIODX(5) 5.85946633E-02 DSMALRBDX 0.
```

DISTRIBUTION ACROSS SHOCK LAYER

ETA	PDUM	STAENT	CAPH	AUDUM	V
0.	6.69487776E-01	1.32794560E-01	1.39465079E-01	1.15503409E-01	0.
1.00000000E-01	6.72015356E-01	1.79333004E-01	1.94102246E-01	1.71732837E-01	-6.80565932E-03
2.00000000E-01	6.75035068E-01	2.18162474E-01	2.42870088E-01	2.21921893E-01	-1.28802297E-02
3.00000000E-01	6.78546914E-01	2.50855084E-01	2.86666152E-01	2.66994282E-01	-1.83355106E-02
4.00000000E-01	6.82550893E-01	2.78605352E-01	3.26213857E-01	3.07694504E-01	-2.32616117E-02
5.00000000E-01	6.87047005E-01	3.02333556E-01	3.62102765E-01	3.44629302E-01	-2.77319693E-02
6.00000000E-01	6.92035250E-01	3.22757596E-01	3.94818172E-01	3.78298116E-01	-3.18070326E-02
7.00000000E-01	6.97515628E-01	3.40443876E-01	4.24763185E-01	4.09115800E-01	-3.55370129E-02
8.00000000E-01	7.03488140E-01	3.55843901E-01	4.52275411E-01	4.37429799E-01	-3.89539629E-02
9.00000000E-01	7.09952784E-01	3.69320989E-01	4.77639744E-01	4.63533311E-01	-4.21233691E-02
1.00000000E+00	7.16909562E-01	3.81170039E-01	5.01098264E-01	4.87675470E-01	-4.50453855E-02

PATH LENGTH (Y/DELTA)	PRESSURE (ATM)	TEMPERATURE (DEG K)	ENTHALPY (CAL/GM)	DENSITY (GM/CC)	DENSITY(ND)
0.	4.16839E-01	6.97862E+03	7.36099E+03	1.21196E-05	4.46184E+01
1.00000E-01	4.18413E-01	8.17373E+03	9.94068E+03	9.12920E-06	3.36093E+01
2.00000E-01	4.20293E-01	1.00926E+04	1.20931E+04	7.04683E-06	2.59431E+01
3.00000E-01	4.22480E-01	1.10671E+04	1.39053E+04	6.16149E-06	2.26837E+01
4.00000E-01	4.24973E-01	1.16508E+04	1.54435E+04	5.64637E-06	2.07872E+01
5.00000E-01	4.27772E-01	1.20582E+04	1.67588E+04	5.29966E-06	1.95108E+01
6.00000E-01	4.30878E-01	1.23660E+04	1.78909E+04	5.05092E-06	1.85951E+01
7.00000E-01	4.34290E-01	1.26109E+04	1.88713E+04	4.86576E-06	1.79134E+01
8.00000E-01	4.38009E-01	1.28119E+04	1.97249E+04	4.72586E-06	1.73983E+01
9.00000E-01	4.42034E-01	1.29809E+04	2.04720E+04	4.61946E-06	1.70066E+01
1.00000E+00	4.46365E-01	1.31258E+04	2.11288E+04	4.53883E-06	1.67098E+01

```
QRYPC 1.04563781E+03 2.12329269E+03  QRYPL 7.97019876E+02 1.62911928E+03  QRY0-1.91653562E-02  QRY1 3.90285795E-02

PRATIO 6.94253851E-01  QRATIO 0.
```

```
      BODY AND SHOCK PROPERTIES
     X 5.45000000D-01      DELTA 3.98354290D-02          W 1.04857618D+00      IO(2) 5.11508695D+00      IO(3) 1.26039236D+00
  IO(4) 0.                 IO(5) 6.98426416D-01     SMALRB 0.                  I1(2) 8.21805264E+00      I1(3) 4.81383353E+00
  I1(4)-3.39766606E-01     I1(5) 4.11805191E+00        RBX 1.00000000E+00     THETAB 1.02579633E+00          Q 1.00000000E+00
 DDELDX 2.36913975E-02      DWDX-6.15840400E-01   DIODX(2) 5.09095087E+00   DIODX(3) 5.94650155E-01   DIODX(4) 0.
DI3DX(5) 7.52600434E-02 DSMALRBDX 0.


  DISTRIBUTION ACROSS SHOCK LAYER
        ETA                 PDUM              STAENT              CAPH                AUDUM               V

0.                 6.62921901E-01   1.29720691E-01   1.36542433E-01   1.16805322E-01   0.
1.00000000E-01     6.65492902E-01   1.76460701E-01   1.91763211E-01   1.74830775E-01  -6.26253618E-03
2.00000000E-01     6.68445812E-01   2.15270208E-01   2.41009173E-01   2.26577949E-01  -1.18474741E-02
3.00000000E-01     6.71780633E-01   2.47789950E-01   2.85200252E-01   2.73013502E-01  -1.68591425E-02
4.00000000E-01     6.75497365E-01   2.75262328E-01   3.25076745E-01   3.14915331E-01  -2.13814978E-02
5.00000000E-01     6.79596007E-01   2.98641406E-01   3.61241124E-01   3.52916505E-01  -2.54828657E-02
6.00000000E-01     6.84076560E-01   3.18669143E-01   3.94188676E-01   3.87537470E-01  -2.92194164E-02
7.00000000E-01     6.88939023E-01   3.35929197E-01   4.24330331E-01   4.19210027E-01  -3.26377530E-02
8.00000000E-01     6.94183397E-01   3.50885498E-01   4.52009887E-01   4.48295433E-01  -3.57768652E-02
9.00000000E-01     6.99809681E-01   3.63910337E-01   4.77517178E-01   4.75098244E-01  -3.86696229E-02
1.00000000E+00     7.05817876E-01   3.75305087E-01   5.01098264E-01   4.99877019E-01  -4.13439315E-02

PATH LENGTH    PRESSURE   TEMPERATURE    ENTHALPY    DENSITY       DENSITY(ND)
 (Y/DELTA)       (ATM)       (DEG K)      (CAL/GM)     (GM/CC)
     0.         4.12751E-01  6.92605E+03  7.19060E+03  1.22174E-05  4.49786E+01
     1.00000E-01  4.14352E-01  8.04225E+03  9.78147E+03  9.23889E-06  3.40132E+01
     2.00000E-01  4.16191E-01  9.97715E+03  1.19327E+04  7.08611E-06  2.60877E+01
     3.00000E-01  4.18267E-01  1.09876E+04  1.37353E+04  6.17184E-06  2.27217E+01
     4.00000E-01  4.20581E-01  1.15821E+04  1.52582E+04  5.64898E-06  2.07968E+01
     5.00000E-01  4.23133E-01  1.19925E+04  1.65541E+04  5.29938E-06  1.95098E+01
     6.00000E-01  4.25923E-01  1.23000E+04  1.76643E+04  5.04919E-06  1.85887E+01
     7.00000E-01  4.28950E-01  1.25428E+04  1.86210E+04  4.86290E-06  1.79029E+01
     8.00000E-01  4.32216E-01  1.27406E+04  1.94501E+04  4.72180E-06  1.73834E+01
     9.00000E-01  4.35719E-01  1.29057E+04  2.01721E+04  4.61392E-06  1.69862E+01
     1.00000E+00  4.39459E-01  1.30462E+04  2.08037E+04  4.53142F-06  1.66825E+01

    QRYPC 9.80357692E+02 1.98595243E+03  QRYPL 7.55742156E+02 1.52720737E+03  QRYO-1.80570554E-02  QRY1 3.65401340E-02

    PRATIO 6.87445088E-01  QRATIO 0.

      RHO IS SMALLER THAN ALLOWED
```

Error Diagnostics

The following table gives the error diagnostics as the message and the corresponding subprogram which prints the message:

Message	Diagnosis	Subprogram
ICODE =, iteration did not converge	Nonfatal	MAIN
Iteration limit in RANH program stopped	Fatal	RANH
RHO is smaller than allowed	Nonfatal	THEP THER
RHO is larger than allowed	Fatal Nonfatal	THEP THER
H is zero or negative	Nonfatal	THEP THER
H is larger than allowed	Nonfatal	THEP THER
Iteration limit reached in PROPIT	Nonfatal	PROPIT
FEMP BLEW	Fatal	RADFLUX
N-R did not converge TBJA =	Nonfatal	FEMP
T did not converge TGUS =, DIG =, LK =	Nonfatal	FEMP

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., July 13, 1971.

APPENDIX A

SUBROUTINE INT1

Language: FORTRAN

Purpose: To solve a set of ordinary differential equations.

Use: CALL INT1 (II,N,NT,CI,SPEC,CIMAX,IERR,VAR,CUVAR,DER,ELE1,ELE2,ELT, ERRVAL,DERSUB,CHSUB,ITEXT)

II — INT1 is a closed subroutine composed of an initialization section and an integration section. The user is required to enter the initialization section before he starts his first integration step. The above calling sequence is used for both initialization and integration, with the value of the code word II determining which of the two sections of INT1 will be entered.

The user must set II = 0 in order to initialize.

During initialization the derivatives will be evaluated by using the initial values of the variables, but no integration will occur and control will be returned to the calling program. When INT1 is called with II > 0, entry is made to the integration section. Upon each entry to INT1, the subroutine stores a 1 in II so that the user need not supply a value of II > 0 for repetitive integration.

Besides serving as a means for specifying the entry point to INT1 from the calling program, II can also be set to specified values in CHSUB:

2 The user will store the integer 2 in II if the answers in CHSUB are not acceptable to him and he wishes to recompute the answers using a shorter interval. This shorter interval must be stored by the user in CI. It must be smaller than the computing interval just used.

3 The user will store the integer 3 in II if he wishes to return to the calling program. The answers for the interval are considered acceptable to the user and will be transferred to the VAR array (explained below) by INT1.

In DERSUB, II may be set to:

4 The user will store the integer 4 in II if he wishes to discontinue calculation of the present interval and return to the calling

program. On return to the calling program, the answers at the beginning of the interval will still be in the VAR array.

If the user does not set II to a value in either CHSUB or DERSUB, II will always be 1 upon the return to the calling program.

N An integer value supplied by the user which is the number of differential equations to be solved. INT1 is compiled to solve a maximum of 20 equations but may be recompiled for larger values of N if necessary.

NT An integer value supplied by the user which is the number of values in the ELT block described later in this writeup. INT1 is compiled with a maximum of 10 values in the ELT block but may be recompiled for more values if necessary.

CI A floating-point value supplied by the user which is the computing interval that INT1 will use initially. CI must be a signed value – positive if integrating forward, negative if integrating backward. Upon entry to CHSUB, CI will contain the computing interval that INT1 will use for the next step unless it has to take a short interval to hit an ELT value or a SPEC value described below. The computing interval used on the present step is available in CHSUB as the algebraic difference between CUVAR (1) and VAR (1). Since the subroutine is used on a binary computer and the interval variation is a halving and doubling process, CI should be a power of 2.

SPEC A floating-point value supplied by the user which specifies how often he wishes INT1 to return control to the calling program so that the user may print his results.

SPEC = 0.0: Control will be returned after every acceptable integration step.

SPEC > 0.0: SPEC is the absolute value of the specified increment of the independent variable for which the user desires control returned to the calling program.

The first printout is made at the initial value of the independent variable. The next return is at the nonzero integer multiple of SPEC closest to the initial value of the independent variable. The remaining returns occur at values which have been updated from this point by the increment given in SPEC. The return times generated by the increment given in SPEC are not altered by an intervening return due to an ELT value (explained subsequently in "ELT").

CIMAX A floating-point value supplied by the user which is the absolute value of the maximum computing interval that will be used. This value will be used if the doubling process would extend the computing interval to a value larger than CIMAX. CIMAX should be set to 0.0 if there is no desired maximum.

IERR — An integer value supplied by INT1 as an error code. It must be checked at every return to the calling program. It may have the following values:

1 A normal return, no error.

2 The ELT block is not monotonic in the direction of integration.

3 The variables have failed to meet the local-truncation-error requirements nine consecutive times. The answers at the beginning of the interval are still in the VAR array.

4 The variables have failed to meet the local-truncation-error requirements at least nine times over the last three intervals. An acceptable answer has been reached, however, and is in the VAR array.

VAR — A double-precision one-dimensional array containing the independent variable followed by the N dependent variables. The user must store the N+1 initial values (in the double-precision mode) in the array for initialization. INT1 will store the new values of the variables in VAR after each integration step when they are accepted by the user in CHSUB. The elements of the VAR block can be printed out in the calling program in accordance with the user's specification in SPEC.

CUVAR — A double-precision one-dimensional array which is given values by INT1 for two purposes. INT1 will store in the same order as the VAR array the values of the independent variable and N dependent variables at which the derivatives are to be evaluated in the DERSUB subroutine. Although CUVAR must be in a double-precision array in INT1 to maintain the "partial double-precision mode" of computation, the evaluation of the derivatives should be in single precision. Two suggested ways of doing this are as follows: (1) Consider CUVAR as a single-precision array of 2(N+1) elements in the DERSUB subroutine and, when using the ith element in a computation, assign to it the subscript value (2i-1), and (2) at the beginning of the DERSUB subroutine, transfer from CUVAR to some newly defined single-precision array and evaluate the derivatives using the latter.

INT1 will also store the tentative answers after each integration in the CUVAR array before calling CHSUB so that the user can check these values to decide to accept or reject the answers. If accepted, the CUVAR values will then be transferred to the VAR array. The decision as to whether the computation in the CHSUB subroutine should be done in single or double precision is a function of the individual application. In most cases single precision is adequate and can be accomplished by applying suggestions (1) and (2) in the preceding paragraph to the VAR and CUVAR arrays.

No values need to be initially stored in CUVAR.

DER — An N+1 single-precision array in which the user will store the derivatives evaluated in DERSUB. The derivatives should be arranged by the user in DERSUB in the same order as the VAR block so that DER (2) will be the derivative of the variable stored in VAR (2), for example. DER (1) will be unused. The derivatives must be computed using values of the variables which have been stored in CUVAR (not VAR) by INT1. To avoid unnecessary double-precision computation, the user should apply the suggestion described under CUVAR.

ELE1 — A one-dimensional array of N values supplied by the user each of which is the upper bound of local relative truncation error for the respective dependent variables. If the error for any variable exceeds its respective ELE1 value, the computing interval is halved and the integration restarted at the beginning of the present interval. If the error for all the variables is less than 1/128 of their respective ELE1 values, the computing interval is doubled for the next integration step.

ELE2 — A one-dimensional array of N values supplied by the user which represents a small value or "relative zero" for the respective dependent variables. If the absolute value of any of the variables is less than its respective ELE2 value, the relative error criterion for that variable will not be applied.

ELT — A one-dimensional array of NT values supplied by the user which are values of the independent variable at which the user specifically desires control returned to his program. The values in the ELT block must be monotonic in the direction of integration, or an error return will be given by INT1.

ERRVAL — A one-dimensional array of N elements in which INT1 stores an estimate of the local truncation error for each of the N dependent variables. The relative errors are computed from these values and compared with the specified ELE1 values.

APPENDIX A

DERSUB — A subroutine written by the user which will be called by INT1 to evaluate the derivatives. The derivatives must be stored in the DER array. INT1 will call DERSUB to evaluate the derivatives with the values of the variable it has stored in the CUVAR array.

These evaluations should be done with the use of single-precision arithmetic. The name given to the DERSUB subroutine must appear in an EXTERNAL statement in the calling program. The user may return to the calling program by storing a 4 in II.

CHSUB — A subroutine written by the user to allow certain logical control. After each integration step, INT1 will make available to the user in CHSUB the tentative answers in the CUVAR array. The VAR array will contain the last accepted answer (that is, the value of the variables at the beginning of the interval). Whenever the user specifies that the answers are acceptable, the values in the CUVAR block are transferred to the VAR block. In CHSUB the DER block will contain the values of the derivatives evaluated with the present CUVAR block. The user has three options:

(1) Not change II. In INT1, II = 1 denotes that the user has accepted the answers in the CUVAR block. Upon entry to CHSUB from INT1, II always equals 1.

(2) Set II = 2. The user does not accept the answers and wishes to recompute the interval using a new computing interval which he stores in CI. This computing interval must be smaller than the computing interval just used. This new value of CI will now be stored by INT1 as the normal computing interval for the subsequent integration steps.

(3) Set II = 3. The user accepts the answer but wishes to denote a condition that he can test in the calling program. Control will be returned to the calling program with the answers in the CUVAR array transferred to the VAR array.

The name given to the CHSUB subroutine must appear in an EXTERNAL statement in the calling program.

ITEXT — An integer code word supplied by the user which gives him the option to have INT1 print out a time history of the computing interval and the reasons for its variation. This printout should be requested only for problems which must be rerun because of unsatisfactory results the first time.

ITEXT = 0: No printout is requested.

ITEXT = 1: A printout is requested.

Restrictions: See arguments listed under CALL statement.

Method: INT1 is a fifth-order integration subroutine. The classical fourth-order Runge-Kutta formula is applied in conjunction with Richardson's "extrapolation to the limit" theory. INT1 is a variable-interval-size routine in which the interval is varied to meet a specified local relative truncation error.

Accuracy: The variable-interval-size mode of logic is used to make available an estimate of the local relative truncation error which is then controlled as explained in the ELE1 block discussion.

Roundoff error is controlled by use of the "partial double-precision mode of computation" as explained in reference (a) of this subroutine.

Reference: (a) Henrici, Peter: Discrete Variable Methods in Ordinary Differential Equations. John Wiley & Sons, Inc., c.1962.

Storage: 2703_8 locations

Subroutine date: August 1, 1968

APPENDIX B

SUBROUTINE ITR1

Language: FORTRAN

Purpose: To solve the single equation of the form $x = f(x)$ for one real root by the Newton-Raphson iteration method.

Use: CALL ITR1 (X,DELTX,FOFX,E1,E2,MAXI,ICODE)

X	An initial guess supplied by the user. On a normal return to the calling program from ITR1, X contains the root.
DELTX	An increment supplied by the user so that $\frac{f(x + DELTX) - f(x)}{DELTX}$ is a reasonable approximation to the derivative of $f(x)$.
FOFX	A function subprogram to evaluate $f(x)$.
E1	Relative error criterion.
E2	Absolute error criterion.
MAXI	A maximum iteration count supplied by the user.
ICODE	An integer supplied by ITR1 as an error code. This code should be tested by the user on return to the calling program. ICODE = 0: Normal return. ICODE = 1: Maximum iteration exceeded. ICODE = 2: Derivative = 0.

Restrictions: A function subprogram with a single argument x must be written by the user to evaluate $f(x)$. The name given to the FOFX subprogram must appear in an EXTERNAL statement in the calling program.

Method: The Newton-Raphson iteration technique (ref. (a) of this subroutine) is used where

$$X_{n+1} = qX_n + (1 - q)f(X_n)$$

$$q = \frac{a}{a - 1}$$

$$a = \frac{f(X_n) - f(X_{n-1})}{X_n - X_{n-1}}$$

APPENDIX B

Accuracy: The iteration process is continued until either of two convergence criteria are satisfied. These criteria are

(1) if $\left|f(X_n)\right| \geqq \epsilon_1$, then $\left|\dfrac{f(X_n) - X_n}{f(X_n)}\right| \leqq \epsilon_1$

(2) if $\left|f(X_n)\right| < \epsilon_1$, then $\left|f(X_n) - X_n\right| \leqq \epsilon_2$

Reference: (a) Scarborough, James B.: Numerical Mathematical Analysis. Fourth ed., Johns Hopkins Press, 1958, p. 192.

Storage: 137_8 locations

Subroutine date: August 1, 1968

APPENDIX C

SUBROUTINE AT62

Language: FORTRAN

Purpose: AT62 approximates the U.S. Standard Atmosphere, 1962 (ref. (a) of this subroutine). Computes density in slugs/ft^3, pressure in lb/ft^2, temperature in degrees Kelvin, and velocity of sound in ft/sec at any geometric altitude z in the range $-16\,500$ feet $\leqq z \leqq 2\,320\,000$ feet.

Use: CALL AT62 (Z,ANS)

Z	Geometric altitude in feet.	
ANS	A one-dimensional array that contains the results.	
	ANS(1)	Density in slugs/ft^3
	ANS(2)	Pressure in lb/ft^2
	ANS(3)	Temperature in degrees Kelvin
	ANS(4)	Velocity of sound in ft/sec

Restrictions: Range: For altitudes below -16 500 feet the values of density, pressure, temperature, and velocity of sound are not valid. The concept of the velocity of sound in the atmosphere becomes essentially meaningless at altitudes in excess of 300 000 feet. To point out this limitation, the velocity of sound at altitudes above 300 000 feet is set equal to the velocity of sound at 300 000 feet. For altitudes above 2 320 000 feet, density, pressure, and temperature are set equal to their respective values at 2 320 000 feet.

Method: The equations and techniques are identical to those used in computing the U.S. Standard Atmosphere, 1962 (ref. (a) of this subroutine).

Accuracy: The tables in the referenced publication were computed with the IBM 7094 electronic data processing system using some double-precision arithmetic. In converting the routine for the Control Data series 6000 computer systems all double-precision arithmetic was eliminated. Accordingly, there may be slight differences between the results of the converted subroutine and the tables.

Reference: (a) Anon.: U.S. Standard Atmosphere, 1962. NASA, U.S. Air Force, and U.S. Weather Bur., Dec. 1962.

Storage: 1654_8 locations

Subroutine date: August 1, 1968

REFERENCES

1. Garrett, L. Bernard; Suttles, John T.; and Perkins, John N. (With appendix C by G. Louis Smith and L. Bernard Garrett): A Modified Method of Integral Relations Approach to the Blunt-Body Equilibrium Air Flow Field, Including Comparisons With Inverse Solutions. NASA TN D-5434, 1969.

2. Taylor, Frances W.: A Computer Program To Determine Equilibrium-Air Flow-Field Data About A Blunt Body by the Method of Integral Relations. NASA TM X-2041, 1970.

3. Suttles, John T.: A Method of Integral Relations Solution for Radiating, Nonadiabatic, Inviscid Flow Over a Blunt Body. NASA TN D-5480, 1969.

4. Wilson, K. H.: RATRAP – A Radiation Transport Code. 6-77-67-12, Lockheed Missiles & Space Co., Mar. 14, 1967.

5. Scarborough, James B.: Numerical Mathematical Analysis. Fifth ed., Johns Hopkins Press, 1962.

NASA-Langley, 1971 —— 1 L-7807

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

FIRST CLASS MAIL

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

U.S.MAIL

POSTMASTER: If Undeliverable (Section 158 Postal Manual) Do Not Return

---

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546