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# COMPUTER USER'S GUIDE FOR A CHEMICALLY REACTING VISCOUS SHOCK-LAYER PROGRAM

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16. Abstracts

The present report describes the computer code for predicting viscous shock-layer flows over nonanalytic blunt bodies (Program VISLNABB) for hypersonic, low Reynolds number flows.

Four specific and one general body geometries are considered. In addition to sphere-cones, cylinder wedges and geometries defined in tabular form, options for hyperboloids and paraboloids are included. Details of the theory and results are included in a separate engineering report. The program, subroutines, variables in common and input and output data are described. Listings of the program code, output data for a sample case and the input data for this sample case are included.

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ABSTRACT

The present report describes the computer code for predicting viscous shock-layer flows over nonanalytic blunt bodies (Program VISLNABB) for hypersonic, low Reynolds number flows.

Two specific and one general body geometries are considered. Program options are for two-dimensional or axisymmetric flow over hyperboloids, paraboloids and geometries defined in tabular form. Details of the theory and results are included in a separate engineering report. The program, subroutines, variables in common and input and output data are described. A summary of the theory, listings of input and output data for four sample cases and a program listing are given in appendices.

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## FOREWARD

Reports Hypersonic Ionizing Air Viscous Shock-Layer Flows Over Nonanalytic Blunt Bodies (CR-2250) and Computer User's Guide For a Chemically Reacting Viscous Shock-Layer Program (CR-2251) by Miner and Lewis should be used together as source or reference material.

# INTRODUCTION

The computer code described in this report has been developed to predict hypersonic, low Reynolds number flows over nonanalytic blunt bodies. The program uses an implicit finite-difference method to solve the partial differential equations governing the viscous shock-layer flow. Two nonequilibrium gas chemistry models are included in the program. The first is for dissociating oxygen and the second is for ionizing, multicomponent air.

The viscous shock-layer method has several significant advantages over conventional boundary-layer methods. First, the flowfield is computed from the body to the shock and viscous effects need not be confined to a thin flow regime near the body. Second, effects such as entropy-layer swallowing and displacement-thickness interaction are avoided. Also, there is no need for any procedure to track streamlines from the shock crossing point to a boundary-layer edge. Third, the viscous shock-layer method, especially when shock slip is included, is applicable to much lower Reynolds number flows than boundary-layer methods are.

The principal purpose of this report is to describe the computer code in sufficient detail to allow a user to use the program and to properly interpret the solution data. Reasonable experience in using computer codes of this size is assumed as is some familiarity with the engineering aspects of the viscous flow problem.

The complete computer program is listed. Also listed are the output data for four sample cases and the required input data for these cases. All of the input variables are described as are the output variables for a converged station solution. All variables in common are described as are the variables in the subroutine or function argument lists. In the variable descriptions, a superscript * denotes a dimensional quantity. All other variables are nondimensional. Each subroutine or function is described in a separate subsection. As a further aid in using the program, an example is included of the Job Control Language needed to run the program on an IBM 370 computer. Also included are a list of all of the common statements and a listing of the occurrence of the common statements by subroutines. Finally, a section is included on preparation of input data with specific advice and suggestions.

Questions on the use of the computer program should be directed to the second author of this report (Dr. Clark H. Lewis) who was the principal investigator of contract NAS9-12630.

## DESCRIPTION OF PROGRAM

Program VISLNABB is a Fortran computer program for predicting hypersonic, low Reynolds numbers, viscous shock-layer flows over nonanalytic axisymmetric or two-dimensional blunt bodies. The governing conservation equations follow the equations given by Davis for perfect gas or dissociating oxygen viscous shock layers but are extended to a more general chemistry; i.e. nonequilibrium, multicomponent air. The method of solution of the equations follows the procedure of Davis using an implicit finite-difference method.

Besides the more general flow chemistry, the present program differs from the methods of Davis in several important respects. First, the present method includes the general extension to nonanalytic, blunt bodies, where the methods of Davis were restricted to analytic blunt bodies such as hyperboloids and paraboloids. A second extension, required by the first, was the removal of the assumption that the shock and body angles were the same for the first global (TVSL) iteration. This assumption was quite good for the analytic, blunt bodies which Davis considered, but was unusable for some classes of non-analytic bodies. This assumption was removed by including the provision for an initial shock shape (and subsequent updating of the shock shape) which need not be the same as the body shape. For example, the shock shape might be obtained from a blunt body, method of characteristics procedure. A third extension was the inclusion of the provision for specifying a body geometry by tabular arrays.

The viscous shock-layer equations are principally parabolic in nature, but there is a dependence upon the downstream shock shape which introduces a slight elliptic nature of the governing equations. The equations are solved in a streamwise direction using a marching integration procedure. The elliptic nature is then satisfied with global iteration.

The dimensional, physical equations are first nondimensionalized by freestream and reference variables. The equations are then normalized by dividing the variables by the variable values behind the shock. The mass conservation (or continuity) and normal momentum equations are integrated using the trapezoidal rule. The streamwise momentum, energy and species conservation equations are of the standard parabolic form

$$W'' + A_1 W' + A_2 W + A_3 + A_4 W_s = 0$$

where W represents the dependent variable, the prime denotes differentiation with respect to $\eta$, $(y/y_{sh})$, the subscript s denotes differentiation with respect to s and the $A_i$ are the functions of the program variables. These equations are integrated by writing the equations in finite-difference form and solving the resulting system of simultaneous algebraic equations.*

The first global iteration is for a thin viscous shock layer (TVSL) only. After the first global iteration is completed the shock data are updated and

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*The solution procedure is discussed in Appendix A.

subsequent global iterations made for a fully viscous shock layer (FVSL) or for TVSL. A major function of the first global iteration is to refine the initial shock shape and to store v profiles on tape or disc. A considerable amount of computing time is saved by the first global iteration being for the binary gas (dissociating oxygen) and switching to the multicomponent air chemistry (if needed) after the first global iteration is completed. The data retained from global iteration to global iteration (the shock data and the v profiles) are largely chemistry independent.

The binary gas chemistry model has another advantage over the multicomponent gas chemistry model. The rate of production terms for dissociating oxygen are written in a form which allows a closer approach to equilibrium than possible for multicomponent air. For near-equilibrium flows it may be found that at the stagnation point a converged station solution is easily obtained for dissociating oxygen but a converged station solution can not be obtained for multicomponent air.

There is in the program no global iteration convergence criterion. For analytic bodies (e.g. hyperboloids) the second and third global iterations give nearly identical results. For some highly nonanalytic bodies, with the shock data averaging which is required, global iteration convergence may be neither practical nor fully possible. The second global iteration, however, will account for the major flow field effects of interest and may be considered adequate for most cases.

In the following subsections a brief description of each routine or subroutine will be given.

## MAIN Routine

MAIN is the master routine of the program. In addition to controlling the overall computational flow of the program, MAIN initializes many of the program variables, reads much of the input data, calculates many of the program variables, and calculates the shock data for the next global iteration. Flow diagrams of MAIN by function and by subroutines called are given in Figs. 1 and 2.

The first function of MAIN is the initialization of counters and of some input/output unit numbers. The next function is the initialization of many of the NAMELIST variables, followed by reading of the NAMELIST INPUT and the readjustment of some of the variables. The next functions are the optional input of the shock shape data, the wall-temperature distribution and the s locations for specific solutions. The normal spacing of the finite-difference grid is next calculated and the reaction rate data are read by Subroutine RTEDTA. This part of the program is performed only once for each calculation.

The global iterations begin after the comment "BEGIN MAIN LOOP." The shock shape data are optionally printed and variables are initialized for the beginning of each global iteration. The reaction rate constant and stoichiometric coefficient arrays are filled in Subroutine SET2. Freestream

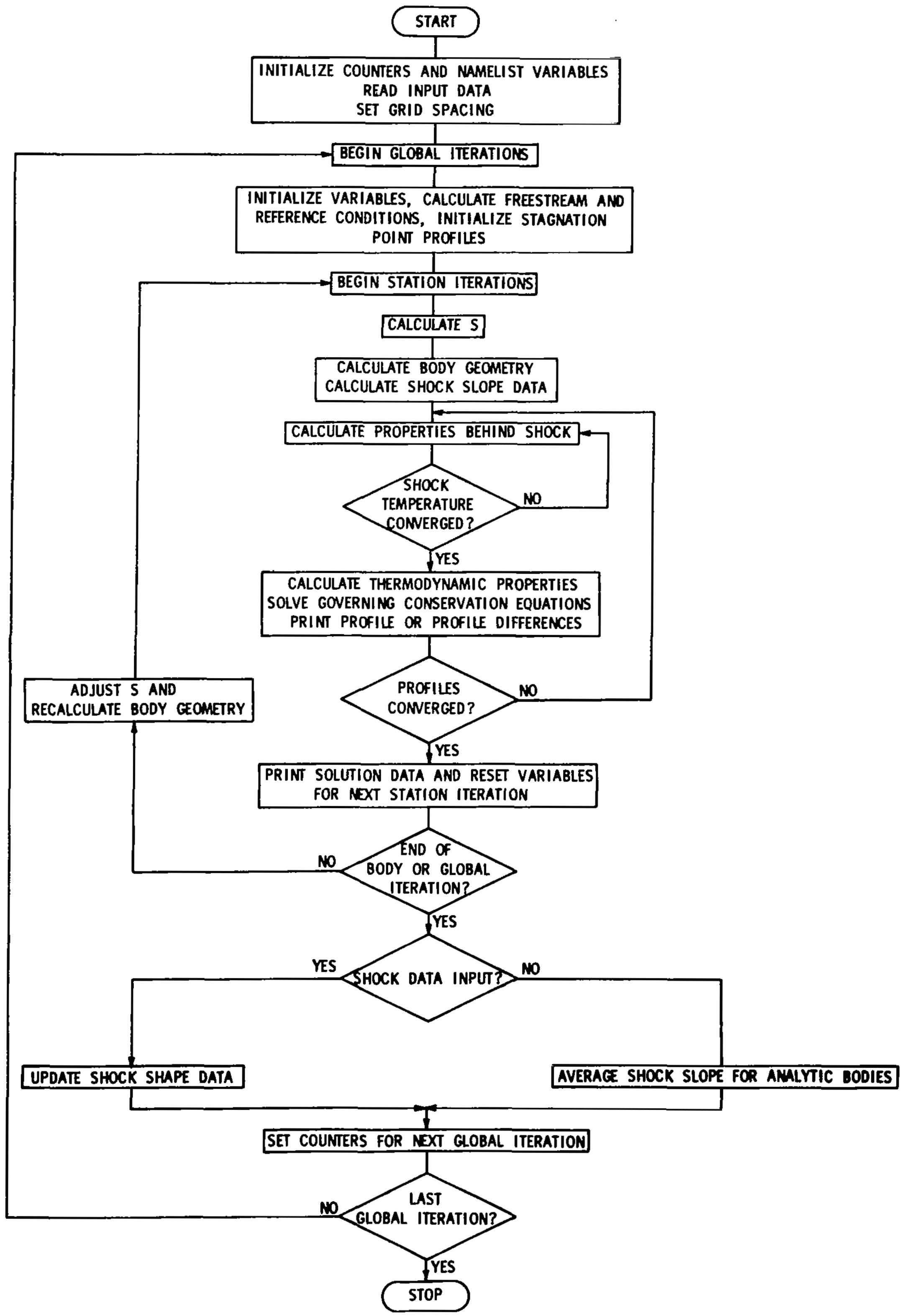


Fig. 1. Flow Diagram of Program VISLNABB by Function.

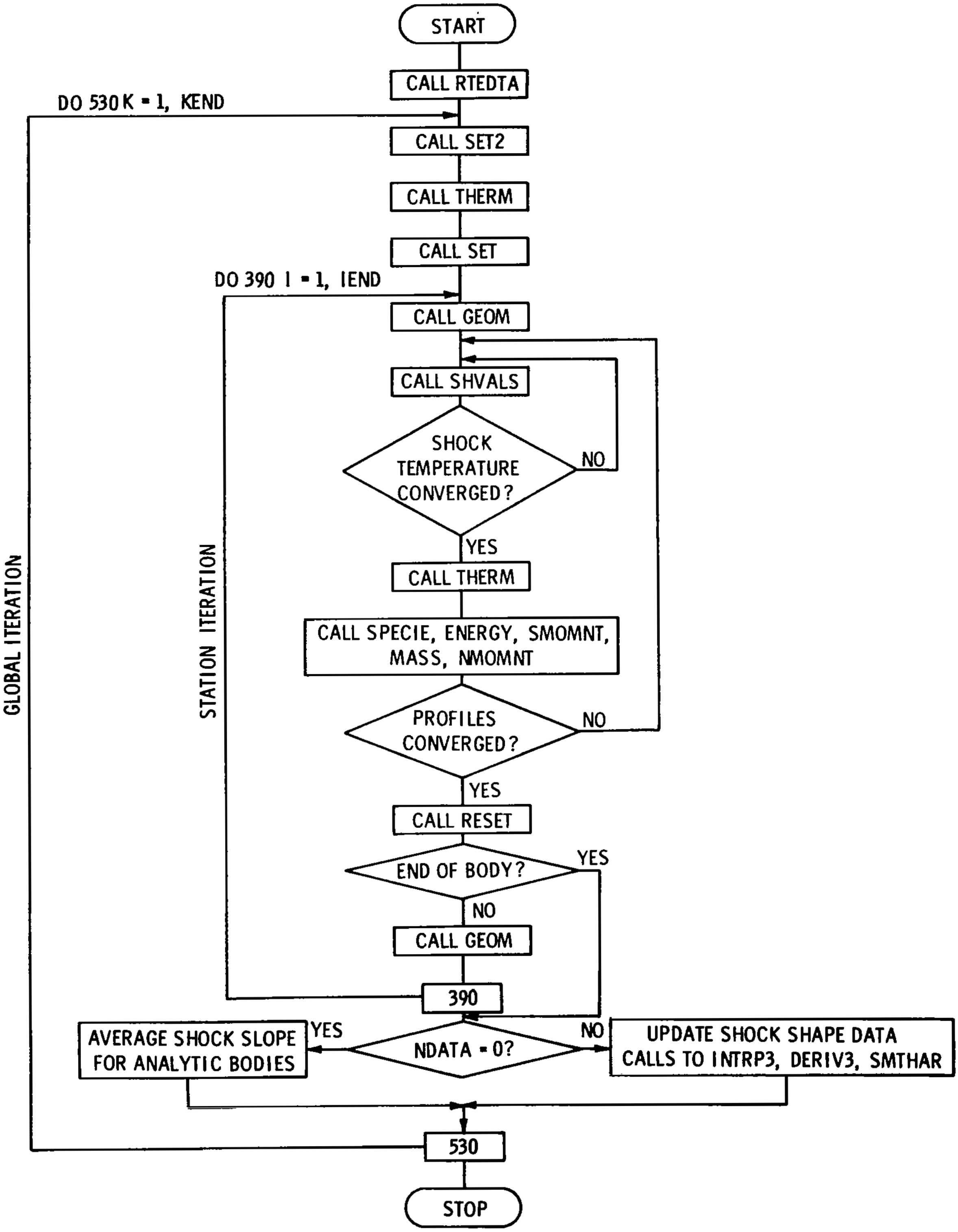


Fig. 2. Flow Diagram of Program VISLNABB by Subroutines Called.

and reference conditions are calculated in the first section of Subroutine THERM and profiles for the stagnation point are initialized in Subroutine SET. The global iterations are performed within a DO loop from 1 to KEND.

Following the comment "BEGIN SOLUTION ALONG BODY", a marching integration procedure is used for obtaining the station solutions. The station solutions are obtained within a DO loop from 1 to IEND. The wall temperature is optionally calculated and for a FVSL global iteration the v profiles from the previous global iteration are retrieved from disc by Subroutine VPRFLE. Subroutine GEOM returns the body angle, curvature and coordinates for s + ds/2. The shock angle and slope are calculated either by interpolation from the shock data arrays or from the body angle and shock-layer thickness.

Properties behind the shock are calculated by Subroutine SHVALS, which is called within an iteration loop requiring convergence of the shock temperature, TTS.

Subroutine THERM is called to provide the thermodynamic properties for the grid points of the shock layer. The governing conservation equations are solved by Subroutines SPECIE (the species equation), ENERGY (the energy equation), SMOMNT (the s momentum equation), MASS (the continuity equation) and NMOMNT (the y or normal momentum equation).*

Station iteration counters are then incremented. If PRNTCI = 1.0, the profiles ($u/u_{sh}$, $T/T_{sh}$ and the $C_i$) with the species sums for O and N are printed. If PRNTCI = 0.0, only the maximum differences between the previous and present profiles are printed. The profiles are tested for convergence by comparing DIFI(I) with CNVRGI(I), (I = 1, NSPL2). All of the values of CNVRGI have been set to CONVRG except for CNVRGI for $NO^+$ which was set to 100 x CONVRG. The values of DIFI(I) are calculated in Subroutines SMOMNT (I = 1), ENERGY (I = 2), and SPECIE (I = 3, NSPL2) from the expression DIFF = $|1 - w/w_{last}|$, w is the present station iteration value of the profile at the grid point and $w_{last}$ is the previous station iteration value. The maximum value of DIFF for the entire profile (at all grid points) is assigned to the appropriate DIFI(I).

If the convergence criteria are not met, another station iteration is performed (at s if NITER < NITMAX, or at s - ds/2 if NITER = NITMAX). If the convergence criteria are met, Subroutine RESET is called to print the station solution data and to reset the appropriate variables for the next station solution.

The step size DS is then adjusted (doubled if permitted or reduced to obtain a solution at a specific station), Subroutine GEOM is called to set the values of the body angle, curvature and coordinates and the program returns to the top of the station iteration loop unless the end of the

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*See Appendix A for the governing equations.

station solutions for the global iteration has been reached (indicated by I = IEND or by S = SEND).

After the stations solutions have been completed, four additional records are written on Unit NTW so that a subsequent eight point, least squares log-log curve fit will have an adequate number of points. The shock data for the next global iteration are then calculated. If NDATA = 0, only the derivative of the shock-layer thickness with respect to s, XNSP, is needed. The XNSP array is smoothed by four consecutive averages over three points. If NDATA ≠ 0, the shock-layer thickness derivative array, XNSP, is smoothed by four consecutive averages over three points. This averaging scheme is a modification of the simple arithmetic average used for NDATA = 0 and reduces to it if the solution points are equally spaced. The modification is for unequal point spacing and for three points on a straight line gives exactly the middle point. Three point Lagrangian interpolation is used to fill the SHSLPN array from the smoothed XNSP array.

After the shock data are calculated, the NTR and NTW files are rewound, the unit numbers are switched, and indicators are reset. The program then returns for another global iteration if K < KEND.

## Subroutine DERIV3

Subroutine DERIV3 uses the first derivative of the Lagrangian interpolating polynomial of second order to calculate the first derivative of the function f at a point x. The equations for the interpolating polynomial are given in the description of Subroutine INTER3.

USAGE:

CALL DERIV3 (F, X, IMAX, IMIN, FP) where F and X are the arrays of the ordinate and abscissa values, IMAX and IMIN are the upper and lower subscripts of the arrays to be used, and FP is the array of the derivative of F with respect to X.

## Subroutine ENERGY

The solution for the energy conservation equation is obtained by this subroutine. The coefficients of the energy equation in standard parabolic form, the $A_i$, are calculated first. The shock slip variables, CS1 and CS2, are next calculated and the wall conditions are set. The call to Subroutine SOLVE returns the new solution to the energy equation in the array T2 ($=T/T_{sh}$). The array T1 is the array of $T/T_{sh}$ from the previous iteration ($s = 0.0$) or the previous station solution ($s > 0.0$). Negative points in the temperature profile are reset to a small positive number and $T_{sh}$ is recalculated. If $s = 0$ the T1 and R1 arrays are updated. The TC and RC arrays are calculated at the average of the T1 and T2 and the R1 and R2 arrays. The T21 array, the previous station iteration T2 array, is compared with the present T2 array and the maximum of the expression

$$|1 - T2/T21|$$

is stored as DIFI(2) for the convergence test. The array T21 is reset and TCNW, the derivative of the TC array with respect to y, evaluated at the wall, is calculated. Program control then returns to MAIN.

USAGE:

CALL ENERGY

## Subroutine GEOM

The body geometry data are calculated in Subroutine GEOM. Provisions are included for two specific geometries with a third geometry specified by a table of z, r and s coordinates. The first two sections of the subroutine are for paraboloids and hyperboloids respectively. These two analytic bodies have a continuous distribution of the surface curvature $\kappa$ or CK.

The third section of the subroutine, on the first call, reads arrays of z, r, s, $\kappa$, and $\theta$ and for all calls returns the body coordinates, curvature and angle by interpolation in these arrays. The curvature might be calculated from the expression

$$\kappa = \left|\frac{d^2r}{dz^2}\right| / \left[1 + \left(\frac{dr}{dz}\right)^2\right]^{3/2}$$

which is equivalent to the alternate expression for curvature

$$\kappa = \left[\left(\frac{d^2r}{ds^2}\right)^2 + \left(\frac{d^2z}{ds^2}\right)^2\right]^{1/2}$$

USAGE:

CALL GEOM (S, DS, RS, CK, CSF, SIF, XB) where S is the surface distance, DS is the increment in S, RS is the radial coordinate, CK is the curvature, CSF is the cosine of the local body angle, SIF is the sine of the local body angle and XB is the axial coordinate. S, DS and RS are passed to Subroutine GEOM and RS, CK, CSF, SIF and XB are returned. RS is recalculated by GEOM.

## Subroutine HCP

Three point Lagrangian interpolation is used to calculate the species enthalpy and specific heats for one temperature TR which is passed to HCP. CPII, HII and HIFAC are returned.

USAGE:

CALL HCP (TR, CPII, HII, HIFAC) where $TR_*$ is the temperature in $^{o}R$, CPII is the array of the species specific heats, $Cp_i$, ($ft^2/sec^2-^oR$), HII is the array of species enthalpies, $h_i^*$, ($ft^2/sec^2$), and HIFAC is the array of species enthalpy factors $(h_i^* - \Delta h_i^F)/T^*$, ($ft^2/sec^2-^oR$), with $\Delta h_i^F$ being the heat of formation.

## Subroutine HCPA

The species enthalpy and specific heat profiles are returned by Subroutine HCPA. The dimensional temperature, TR, is calculated from the element of the TA array. A second-order Lagrangian interpolating polynomial is used to return the species enthalpy factor and specific heat. The enthalpy is calculated and the enthalpy and specific heat are nondimensionalized. TA, IE, HREF, CPREF, TTS and TREF are passed to Subroutine HCPA and HI and CPI are returned.

USAGE:

CALL HCPA (TA, IE, HREF, CPREF, TTS, TREF, HI, CPI) where TA is the temperature array, $T^*/T_{sh}\, T^*_{ref}$; IE is the number of points in the TA array; HREF is the reference enthalpy, $h^*_{ref} = U_\infty^{*2}$; CPREF is the reference specific heat, $C^*_{p_{ref}} = C^*_{p_\infty}$; TTS is the shock temperature, $T_{sh} = T^*_{sh}/T^*_{ref}$; TREF is the reference temperature, $T^*_{ref} = U_\infty^{*2}/C^*_{p_\infty}$; HI is the species enthalpy, $h_i^*/h^*_{ref}$; and CPI is the species specific heat, $C^*_{p_i}/C^*_{p_{ref}}$.

## Subroutine INTERP

This subroutine sets up the calling argument for the two point table look up function TLU and tests the return flag from TLU.

USAGE:

CALL INTERP (XX, XN, F2, IE, FF) where XN and F2 are the arrays of coordinate points and function values, IE is the number of points in the arrays, XX is the passed coordinate value and FF is the returned function value.

## Subroutine INTER3

Subroutine INTER3 uses a second-order Lagrangian interpolating polynomial interpolating on the points $x_1$, $x_2$, $x_3$, with the corresponding function values $f_1$, $f_2$ and $f_3$ to provide a function value F corresponding to the abscissa value x.

The general form of the polynomial is

$$F(x) = \sum_{k=1}^{3} f_k L_k (x)$$

where $L_k (x)$ is given by

$$L_k (x) = \prod_{\substack{m=1 \\ m \neq K}}^{3} \frac{x-x_m}{x_k-x_m}$$

USAGE:

CALL INTER3 (X, X1, X2, X3, F1, F2, F3, F) where X1, X2 and X3 are the abscissa values; F1, F2, and F3 are the function values; and F is the returned function value corresponding to X.

## Subroutine INTRPS

This subroutine sets up the calling argument for Subroutine SMOOTH. A principal function of the routine is to provide SMOOTH with the adjusted value of NU while preserving the value of NNU.

USAGE:

CALL INTRPS (XX, YY, X, Y, NP, NNU, DYY) where X and Y are the abscissa and ordinate arrays of NP elements, XX is the location in the X array for interpolation and differentiation, YY is the returned function value with first derivative DYY and NNU is half of the preferred number of points to be used in the log-log, walking least squares curve fit.

## Subroutine INTRP3

This subroutine scans through the array X to find the location of XX and then calls INTER3 to return the function value YY.

USAGE:

CALL INTRP3 (XX, X, Y, NPNTS, YY) where X and Y are the abscissa and ordinate arrays of NPNTS elements.

## Subroutine MASS

The solution of the mass conservation or continuity equation is provided by Subroutine MASS. For s = 0, the equations are in a reduced form and the first section of the routine is used. For s > 0, the general form of the equation is solved in the second section.

The shock-layer thickness, XNS, is calculated by integrating the continuity equation from 0 to $y_{sh}$. The expression for XNS is quadratic if the flow is axisymmetric, but is linear for two-dimensional flow. For $s > 0$ an alternate shock-layer thickness, XNSIV1 is calculated by matching the freestream mass flow into the shock with the mass flow between $y = 0$ and $y_{sh}$. If NAN = -1 XNS is not changed. If NAN = 1 or -2, XNS is set to XNSIV1. For NAN = 0, XNS is set to the average of itself and XNSIV1.

The normal velocity profile, VC, is then calculated by integrating the continuity equation from 0 to y. Shock coordinates are then calculated, as are values of VPG, VG, VGS, RNSH, RCSF and VS. After calculating derivatives of the v profile, control is returned to MAIN.

USAGE:

CALL MASS

## Subroutine NMOMNT

The solution for the normal momentum equation is obtained in this subroutine. The trapezoidal rule is used to integrate the normal momentum equation. The derivatives of the pressure are first evaluated at the outer edge (behind the shock) and then evaluated inward. With the pressure known at the outer edge, the pressure profile can be calculated proceeding inward.

The normal momentum equation is divided into two parts for the integration. The first part is the thin viscous shock layer (TVSL) contribution. The second part is the fully viscous shock layer (FVSL) contribution. For FVSL the two contributions are added. For TVSL only the first contribution is used. The pressure profile array for the current station iteration is P2 which is averaged with P1 (from the previous station solution or iteration if $s = 0$) to give the array PC. The pressure profile used elsewhere in the program is that given by the array PC. The FVSL contribution is alternately calculated using the normal velocity profile and derivatives from the present station iteration instead of from the previous global iteration for the present value of s. The alternate pressure profile array PE is then calculated using only data from the present station iteration. This profile is printed but is not used in other program computations.

After calculating the pressure profile, the density profile is recalculated and control is returned to MAIN.

USAGE:

CALL NMOMNT

## Subroutine RESET

The converged station solution data are written by this subroutine and program parameters are reset for the next station solution. Additionally, solution parameters such as drag and heat-transfer coefficients are calculated in this subroutine.

The first section of the subroutine prints the header information for the beginning of the global iteration. The skin-friction and heat-transfer coefficients are calculated and the Mach number, temperature and electron concentration profiles are calculated. Solution profiles are reset for the next station solution. The drag coefficients are calculated and the shock crossing values are reset.

The data for the converged station solution are then printed. Profiles are printed for every fifth station solution and for the values of s in the SPRF array.

USAGE:

CALL RESET

## Subroutine RTEDTA

This routine reads from card input or disc storage the reaction rate data for both a binary gas mixture (dissociating oxygen) and for a seven species (six major species plus electrons) gas mixture (multicomponent air). A rate data title card is read first. For each gas mixture, the number of major species plus catalytic third bodies (NJ2 or NJ6), reaction equations (NR2 or NR6) and catalytic third bodies (NZ2 or NZ6) are read followed by the alphameric array of the species and third body names (NAME2 or NAME6). Next the reaction equations and the reaction rate constants (KREQ2 or KREQ6 and RATE2 or RATE6) are read followed by the catalytic third body array (ZSUB2 or ZSUB6). The stoichiometric coefficient arrays are later set in Subroutine SET2 by matching the species names in the KREQ array with the names in the NAME array. The first and fourth elements of the RATE arrays ($CO_r$ and $DO_r$) are replaced by the $\log_e (CO_r)$ and $\log_e (DO_r)$ if the first three characters of the rate title card are 'LOG'.

USAGE:

CALL RTEDTA

## Subroutine SET

The initial profiles for each global iteration are set in this routine. For a first global iteration the velocity and temperature profiles are set to straight lines, but for subsequent global iterations these profiles are set to the converged stagnation point profiles from the previous global iteration. The species profile arrays are filled with the freestream species concentration values unless the previous global iteration was for the same number of species. In that case, the species concentration profiles are set to the previous global iteration stagnation point profiles.

USAGE:

CALL SET

## Subroutine SET2

The freestream and wall species concentrations are initialized in this subroutine for each global iteration. Also the stoichiometric coefficient arrays ALPHSB and BETASB are filled as is the catalytic third body efficiency array ZSUB. The routine selects the appropriate data for the arrays depending on the value of NS (2 or 6). After the arrays are set, the array data, and the reaction equations and rate constants for the global iteration are printed. The ZSUB, ALPHSB and BETSUB arrays are also printed.

USAGE:

CALL SET2

## Subroutine SHVALS

The flow properties behind the shock are calculated by SHVALS. The thermodynamic and transport properties are first calculated followed by velocity, pressure, temperature and density values. The velocity components are first calculated as normal and tangent to the shock. The velocity components normal and tangent to the body are then calculated. Principal values of the shock properties returned are the average of the present and the previous station solution values. The derivatives of the shock properties are also returned.

USAGE:

CALL SHVALS (SP, CP, SPB, CPB, TTSH, VRSH, URSH, PPSH, ID)

where SP = $\sin \alpha$, CP = $\cos \alpha$, SPB = $\sin \alpha \sin \phi + \cos \alpha \cos \phi$, CPB = $\cos \alpha \sin \phi - \sin \alpha \cos \phi$, TTSH is the shock temperature, VRSH and URSH are the velocity components normal and tangent to the shock, PPSH is the shock pressure and ID is an indicator (1 or 2) for calculations in the first part of the subroutine only ($s = 0$) or for the entire subroutine.

## Subroutine SMOMNT

The solution of the longitudinal momentum equation is obtained in SMOMNT. The coefficients for the equation in the standard parabolic form are first calculated followed by the shock slip variables. Subroutine SOLVE is called to return the array U2. With shock slip the shock velocity is recalculated. The average velocity profile (UC) is computed and the new profile U2 is compared with the previous station iteration velocity profile UC1. The derivative of the velocity profile is calculated and control is returned to MAIN.

USAGE:

CALL SMOMNT

## Subroutine SMOOTH

SMOOTH uses a log-log, walking least squares curve fit of the form $R = AZ^B$ for interpolation and differentiation. The input array is scanned to assure the point for curve fitting is within range and that there are enough array points for the curve fit. If needed, the number of points to be used in the curve fit is reduced.

The function is curve fitted and the function and the first and second derivatives returned.

USAGE:

CALL SMOOTH (ZD, Z, R, NPTS, RF, RP, NU, RPP)

where Z and R are the coordinate and function arrays (which may contain only positive values) of dimension NPTS, ZD is the coordinate point for interpolation and differentiation, NU is half of the number of points of Z and R to be used in the curve fit and RF, RP and RPP are the returned function value and first and second derivatives with respect to Z.

## Subroutine SMTHPR

This routine uses Subroutine INTRPS (and consequently SMOOTH) to interpolate for a single coordinate value. The coordinate and function values are first shifted to provide SMOOTH with only positive values and are then reshifted after the call to INTRPS.

USAGE:

CALL SMTHPR (S, YS, XX, YX, NPX, NNU)

where XX and YX are the coordinate and function arrays of dimension NPX to be used in the curve fitting by SMOOTH, S is the coordinate value, YS is the returned function value and two NNU points are to be used in the curve fit procedure.

## Subroutine SOLVE

This subroutine calculates the solution of parabolic partial differential equations in the standard form. Required for the solution are the upstream function values (W1), the coefficients of the parabolic partial differential equation in standard form (A1, A2, A3, and A4), the finite-difference grid interval array (DN) and the constants E1 and F1 which set the wall value or gradient. The equation is solved by equivalently using a tridiagonal finite-difference matrix. The matrix coefficients are evaluated from the wall outward and then the function is evaluated from the outer edge (shock) inward. With shock slip, the function shock value is calculated using the slip variables CS1 and CS2.

USAGE:

CALL SOLVE (W1, W2, E1, F1, CRNI, W2IE, CS1, CS2, SSFAC)

where W1 is the previous station solution of the equation, W2 is the returned solution, E1 and F1 are constants for the wall value of W2 (E1 = 0 gives W2 = F1 at the wall and E1 = 1 with F1 = 0 gives the gradient of W2 at the wall equals zero), CRNI ( = 1) specifies a fully implicit finite-difference procedure, W2IE is the shock value of W2, CS1 and CS2 are the slip variables and SSFAC denotes shock slip (1.0) or no shock slip (-1.0).

## Subroutine SPECIE

The solution for the species conservation equation is obtained in this routine. The Q1 and Q2 arrays are used as substitute arrays to obtain the derivatives of the species flux terms, then used in the calls to SOLVE for the species concentrations and finally in computing the derivatives of the species concentration profiles. Direct solutions are obtained for NS - 1 species equations and the profile for the last species, $O_2$ for dissociating oxygen and $N_2$ for multicomponent air, is obtained by summing over the other species.

The coefficients of the standard form of the species conservation equations are calculated, the slip variables CS1 and CS2 are calculated, the wall value constants E1 and F1 are set and Subroutine SOLVE is called to return the new species concentration profiles.

The species profiles are checked for being within a 0.0 - 1.0 range and the profiles and production terms for the $NS^{th}$ species are recalculated. Finally, the sums are obtained for the enthalpy-production term product, the enthalpy-production term derivative product, the specific heat-species flux term product and the enthalpy-species flux to the wall product. Control is then returned to MAIN.

USAGE:

CALL SPECIE

## Subroutine THERM

The species production terms and transport properties are calculated in this subroutine. To reduce the computing time required for the dissociating oxygen chemistry model, the properties are calculated in line using expressions specific for a two component gas mixture instead of the more general expressions used in the production term and transport property subroutines for a multicomponent gas mixture.

The first part of the subroutine is accessed only once at the beginning of each global iteration. This part calculates the freestream and reference variables. Also, the species viscosity curve fit constants and reaction rate constants for dissociating oxygen are set in this part of the subroutine.

The second part of the routine is accessed for each station iteration. The enthalpy and specific heat profiles are returned by HCPA and, for a multicomponent gas mixture, the viscosity and thermal conductivity arrays are returned by VISCNA.

The next section computes the production terms for the binary gas (dissociating oxygen) chemistry and also the equilibrium atom concentration (CAEQ) for the binary gas. For the multicomponent gas, the production terms are returned by Subroutine WISUB. The next section optionally computes the viscosity and thermal conductivity for the binary gas. The species flux terms are then calculated. The AJM array is set to zero since multicomponent diffusion is not included. The arrays of $\bar{\mu}'/\bar{\mu}$ and $\bar{k}'/\bar{k}$ are then formed where the primes indicate differentiation with respect to y and the bars denote $\mu/\mu_{sh}$ and $k/k_{sh}$.

In the final section of the routine the wall equilibrium concentration for dissociating oxygen is calculated as is the equilibrium wall enthalpy for dissociating oxygen, $h_{w,eq}$, HTFLB. For the multicomponent gas, HTFLB is replaced by $h_w$. Program control then is returned to MAIN.

USAGE:

CALL THERM (ISKI, BRAD, CONO, VISCO, EPS, VIS2)

where ISKI is a control variable indicating the first or second part of the routine to be used, BRAD is the nose radius in feet, CONO and VISCO are the edge or shock thermal conductivity and viscosity, EPS is the Reynolds number parameter, $\varepsilon$, and VIS2 is the wall viscosity.

## Function TLU

Linear, two point interpolation is used to return the value from the Z array associated with the name TLU for the XSTAR value in the X array. The array dimensions are NTABLE. NFLAG is a function return code, 0 if XSTAR is within the range of the X array, 1 (with TLU = 0.0) if XSTAR is not in the range of the X array. The X array must be strictly increasing.

USAGE:

TLU (NTABLE, Z, X, XSTAR, NFLAG)

## Subroutine VISCNA

This routine computes the viscosity and thermal conductivity arrays for all points of the temperature array, TC.

USAGE:

CALL VISCNA (TC, CC, CPI, IE, VST, CST, TTS, TREF, CPREF) where TC is the input temperature array, CC is the species concentration array, CPI is the specific heat array, IE is the number of points in the arrays, VST and CST are the mixture viscosity and thermal conductivity arrays, TTS is the shock temperature and TREF and CPREF are the reference temperature and specific heat.

## Subroutine VISCON

The viscosity and thermal conductivity for a single temperature value are calculated by this subroutine.

USAGE:

```
CALL VISCON (CI, CPI, AMU, AKAY, TR)
```

where TR is the temperature in degrees Rankine, CI and CPI are the species concentrations and specific heats and AMU and AKAY are the mixture viscosity and thermal conductivity.

## Subroutine VPRFLE

The normal velocity profile from the previous global iteration (written on tape or disc) is retrieved and smoothed in this routine for a fully viscous shock layer. A minimum of eight records are needed from the previous global iteration. The gradient of the normal component of the shock velocity is returned by Subroutine INTERP and the normal velocity profile values are returned by Subroutine SMTHPR.

USAGE:

```
CALL VPRFLE (S, VP, V, IE, NTR, ICALL)
```

where S is the surface distance location, VP is the derivative with respect to S of the component of the shock velocity normal to the body, V is the normal velocity profile array of dimension IE, NTR is the logical unit number for the tape or disc and ICALL is a control variable (= 1, the first eight records are read; $\neq$ 1, further records are read, if available and as needed, to have S in the proper span of the records).

## Subroutine WISUB

Subroutine WISUB computes the species production terms for the gas mixture. The forward and backward reaction rates are computed. The two parts of the production rate terms are computed followed by the derivative of the production term with respect to temperature in degrees Kelvin.

USAGE:

```
CALL WISUB (RHON, T, N)
```

where RHON is the density in slugs/$ft^3$, T is the temperature in degrees Rankine and N is the array subscript for the CC, WO, W1 and DW arrays.

## Subroutine BLOCK DATA

Tables of thermodynamic data and other constants are initialized in BLOCK DATA. The species specific heats in $ft^2/sec^2$ - °R are in CPTAP, the species enthalpy, as $(h_i - \Delta h_i^F)/T$, in $ft^2/sec^2$ - °R are in HTAB, the corresponding temperature values are in TMPTAB and NTAB is the number of table entries.

The species viscosity curve fit constants are in VSA, VSB and VSC, the species heats of formation are in DELHIF, the molecular weights in EMI and the species names in NSPI in the order for which the species data are assigned. Note that O and $O_2$, the species for dissociating oxygen, are the first two species in the NSPI array. Thus, a calculation for dissociating oxygen uses the thermodynamic properties and other data for the first two species only.

## DESCRIPTION OF VARIABLES IN COMMON

The Fortran variables which occur in the labeled common are listed below with the name of the common block in which they occur along with a brief description of the variables.

| Fortran Symbol | Common Name | Description |
|---|---|---|
| AA(51) | COMAR1 | array used to integrate $\rho u$. |
| AJB(51,6) | COMDBL | factor in transport term for species equation, $kLe/C_p$. |
| AJM(51,6) | COMDBL | multicomponent Lewis number factor in species equation, set equal to zero. |
| ALP | COMXR | shock angle, $\alpha$. |
| ALPHSB(15,11) | COMABZ | $\alpha_{rj}$, forward stoichiometric coefficients. |
| ALSUB(15) | COMABZ | $\sum_r \alpha_{rj} - 1$ |
| ALT | COMXR | altitude in feet. |
| A1(51), A2(51), A3(51), A4(51) | SOLV | coefficients of the standard form of the conservation equations. |
| BB(51) | COMAR1 | array used to integrate $\eta\rho u$. |
| BETASB(15,11) | COMABZ | $\beta_{rj}$, backward stoichiometric coefficients. |
| BETSUB(15) | COMABZ | $\sum_r \beta_{rj} - 1$ |
| BO | COMXR | $T_w^*/T_o^*$ |
| CAEQ(51) | COMAR1 | Equilibrium species concentration of atomic oxygen that would exist for dissociating oxygen at the local temperature and pressure. |
| CAINF | COMBC | $C_{a_\infty}$, freestream atomic oxygen concentration. |
| CAT | COMG | indicator for fully catalytic (1.0) or noncatalytic wall (-1.0) boundary condition. |

| | | |
|---|---|---|
| CAW | COMBC | $C_{a_w}$, input atom concentration at surface for dissociating oxygen. |
| CC(51,6) | COMDBL | $C_{ij}$, species concentrations. |
| CCFAC | COMFAC | weighting function for updating the C1 array at the stagnation point. |
| CCL(51,6) | COMDBL | array of previous iteration values of the array CC. CCL is used in the convergence test. |
| CCN(51,6) | COMDBL | derivative of $C_{ij}$ with respect to $\eta$. |
| CDF | COMXR | coefficient for friction drag. |
| CDFD | COMXR | term in calculating CDF. |
| CDF1 | COMXR | term in calculating CDFD. |
| CDF2 | COMXR | term in calculating CDFD. |
| CDP | COMXR | coefficient for pressure drag. |
| CDPD | COMXR | term in calculating CDP. |
| CDP1 | COMXR | term in calculating CDPD. |
| CDP2 | COMXR | term in calculating CDPD. |
| CIE(6) | COMEDG | $C_{i_{sh}}$, species concentrations behind the shock as calculated by the program. |
| CINF(6) | COMFSA | $C_{i_\infty}$, freestream species concentrations. |
| CINF6(6) | COMBC | the input freestream species concentrations for multicomponent air. |
| CIW(6) | COMW | $C_{i_w}$, the wall species concentrations as calculated by the program. |
| CIWW(6) | COMW | $C_{i_w}$, the wall species concentrations for a fully catalytic surface. |
| CIWW6(6) | COMBC | the input wall species concentrations for multicomponent air for a fully catalytic surface. |
| CK | COMG2 | the value of $\kappa$ at s. |
| CK2 | COMG2 | the value of $\kappa$ at s + ds/2. |

| | | |
|---|---|---|
| CNS | COMG | $y_{sh}$, shock-layer thickness, more exactly, the average of $y_{sh}$ at the present station and at the previous station. |
| CON(51) | COMAR1 | $\bar{\mu}$, $\mu/\mu_{sh}$, viscosity. |
| CONO | INSH | $\mu_{sh}/Pr$ |
| CONREF | COMREF | $\mu^*_{ref}\ C^*_{P_{ref}}$, reference thermal conductivity. |
| CO1 | COMAR1 | array used in calculating the derivative of v with respect to s. |
| CO2 | COMAR1 | a second array used in calculating the derivative of v with respect to s. |
| CP | COMG1 | cos $\alpha$ at s + ds/2. |
| CPB | COMG1 | cos $\alpha$ sin $\phi$ - sin $\alpha$ cos $\phi$ at s + ds/2. |
| CPI(51,6) | COMDBL | $C^*_{p_i}$, $ft^2/sec^2$ - °R, species specific heat. |
| CPIFS(6) | COMFSA | $C^*_{p_{i_\infty}}$, $ft^2/sec^2$ - °R, freestream species specific heat. |
| CPIW(6) | COMW | $C^*_{p_{i_w}}$, $ft^2/sec^2$ - °R, species specific heat at the surface. |
| CPJSUM(51) | COMSUM | $\sum_i C_{p_{ij}} J_{ij}$, sum over the species of the product of specific heat and the diffusional flux. |
| CPREF | COMREF | $C^*_{p_\infty}$, the reference specific heat. |
| CPST(51) | COMAR1 | $\sum_j C_{p_{ij}} C_{ij}$ |
| CPTAB(50,6) | COMTAB | table of species specific heat vs. temperature from BLOCK DATA. |
| CRNI | COMG | indicator (set to 1.0 and never changed) specifying a fully implicit finite-difference solution procedure. |
| CR0(15), CR1(15), CR2(15) | RTECON | Coefficients for the forward reaction rate equations. |
| CSF | COMG3 | cos $\phi$ at s. |

| | | |
|---|---|---|
| CSF2 | COMG2 | cos $\phi$ at s + ds/2. |
| C1(51,6) | COMDBL | array of species concentrations from the previous station iteration (if s = 0) or from the previous station (if s > 0). |
| C2(51,6) | COMDBL | array of species concentrations for present station iteration. |
| C20(51,6) | COMDBL | array of species concentrations at s = 0, saved for starting subsequent global iteration. |
| DELHIF(6) | COMFSA | standard species heat of formation at 0° K. |
| DIF | COMTST | maximum difference in the $u/u_{sh}$ arrays between station iterations. |
| DIFI(8) | COMTST | maximum difference in the $u/u_{sh}$, $T/T_{sh}$, and $C_{ij}$ arrays between station iterations. |
| DN(51) | SOLV | $\Delta\eta$, or $\Delta y/y_{sh}$, normal spacing in the finite difference grid. |
| DR0(15), DR1(15), DR2(15) | RTECON | Coefficients for the backwards reaction rate equations. |
| DS | SOLV | $\Delta s$, or ds, step size in the streamwise direction. |
| DW(51,6) | COMDBL | derivative of the species production term with respect to temperature (°K). |
| ELN(6) | COMEL | number of nitrogen atoms per species molecule. |
| ELO(6) | COMEL | number of oxygen atoms per species molecule. |
| EMBAR(51) | COMAR1 | $\overline{M}$, mixture molecular weight. |
| EMI(6) | COMVS | $M_i$, species molecular weight. |
| EPS | INSH | $\varepsilon$, Reynolds number parameter, $\varepsilon = (\mu^*_{ref}/\rho^*_\infty U^*_\infty R^*_n)^{1/2}$ |
| GAMMMI(15,6) | COMABZ | $-(\beta_{rj} - \alpha_{rj})$ if $(\beta_{rj} - \alpha_{rj}) < 0$ |
| GAMMPL(15,6) | COMABZ | $(\beta_{rj} - \alpha_{rj})$ if $(\beta_{rj} - \alpha_{rj}) > 0$ |
| HANGLE | BODY | asymptotic half angle for hyperboloids. |
| HDWSUM(51) | COMSUM | sum over the species of the product of DW and HI. |

| | | |
|---|---|---|
| HI(51,6) | COMDBL | $h_i^*$, $ft^2/sec^2$, species static enthalpy. |
| HINF(6) | COMFSA | $h_{i_\infty}^*$, $ft^2/sec^2$, freestream species static enthalpy. |
| HIW(6) | COMW | $h_{i_w}^*$, species static enthalpy at the body surface. |
| HJSUMW | COMSUM | sum over the species of the product of enthalpy and the diffusional flux at the wall. |
| HREF | COMREF | $h_{ref}^* = U_\infty^{*2}$, reference enthalpy. |
| HTAB(50,6) | COMTAB | $(h_i^* - \Delta h_i^F)/T$, $ft^2/sec^2 - {}^oR$, table of species static enthalpy over temperature versus temperature from BLOCK DATA. |
| HTFLB | COMW | mixture enthalpy at the wall if NS = 6; if NS = 2, the wall enthalpy for O-$O_2$ in equilibrium. |
| HWSUM(51) | COMSUM | sum over the species of the product of enthalpy, species concentration and species production terms. |
| I | COMG | index for the streamwise solution DO loop. |
| IE | SOLV | number of points in the normal direction of the finite-direction grid. |
| IEND | COMXR | maximum number of stations in the streamwise direction; upper limit of the variable I. |
| IGEOM | BODY | indicator for body geometry,<br>1. hyperboloid<br>2. paraboloid<br>3. geometry defined by table of r, z and s |
| IJK | KJI | indicator, 0 for first call to Subroutine GEOM, 123 for subsequent calls. |
| IM | SOLV | IE-1. |
| IUN | COMXR | input unit number for reaction rate data. |
| JFAC | BODY | indicator for axisymmetric flow (1) or two-dimensional flow (0). |
| K | COMG | index for the global iteration DO loop. |
| KNTR1 | KNTR | counter for the number of records read on unit NTR. |

| | | |
|---|---|---|
| KNTW1<br>KNTW2 | KNTR | counters for the number of records written on unit NTW. |
| KPLTTP | COMXR | indicator for plot data being written on unit NTPL; 0, no; 1, yes. |
| KREQ2(15,6)<br>KREQ6(15,6) | COMSET | arrays for the reaction equations for the dissociating oxygen (KREQ2) and multicomponent air (KREQ6); used to set the values of ALPHSB and BETASB. |
| KRTITL(18) | COMSET | title card for reaction rate data. If 'LOG' appears in the first three spaces, CO(J) and (DO)J are replaced by ALOG(CO(J)) and ALOG(DO(J)). |
| KTITLE(20) | TITLE | title card for the computation case being run. KTITLE is printed with each station solution. |
| NAME2(11)<br>NAME6(11) | COMSET | arrays of species and catalytic third body names, left justified. |
| NAN | INV2 | indicator for analytic or nearly analytic bodies; 1, yes; 0, no. Negative values of NAN specify alternate methods of calculating the shock-layer thickness, XNS. (See the description of Subroutine MASS). |
| NITER | COMG | counter for the number of iterations at each streamwise station. |
| NITMIN | COMXR | control variable allowing DS to be doubled if NITER $\leq$ NITMIN. |
| NITTOT | COMXR | total number of station iterations performed for each global iteration. |
| NJ | COMNS2 | number of species plus catalytic third bodies. |
| NJ2<br>NJ6 | COMSET | values to be assigned to NJ for dissociating oxygen (NJ2) or multicomponent air (NJ6). |
| NR | COMNS2 | number of reaction equations. |
| NR2<br>NR6 | COMSET | values to be assigned to NR for dissociating oxygen (NR2) or multicomponent air (NR6). |

| | | |
|---|---|---|
| NS | COMNS | number of major chemical species; 2 for dissociating oxygen, 6 for multicomponent air. |
| NSM1 | COMNS2 | NS - 1. |
| NSOLD | COMSO | value of NS for the previous global iteration. |
| NSPI(6) | COMVS | alphameric array of the six major chemical species, left justified, from BLOCK DATA. |
| NSPRF | COMPRF | number of values of s at which solutions are to be specifically obtained and with profiles printed; maximum value, 10. |
| NTAB | COMTAB | number of entries in the CPTAB, HTAB and TMPTAB arrays, 49. |
| NTOT | COMXR | total number of station iterations for all global iterations. |
| NTPL | COMXR | output unit number for optional plot data, (13). |
| NTW | COMXR | unit number for storing v profiles for subsequent global iteration, 15 or 16. Profiles are written on unit NTW and read from unit NTR. The values are switched at the end of each global iteration. |
| NZ | COMNS2 | NJ - NS, number of catalytic third bodies. |
| NZ2 | COMSET | NJ2 - NS2. |
| NZ6 | COMSET | NJ6 - NS6. |
| OLDSLP | COMXR | previous value of XNSP(I). |
| PC(51) | COMAR1 | $P/P_{sh}$, average of the P1 and P2 arrays. |
| PCN(51) | COMAR1 | derivative of PC with respect of $\eta$. |
| PE(51) | COMAR1 | alternate pressure array. |
| PFAC(51) | COMAR1 | pressure related factor occurring in the standard form of the energy and s momentum equations. |
| PHI | COMXR | body angle at s + ds/2. |
| PINF | COMFS | $P_\infty^*$, $lbf/ft^2$, freestream static pressure. |
| PPS | OUTSH | average of current and previous station or iteration values of $P_{sh}$. |

| | | |
|---|---|---|
| PPSO | COMSO | $P_{sh}$ at the stagnation point. |
| PPS1 | OUTSH | $P_{sh}$ for the previous station or, if s = 0, iteration. |
| PPS2 | OUTSH | $P_{sh}$ for the present station iteration. |
| PREF | COMREF | $P^*_{ref}$, reference pressure, $\rho^*_\infty U^{*2}_\infty$. |
| P2(51) | COMAR1 | derivative of $P/P_{sh}$ with respect to s. |
| PSP | OUTSH | derivative of $P_{sh}$ with respect to s. |
| PO(51) | COMAR1 | array of $P/P_{sh}$ at the stagnation point. |
| PON(51) | COMAR1 | derivative of PO with respect to $\eta$. |
| P1(51) | COMAR1 | array of $P/P_{sh}$ for the previous station, or, if s = 0, iteration. |
| P1N(51) | COMAR1 | derivative of P1 with respect to $\eta$. |
| P2(51) | COMAR1 | array of $P/P_{sh}$ for the present station iteration. |
| P2N(51) | COMAR1 | derivative of P2 with respect to $\eta$. |
| Q1(51) }<br>Q2(51) } | COMAR1 | substitute arrays, principally for solving the species conservation equations. |
| R | COMVS | universal gas constant, from block data, 49686 lb $ft^2/(lb\text{-}mole\ sec^2\ {}^\circ R)$. |
| RATE2(15,6) }<br>RATE6(15,6) } | COMSET | reaction rate constants, C0, C1, C2, D0, D1, D2 for the dissociating oxygen (RATE2) or for multicomponent air (RATE6). |
| RC(51) | COMAR1 | $\rho/\rho_{sh}$, density, average of R1 and R2. |
| RCON(51) | COMAR1 | $(1/\bar{k})\ (d\bar{k}/d\eta)$ where $\bar{k} = k/k_{sh}$. |
| RCSF(51) | COMAR1 | $y_{sh} \cos \phi/(r_w + y_{sh}\ \eta \cos \phi)$. |
| REFAC | COMG | $\rho_{sh}\ v_{sh}\ y_{sh}/\varepsilon^2\ \mu_{sh}$. |
| REYIN | COMFS | $Re_\infty$, $\rho^*_\infty\ U^*_\infty\ R^*_n/\mu^*_\infty$, freestream Reynolds number. |
| REYSH | OUTSH | $Re_{sh}$, $\rho^*_\infty\ U^*_\infty\ R^*_n/\mu^*_{sh}$, shock Reynolds number. |
| RINF | COMFS | $\rho^*$, freestream density, $slugs/ft^3$. |

| | | |
|---|---|---|
| RNSH(51) | COMAR1 | $y_{sh}/(1 + \kappa\, y_{sh}\, \eta)$. |
| RREF | COMREF | $\rho^*_{ref} = \rho^*_\infty$. |
| RRS | OUTSH | average of current and previous station or iteration values of $\rho_{sh}$. |
| RRS1 | OUTSH | $\rho_{sh}$ for the previous station or, if s = 0, the previous station iteration. |
| RRS2 | OUTSH | $\rho_{sh}$ for the present station iteration. |
| RS | COMG3 | $r_w$, body radius at s. |
| RSH | COMRX | $r_{sh}$, radial coordinate of current shock point. |
| RSP | OUTSH | derivative of $\rho_{sh}$ with respect to s. |
| RS2 | COMG2 | $r_w$, body radius at s + ds/2. |
| RVISC(51) | COMAR1 | $1/\bar{\mu}\ (d\bar{\mu}/d\eta)$ where $\bar{\mu} = \mu/\mu_{sh}$. |
| R1(51) | COMAR1 | $\rho/\rho_{sh}$, density at previous station, or, if s = 0, from the previous station iteration. |
| R2(51) | COMAR1 | $\rho/\rho_{sh}$, density for the current station iteration. |
| S | INSH | $s = s^*/R^*_n$, surface distance coordinate. |
| SEND | COMXR | final value of s. |
| SIF | COMG3 | sin $\phi$ at s. |
| SIGM | PRLE | $\sigma$, Prandtl number. |
| SMALLT | COMSML | a small number for test purposes. |
| SP | COMG1 | sin $\alpha$ at s + ds/2. |
| SPB | COMG1 | sin $\alpha$ sin $\phi$ + cos $\alpha$ cos $\phi$ at s + ds/2. |
| SPRF(10) | COMPRF | array of values of s at which specific solutions are to be obtained and profiles printed. |
| SSFAC | COMG | indicator for shock slip; 1.0, yes; -1.0, no. |
| SWFAC | COMG | dummy indicator for wall slip; 1.0, yes; -1.0, no. The program only includes no wall slip. |
| TB | COMW | $T^*_w$, wall temperature, $^o$R. |

| | | |
|---|---|---|
| TC(51) | COMAR1 | $T/T_{sh}$, temperature, average of T1 and T2. |
| TCIE | COMEDG | TC(IE). |
| TCNW | COMBC | derivative of $T/T_{sh}$ with respect to $\eta$ at the wall. |
| TCW | COMW | TC(1). |
| THIN | COMG | indicator for TVSL (1.0) or FVSL (-1.0) flow. |
| TINF | COMFS | $T_\infty^*$, freestream temperature, $^oR$. |
| TMPTAB(50) | COMTAB | $T_\infty^*$, $^oR$, table of temperature values for species enthalpy and specific heat, from BLOCK DATA. |
| TPSH | INSH | $d\bar{T}/d\eta$ at the shock where $\bar{T} = T/T_{sh}$. |
| TREF | COMREF | $T_{ref}^*$, reference temperature, $^oR$, $U_\infty^{*2}/C_{p_\infty}^*$. |
| TSP | OUTSH | derivative of $T_{sh}$ with respect to s. |
| TTS | OUTSH | $T_{sh}$, shock temperature, average of TTS1 and TTS2. |
| TTSO | COMSO | $T_{sh}$ at the stagnation point. |
| TTS1 | OUTSH | $T_{sh}$ at the previous station or, if s = 0, for the previous station iteration. |
| TTS2 | OUTSH | $T_{sh}$ for the present station iteration. |
| TW | COMW | $T_w$, wall temperature. |
| T1(51) | COMAR1 | $T/T_{sh}$ for the previous station, or, if s = 0, for the previous station iteration. |
| T2(51) | COMAR1 | $T/T_{sh}$ for the present station iteration. |
| T20(51) | COMAR1 | $T/T_{sh}$ at the stagnation point. |
| T21(51) | COMAR1 | $T/T_{sh}$ from the previous station iteration. |
| UC(51) | COMAR1 | $u/u_{sh}$, tangential velocity, average of U1 and U2. |
| UCN(51) | COMAR1 | derivative of UC with respect to $\eta$. |
| UC1(51) | COMAR1 | $u/u_{sh}$ from the previous station iteration. |

| | | |
|---|---|---|
| UFAC | COMFAC | factor to average the updating of the U1 and T1 profiles at the stagnation point if more than 20 iterations are required. |
| UINF | COMFS | $U_\infty^*$, freestream velocity, ft. |
| UPSH | INSH | derivative of the component of $u/u_{sh}$ tangent to the shock with respect to $\eta$. |
| URSH | COMUV | $u_{sh}$, shock velocity component tangent to the shock. |
| UREF | COMREF | $U_{ref}^*$, reference velocity, $U_\infty^*$. |
| USP | OUTSH | derivative of $u_{sh}$ with respect to s. |
| UUS | OUTSH | $u_{sh}$, shock velocity component tangent to the body, average of UUS1 and UUS2. |
| UUSO | COMSO | $u_{sh}$, at the stagnation point. |
| UUS1 | OUTSH | $u_{sh}$ at the previous station, or, if $s = 0$, from the previous station iteration. |
| UUS2 | OUTSH | $u_{sh}$ for the present station iteration. |
| U1(51) | COMAR1 | $u/u_{sh}$ at the previous station or, if $s = 0$, from the previous station iteration. |
| U2(51) | COMAR1 | $u/u_{sh}$ for the present station iteration. |
| U20(51) | COMAR1 | $u/u_{sh}$, at the stagnation point. |
| VC(51) | COMAR1 | $v/v_{sh}$, normal velocity component. |
| VCD(51) | COMAR1 | $v = v^*/u_{ref}^*$; VC x VVS. |
| VCI1(51) | COMAR1 | v profile from the previous global iteration at s. |
| VCI2(51) | COMAR1 | v profile from the previous global iteration at $s + ds/2$. |
| VG(51) | COMAR1 | average of VCI1 and VCI2. |
| VGN(51) | COMAR1 | derivative of VG with respect to $\eta$. |
| VGS(51) | COMAR1 | derivative of VG with respect to s. |
| VISC(51) | COMAR1 | $\mu/\mu_{sh}$, viscosity. |
| VISCO | INSH | $\mu_{sh}^*/\mu_{ref}^*$. |

| | | |
|---|---|---|
| VPG | COMG | average of VSP at s and at s + ds/2 from the previous global iteration. |
| VRSH | COMUV | $v_{sh}$, shock velocity component normal to the shock. |
| VS(51) | COMAR1 | derivative of the v profile with respect to s. |
| VSA(6) VSB(6) VSC(6) | COMVS | coefficients for the species viscosity curve fit equations. |
| VSP | OUTSH | derivative of $v_{sh}$ with respect to s. |
| VSPP1 | COMVSP | derivative of $v_{sh}$ with respect to s at s, from the previous global iteration. |
| VSPP2 | COMVSP | derivative of $v_{sh}$ with respect to s at s + ds/2, from the previous global iteration. |
| VSREF | COMREF | $\mu^*_{ref}$, reference viscosity, lbf-sec/$^oR$, corresponding to $T^*_{ref}$. |
| VVS | OUTSH | $v_{sh}$, shock velocity component normal to the body, average of VVS1 and VVS2. |
| VVSO | COMSO | $v_{sh}$, at the stagnation point. |
| VVS1 | OUTSH | $v_{sh}$ at the previous station or, if s = 0, from the previous station iteration. |
| VVS2 | OUTSH | $v_{sh}$ for the present station iteration. |
| VO(51) | COMAR1 | $v/v_{sh}$, at the stagnation point. |
| VON(51) | COMAR1 | derivative of VO with respect to $\eta$. |
| V1(51) | COMAR1 | $v/v_{sh}$ profile at the previous station, or, if s = 0, from the previous station iteration. |
| V2(51) | COMAR1 | $v/v_{sh}$ profile for the present station iteration, equal to VC. |
| V2N(51) | COMAR1 | derivative of V2 with respect to $\eta$. |
| WREF | COMREF | $W^*_{ref}$, reference value for nondimensionalizing the production terms, $U^*_\infty/R^*_n$. |
| WVFAC | COMXR | averaging factor for the $v/v_{sh}$ profiles before they are written on disc. |

| | | |
|---|---|---|
| WO(51,6) | COMDBL | first component of the species production term. |
| W1(51,6) | COMDBL | second component of the species production term. |
| XB | COMG3 | x, axial coordinate of the current solution point. |
| XJFAC | BODY | indicator for axisymmetric (1) or two-dimensional (0) flow, the real variable equivalent of JFAC. |
| XLE | PRLE | Le, binary Lewis number. |
| XN(52) | SOLV | array of $\eta$, $y/y_{sh}$, values. |
| XNS | INSH | $y_{sh}$, shock layer thickness calculated for the current station. |
| XNSIVO | INV2 | term in computing $y_{sh}$. |
| XNSIV1 | INV2 | $y_{sh}$ as calculated by matching the freestream mass flow through the shock with the mass flow through the shock layer. |
| XNSP(202) | COMARL | derivative of XNS with respect to s at s. |
| XNSPM | COMG2 | derivative of XNS with respect to s at s + ds/2 from the previous global iteration. |
| XNSTMP | INV2 | storage variable for the value of $y_{sh}$ obtained by integrating the n momentum equation. |
| XNSO | COMXR | an initial value for $y_{sh}$ at the stagnation point. |
| XNS1 | COMG3 | value of $y_{sh}$ at the previous station, or, if s = 0, from the previous station iteration. |
| XSH | COMXR | $X_{sh}$, axial coordinate of the current shock point. |
| XSOL(200) | COMARL | array of s values at which solutions were obtained. |
| XU25 | COMTST | U2(15), the fifteenth value of the U2 array. |
| ZSUB(5,6) | COMABZ | array of the third body occurrences or the third body catalytic efficiencies relative to Argon. |
| ZSUB2(5,6)<br>ZSUB6(5,6) | COMSET | values to be given ZSUB for dissociating oxygen (ZSUB2) or for multicomponent air (ZSUB6). |

## DESCRIPTION OF INPUT DATA

To reduce the need to read in a large number of data cards for each case, most of the card input can be read on input units other than the main card input unit. The auxiliary input unit numbers are initialized but can be changed, in most cases, through the namelist input data. The input data are described in the order that it is required with the unit number and format.

### Data Input in MAIN

KTITLE, Unit 5, (20A4)

An alphameric card image array of descriptive information for the particular case being run. KTITLE is printed as a header for each streamwise solution.

INPUT, Unit 5 (NAMELIST format)

The principal control and scalar variables are read through the NAMELIST INPUT. Many of the variables are initialized before INPUT is read so that only the principal variables need to be included in the NAMELIST. The individual variables for INPUT are described in a separate subsection below.

(CINF6(J), J=1,6), Unit 5, (6F10.5)

Freestream species concentrations for the six principal air species, O, $O_2$, NO, N, $NO^+$ and $N_2$.

(CIWW6(J), J=1,6), Unit 5, (6F10.5)

Species concentration for the six principal air species at the body surface. These values are not used for an NCW (CAT=-1.0) case, but are used for an ECW (CAT=1.0) case. For ECW, the values for CIWW6 correspond to the equilibrium wall concentrations.

SN(N), SHSLPN(N), ENSHN(N), ENO, Unit NTSH (default value for NTSH is 5), (3E15.6, A1), optional, read if NDATA $\neq$ 0.

Array members (up to 300) defining an initial shock shape.

SN, s, location on the body surface of the corresponding shock points.

SHSLPN, local slope of the shock, i.e., $dy_{sh}/ds$.

ENSHN, $y_{sh}$, local shock-layer thickness.

Note: SHSLPN is recalculated from differentiating ENSHN and averaging four times this derivative over three points. The user might wish to use the value of SHSLPN which is read in and eliminate the need for the ENSHN array retaining the smoothing procedure.

ENO, a control character indicating if more cards are to be read. If ENO is a blank character, more cards are read. If ENO is any non-blank character, no more cards of these arrays are read and NSDATA is set to the current value of N.

STWA(N), TWA(N), ENO, Unit NTTWA (default value for NTTWA is 5), (2E15.6,A1); optional, read if KTWAL ≠ 0.

Array members (up to 100) defining a body surface temperature distribution.

STWA, s, surface location for the corresponding temperature.

TWA, surface temperature, $^{o}$R.

ENO, control character as described above. If ENO is non-blank no more cards for these arrays are read and NPTT is set to the current value of N.

SPRF, Unit 5, (10F8.0); optional, read if NSPRF ≠ 0.

An array (maximum 10) of values of s, the number being equal to NSPRF, at which specific solutions are to be obtained and full profiles are to be printed. The values of this array should be selected to avoid abrupt and large changes in DS, if possible. If a solution is desired at a specific location, two or three solution stations upstream should be specified so that the program approaches the desired solution station with a constant DS.

SPRF(NSPRF) is set equal to SEND.

## Data Input in Subroutine RTEDTA

Subroutine RTEDTA is called once by MAIN for each case to read the reaction rate data. All data in this subroutine are read on input unit IUN (default value for IUN is 19). The value of IUN is passed through common from MAIN.

KRTITL, (A3,17A4)

An alphameric array giving header information for the reaction rate data.

The remaining data are read for both a two and a seven species chemistry system. Each variable ends with the character 2 or 6 (e.g. NJ2 and NJ6, being the values of NJ for a two or a seven species chemistry system. The values for the required system are later selected in subroutine SET2.

NJ2, NR2, NZ2, (3I3)

The values of NJ, NR and NZ for the two species chemistry system.

(NAME2(I), I=1,NJ), 20A4

Species and catalytic third body names, left justified in the A fields.

((KREQ2(I,J), J=1,6), (RATE2,(I,K),K=1,6), I=1,NR2), (6(1X,A4),2(F10.0, F6.0,F4.0))

KREQ2, the specie names for the reaction equation. The first three are for the forward reaction, the second three are for the backward reaction. Blanks are to be included as needed. As an example of the equation:

02.. + 02.. + .... = 0... + 0... + 02.. where the periods represent blank characters.

RATE2, the forward and backward rate constants; C0, C1, C2, D0, D1, D2; for the corresponding reaction equations. C0 and D0 may be in either of the two conventional forms (e.g. for the equation above C0 as 44.92469 or $3.24 \times 10^{19}$). Internally the program uses the first form. If the second form is input, the form is indicated to the program by the first three characters of KRTITL being 'LOG'. If so, C0 and D0 are replaced by $\log_e$(C0) and $\log_e$(D0).

((ZSUB2(I,J),J=1,NS2),I=1,NZ2),(6F10.5), optional, read if NZ2 (=NJ2-NS2)>0.

The ZSUB array for the two species chemistry system. The corresponding variables are also read for the seven species chemistry system, these being NJ6, NR6, NZ6, NAME6, KREQ6, RATE6, and ZSUB6.

## Data Input in Subroutine GEOM

If the body geometry is specified in tabular form (IGEOM=3), the first time subroutine GEOM is called by MAIN the body geometry tables are read.

ZAX(I), RWA(I), SUR(I), CKA(I), THA(I), KND, Unit IRN4 (assigned value for IRN4 is 4), (5E14.6,A1)

Arrays, of up to 300 members, specifying the body geometry.

ZAX, $z = z^*/R_n^*$, axial coordinate of the current point.

RWA, $r = r^*/R_n^*$, the radial distance from the body axis to the surface for the current point.

SUR, $s = s^*/R_n^*$, the surface distance from the stagnation point to the current point.

CKA, $\kappa = \kappa^*/R_n^*$, surface curvature.

THA, $\theta$, angle between body tangent and axis.

KND, control character. If KND is a blank character, more cards are read for the geometry arrays. If KND is a non-blank character, no more cards are read and I is retained as the number of elements in the arrays.

Input Data in NAMELIST INPUT

The variables below are read through NAMELIST INPUT on Unit 5. On some computing systems (e.g. IBM) variables in the NAMELIST statement need not appear in the card input and many of the variables are initialized before the READ (5,INPUT) statement and need not appear in the card stream. The real variables are described first followed by the integer variables. The initialized value, when appropriate, is given in parentheses after the variable name.

ALT, variable to indicate in the output the altitude of the case conditions. ALT is not actually used in the calculations.

BRAD, $R_n^*$, the body nose radius in feet.

CAINF, (0.0), the freestream atom concentration for a binary reacting mixture.

CAT, (1.0), indicator for catalytic or noncatalytic wall condition; 1.0 for catalytic wall; -1.0 for noncatalytic wall.

CAW, (0.0), the atom concentration for a binary reacting mixture at the wall for a catalytic wall. CAW is not used for a noncatalytic wall.

CCFAC, (0.0), weighting factor used in the updating of the species concentration profiles for a seven species gas mixture at the stagnation point.

CONVRG, (0.01), convergence criterion. The variable values for U, T and $C_i$ (except for $NO^+$) are required to change by less than CONVRG between station iterations at each point in the finite-difference grid for convergence. For $NO^+$ the convergence criterion is 100 x CONVRG.

DS, (0.1), initial step size in the s direction. After the stagnation point solution, DS may be doubled or halved depending upon the values of DSMAX, NITMIN and NITMAX.

DSMAX, (5.0), an approximate upper limit of the step size, DS. DS may be doubled until DS > DSMAX but then DS may not be further increased.

HANGLE, (10.0), asymptotic half angle for hyperboloids.

PRINTCI, (0.0), control variable which allows printing of full profiles for each station iteration with atomic balance sums if PRINTCI=1.0. Printing of these profiles is suppressed if PRINTCI=0.0.

RINF, $\rho_\infty^*$, freestream density in slugs/ft$^3$.

SEND, (0.0), the final value at which a solution is to be obtained. If NDATA=0, SEND is set to DS x (IEND-1). If NDATA $\neq$ 0, SEND is reset to SN(NSDATA) if SEND = 0.0 or > SN(NSDATA).

SIGM, (0.7), $\sigma$, Prandtl number.

SITEST, (0.0001), convergence criterion for the shock temperature returned by Subroutine SHVALS.

SMALLT, ($1.0 \times 10^{-6}$), small factor to be added to or subtracted from 1.0. For computations with 14 or more significant figure accuracy (equivalent to IBM double precision) SMALLT should be set to $1.0 \times 10^{-10}$.

SSFAC, (-1.0), control variable which specifies if the calculation is to be with no shock slip (-1.0) or with shock slip (1.0).

SWFAC, (-1.0), control variable, unused except for header output, specifies no wall slip.

TB, $T_w^*$, body surface temperature, °R.

THINI, (-1.0), control variable for the second and subsequent global iterations being TVSL (1.0) or FVSL (-1.0). THIN is set equal to THINI at the end of each global iteration.

TINF, $T_\infty^*$, freestream temperature, °R.

UFAC, (0.5), specifies the amount of the previous station iteration u and T profiles to be mixed with the new iteration values of u and T at the stagnation point if more than twenty station iterations are required for a solution.

UINF, $U_\infty^*$, freestream velocity, ft/sec.

WVFAC, (0.25), the amount of the new v profiles at each station to be mixed with the v profiles from the previous global iteration before the v profiles are written on disc or tape if the present global iteration is FVSL. Only third and subsequent global iterations are affected.

XKETA, (1.0), parameter which determines the spacing of the points of the finite-difference grid. A value of 1.0 gives uniform spacing, a value such as 1.04 gives more grid points near the body surface.

XLE, (1.4), Le, binary Lewis number.

XNSO, (0.1166), an initial value of the stagnation shock-layer thickness, used only for the first station iteration.

IE, (51), number of points in the finite difference grid in the normal direction.

IEND, (200), maximum number of solution stations in the streamwise direction. IEND should not exceed 200.

IGEOM, Indicator for body geometry;

1. hyperboloid
2. paraboloid
3. tabular data geometry

IUN, (19), input unit number for reaction rate data.

JFAC, (1), indicator for axisymmetric (1) or two-dimensional (0) flow.

KEND, (2), number of global iterations to be made.

KPLTTP, (0), indicator which specifies whether plot data are to be written on Unit NTPL; 0, no; 1, yes.

KTWAL, (0), indicator for input wall temperature distribution data on Unit NTTWA; 0, no; 1, yes.

NAN, (1), indicator for analytic or near analytic bodies; 1, yes; 0, no. Negative values of NAN specify alternate methods of calculating the shock-layer thickness, XNS, as given in the description of Subroutine MASS.

NDATA, (0), indicator for input of shock shape data on Unit NTSH; 0, no; 1, yes.

NITMAX, (9999), number of station iterations permitted at a station before the s step size is halved and the program tries for a converged solution at the reduced value of s.

NITMIN, (3), the s step size is doubled if a converged solution is obtained at a station in NITMIN or fewer station iterations.

NITMNI, (3), the value assigned to NITMIN for the second and subsequent global iterations.

NS, (2), number of species for the first global iteration; selects gas chemistry model; 2, binary reacting gas; 6, multicomponent reacting air.

NSI,(2), value assigned to NS for second and subsequent global iterations.

NSPRF, (0), number of values of s to be read into array SPRF at which specific solutions are to be obtained and profiles printed.

NTSH, (5), Input Unit number for shock shape data arrays.

NTTWA, (5), Input Unit number for wall temperature distribution arrays.

## PREPARATION OF INPUT DATA

The principal guide to the user on preparing input data for the computer code is the section "Description of Input Data." This section describes steps which a user should follow in preparing input data for the program. It is suggested that the user cross reference this section with the section "Description of Input Data."

### Minimum Input Data Required

Much of the input data for the program is optional. This subsection describes the minimum input data which the program requires. On logical unit 5 the program requires KTITLE (the title card), the NAMELIST INPUT, and the freestream and wall species concentration values for multicomponent air (CINF6 and CIWW6). Also required are the reaction rate data read by Subroutine RTEDTA on unit IUN which is initialized by the program (IUN = 19) but may be changed by the user as needed.

The bodies which can be treated with the minimum data required are analytic or nearly analytic bodies (e.g. hyperboloids and paraboloids) for which it may reasonably be assumed that the shock and body angles are the same for the first global iteration (that the pressure distribution is Newtonian). Also, for such a case, the step size should be held constant and DSMAX should equal DS in the INPUT data. For such a case (with NDATA = 0) the maximum value of s (surface distance) would be DS x (IEND + 1).

While most of the variables in the NAMELIST INPUT are initialized, some of the variables are not initialized and values of these variables must be provided. The noninitialized variables are ALT, the altitude; BRAD, the nose radius; RINF, the freestream density; TB, the surface temperature; TINF, the freestream temperature; UINF, the freestream velocity and IGEOM, the indicator for the body geometry. These variables are specific to a given case and must be assigned values in INPUT.

### Shock Shape Data Input

With NDATA $\neq$ 0, a shock shape can be input to the program. For hyperboloids (with shock and body angles equal) the requirements for a constant step size is thus removed. For some bodies it is not appropriate to use the assumption that shock and body angles are equal if the pressure distribution is non-Newtonian. A shock shape from a blunt body, method of characteristics procedure may work well. The user should follow two guidelines in preparing shock shape input data. First, the distributions shock slope (SHSLPN) and shock-layer thickness (ENSHN) should be smooth. Second, the spacing of the points (the array SN) should be quite small near the stagnation point but may increase gradually downstream (e.g. geometrically). In the stagnation region, the SN array should be a tenth of DS or smaller.

For a nearly analytic body, with a smooth contour and with continuous curvature, it may be permissible for the shock angle to equal the body angle for the shock data input. This would imply that the SHSLPN array would be zero and the ENSHN array constant.

## Surface Temperature Input Data

The principal caution for the input of surface temperature data is that the spacing of the data points should change gradually and smoothly. Any large and abrupt changes in the distribution of the data points may cause difficulties in interpolating for the surface temperature and lead to erroneous results.

## Input of Body Geometry Data

The program provides for tabular input of the body geometry data in Subroutine GEOM with IGEOM = 3. This option allows the user to consider bodies other than hyperboloids and paraboloids. Due care, however, must be exercised in the preparation of these data. The body contour must be smooth. Also, the distribution of the body angle or the derivative of r with respect to z must also be smooth. The spacing of the geometry points must be sufficiently small in the stagnation region (for several nose radii downstream of s = 0) to provide an accurate specification of the body contour. Since data points are required downstream of a solution location, the input arrays should provide geometry data to s = SEND + 2DSMAX. Finally, the body curvature must also have a smooth and continuous distribution. Accurate and complete specification of the surface contour is especially important since the shock shapes for the second and later global iterations are calculated from the body geometry, the body angle and the shock-layer thickness derivative.

## Variable Values for Specific Conditions

Axisymmetric or Two-Dimensional flow is selected by the variable JFAC (1 or 0).

Body Geometry is specified by the variable IGEOM (1, hyperboloid; 2, paraboloid; and 3, tabular data geometry).

Fully Viscous Shock-Layer flow is specified by THINI = -1.0 (effective on the second and subsequent global iterations). THINI = 1.0 specifies Thin Viscous Shock-Layer flow after the first global iteration.

Gas Chemistry is specified by NS and NSI (for the first and subsequent global iterations, respectively). Values of 2 specify dissociating oxygen. Values of 6 specify multicomponent, ionizing air. Computing time is saved and little accuracy is lost if NS = 2 even if NSI = 6.

Nearly Analytic or analytic geometries are specified by NAN = 1. Non-analytic geometries are specified by zero or negative values of NAN. The options for NAN $\leq$ 0 are described in the description of Subroutine MASS.

Shock Slip is specified by SSFAC = 1.0. No shock slip is specified by SSFAC = -1.0.

Wall Catalyticity is specified by the variable CAT. CAT = -1.0 specifies a noncatalytic wall (NCW) with $\left.\frac{\partial C_i}{\partial y}\right|_{wall} = 0$. CAT = 1.0 specifies a catalytic wall and the values of CAW and CIWW6 are used for dissociating oxygen and multicomponent air, respectively.

## DESCRIPTION OF OUTPUT DATA

The principal printed output of the program is on Unit 6. Supplemental output of the program is on other units. The Unit 6 output is described followed by the output on the other units.

### Unit 6 Output

At the beginning of the Unit 6 output, KTITLE, the case header card, is written. Following KTITLE, the NAMELIST INPUT, is printed. Some values of the NAMELIST variables may be reset between the reading and the printing of INPUT. The remaining Unit 6 output is repeated for each global iteration and within each global iteration the station output is repeated for each solution station.

The global iteration output begins with a listing of the reaction rate data subheader card followed by the reaction equations and reaction equation rate constants, the ALSUB, ALPHSB, BETSUB, BETASB arrays. Following is the ZSUB array if NZ is > 0.

After the reaction rate data the values of VSREF and VSINF ($\mu^*_{ref}$ and $\mu^*_\infty$) as calculated in the first section of subroutine THERM are printed.

At the beginning of each global iteration, after a converged station solution is obtained, header information to the global iteration is printed. The first line gives the following data.

UINF $U^*_\infty$, ft/sec, freestream velocity.

PINF $p^*_\infty$, lbf/ft$^2$, freestream static pressure.

TINF $T^*_\infty$, $^oR$, freestream static temperature.

CAINF $C_{a_\infty}$, freestream oxygen atom concentration for the dissociating oxygen chemistry model.

TB $T_w$, $^oR$, wall temperature.

BRAD $R^*_n$, ft, nose radius.

PR Pr, Prandtl number.

LE Le, binary Lewis number.

YSH $y_{sh}$, at the stagnation point.

ALT altitude, ft.

The second line describes the conditions and gives THIN SHOCK LAYER, (TVSL), or NO THIN SHOCK LAYER, (FVSL), NO WALL SLIP, NO SHOCK SLIP or SHOCK SLIP, CAT WALL, (ECW), or NO CAT WALL, (NCW), the number of steps in the y direction (IE), the maximum number of steps in the s direction (IEND), and the initial step size (DS).

The next line gives the values in the SPRF array if NSPRF > 0.

The final line gives the following data.

TW/TS $T_w^*/T_o^*$, ratio of wall to stagnation temperature, BO.

EPS $\varepsilon$, $\{\mu_{ref}^*/(\rho_\infty^* U_\infty^* R_n^*)\}^{1/2}$, Reynolds number parameter.

REYIN $Re_\infty$, $\rho_\infty^* U_\infty^* R_n^*/\mu_\infty^*$, freestream Reynolds number based on the nose radius.

REYSH $Re_{sh}$, $\rho_\infty^* U_\infty^* R_n^*/\mu_{sh}^*$, shock Reynolds number.

TREF $T_{ref}^*$, °R, $U_\infty^{*2}/C_{p_\infty}^*$, reference temperature.

UREF $U_{ref}^*$, ft/sec, reference velocity, $U_\infty^*$.

RREF $\rho_{ref}^*$, slugs/ft$^3$, reference density, $\rho_\infty^*$.

ITER global iteration number.

The remaining output on Unit 6 is station output and for each solution station the output is similar. The station output begins (if PRINTCI = 0.0) with a line after each station iteration is completed giving K (the global iteration number), I (the station number), S (the streamwise location of the solution being attempted), NITER (the number of the station iteration) and DIFI (the maximum difference found for the $u/u_{sh}$, $T/T_{sh}$ and $C_i$ arrays, respectively). If, however, PRINTCI = 1.0, this line is replaced by an output array giving the same information with the $y/y_{sh}$ (XN), $u/u_{sh}$ (UC), $T/T_{sh}$ (TC), the $C_i$ arrays (headed by the species names), the sum of the $C_i$ (SUMCI), the atom concentration sums for O (SUMO) and for N (SUMN).

After a converged solution is obtained, KTITLE is printed followed by the solution data for the station. For each station, four lines of output are printed. Additional output (profiles) are printed if s equals one of the values of the SPRF array or if I = 1, 6, 11, etc. (every fifth station).

LINE 1:

S s, surface distance.

X x, axial coordinate to current surface point.

R $r_w$, radial distance from the body axis to current surface point.

YSH $y_{sh}$, current shock-layer thickness, CNS.

YSHP derivative of $y_{sh}$ with respect to s.

XSH $x_{sh}$, axial coordinate for the current shock point.

RSH $r_{sh}$, radial distance from the body axis to the current shock point.

NO ITER number of station iterations required to obtain the converged solution.

NITTOT total number of station iterations required for the current global iteration.

NTOT total number of station iterations required including those for any previous global iterations.

I I, the current station number.

K K, the current global iteration number.

LINE 2:

DS ds, step size in the s direction.

CF $C_f$, skin friction coefficient.

HEAT $q_w$, dimensionless heat transfer coefficient.

STAN St, $-q_w/(H_\infty - H_w)$, Stanton number, where $H_w$ is the enthalpy at the wall if NS = 6 and if NS = 2 the wall enthalpy for O and $O_2$ in equilibrium.

CDF $C_{D_f}$, the skin friction contribution to the drag coefficient.

CDP $C_{D_p}$, the pressure contribution to the drag coefficient.

CDTOT $C_D$, total drag coefficient.

PWALL $P_w$, (PC(1) x PPS), wall pressure.

TWALL $T_w^*$, $^oR$, wall temperature.

PW/PO $P_w/P_{w_{s=0}}$, ratio of wall pressure to wall pressure at the stagnation point.

LINE 3:

YSHP(S derivative of $y_{sh}$ with respect to s at s from the SHSLPN array.

YSHP(S + DS/2 derivative of $y_{sh}$ with respect to s at s + ds/2 from the SHSLPN array.

NEW YSHP derivative of $y_{sh}$ with respect to s as calculated by the program.

ALPHA(S + DS/2 $\alpha$, shock angle at s + ds/2.

PHI(S + DS/2 $\phi$, body angle at s + ds/2.

KAPPA(S $\kappa$, body curvature at s.

KAPPA(S + DS/2 $\kappa$, body curvature at s + ds/2.

LINE 4:

USH $u_{sh}$, tangential velocity component behind the shock;first value $U^*_{sh}/U^*_{ref}$; second value $U^*_{sh}$, ft/sec.

VSH $v_{sh}$, normal velocity component behind the shock; first value, $V^*_{sh}/U^*_{ref}$; second value, $V^*_{sh}$, ft/sec.

TSH $T_{sh}$, temperature behind the shock; first value, $T^*_{sh}/T^*_{ref}$; second value, $T^*_{sh}$, °R; third value, $T^*_{sh}$, °K.

RSH $\rho_{sh}$, density behind the shock.

PSH $P_{sh}$, pressure behind the shock.

VPG average of the derivatives of $v_{sh}$ with respect to s at s and s + ds/2 from the previous global iteration.

The profile output is printed only if the value of s is one of the values of the SPRF array or if I = 1, 6, 11, etc. The first block of profile data is printed for both dissociating oxygen and for multicomponent air. The second block of profile data is printed only for multicomponent air.

The first block of profile data includes N, the grid point number; Y/YSH, the XN array; U/USH, the UC array, the tangential velocity profile; V/VSH, the VC array, the normal velocity profile; T/TSH, the TC array, the temperature profile; R/RSH, the RC array, the density profile; P/PSH(APPR) the PC array, the pressure profile; P/PSH, the PE array, an alternate pressure profile; CA, the CC(N,1) array, the concentration profile of oxygen atoms; CAEQ, the CAEQ array, the species concentration of atomic oxygen that would exist for dissociating oxygen at equilibrium; XM, the Mach number profile; and T °R, the temperature profile in degrees Rankine.

The second block of profile data includes N, the grid point number; Y/RN, $y^*/R_n^*$; the species concentration profiles for O, $O_2$, NO, N, $NO^+$ and $N_2$; $E^-$/CC, the electron number density profiles; Y IN, $y^*$ in inches; and Y-CM, $y^*$ in centimeters.

## Unit 1 Output

The program output on Unit 1 provides convenient access to principle data generated by the program as a function of s. The following data are printed for each converged solution.

| | |
|---|---|
| K | the global iteration number. |
| I | the station number. |
| S/RN | $s = s^*/R_n^*$, surface distance. |
| ITER | the number of station iterations needed to obtain a converged solution at that value of s. |
| YSH | $y_{sh}$, shock layer thickness, XNS. |
| YSHP | the calculated derivative of $y_{sh}$ with respect to s, XNSP(I). |
| CF | $C_f$, the skin friction coefficient, CFCH. |
| HEAT | $q_w$, the nondimensionalized heat transfer. |
| STAN | St, Stanton number. |
| PW/PO | ratio of $P_w$ to $P_w$ at the stagnation point. |
| Q/QO | ratio of $q_w$ to $q_w$ at the stagnation point. |
| S | $s^*$, ft, surface distance. |
| QDOT | $q_w^*$, heat transfer, BTU/ft$^2$ sec. |

## Unit 3 Output

The output for Unit 3 is similar in approach to that on Unit 1 but of different content.

K the global iteration number.

I the station number.

ITER the number of station iterations needed to obtain a converged solution at the value of s.

S/RN $s^*/R_n^*$, surface distance.

YSH $y_{sh}$, the shock-layer thickness, XNS.

YSH-D $y_{sh}$ as calculated from the integration of the mass conservation equation.

YSH-ST $y_{sh}$ as calculated by matching the mass flow through the shock with the mass flow through the shock layer.

YSH-AV $y_{sh}$ as the average of YSH-D and YSH-ST.

E-/CC,MAX the peak value of the electron number density.

XN,E-MAX the value of $y/y_{sh}$ corresponding to the peak $N_e/cm^3$.

Y,IN,E-M the value of $y^*$, in inches, corresponding to the peak $N_e/cm^3$.

S/RN $s^*/R_n^*$, surface distance.

S FT $s^*$, ft, surface distance.

## Unit 8 Output

The output on Unit 8 is divided into two groups. The first group is printed only if NDATA ≠ 0; that is, if shock shape data are input to the program.

The first group of output data consists of S, $s^*/R_n^*$, the surface distance (the array SN); YSHP, the corresponding derivative of $y_{sh}$ with respect to s (the array SHSLPN); and N, the array subscript.

The second group of output data is written line by line as solutions are obtained. The first part of the line is written before a solution at the given station is attempted. The second part of the line is written after a converged solution is obtained at the given station. The data for the first part of the line are as follows.

STA. NO. I, the station number.

S s, surface distance.

OLDXNSP — $y'_{sh}$ (the derivative of $y_{sh}$ with respect to s) at s from the previous global iteration or from the array SHSLPN.

XNSPM — $y'_{sh}$ at s + ds/2 from the previous global iteration or from the array SHSLPN.

ALPHA(S+DS/2) — $\alpha$, the shock angle at s + ds/2.

The remainder of the line is printed after a converged station solution is obtained. These data are:

NEW XNSP — the new value of $y'_{sh}$ computed by the program.

NEW YSH — $y_{sh}$, XNS, computed by the program.

XSH — x coordinate of the shock point.

RSH — r coordinate of the shock point.

Unit 9 Output

At the end of each station iteration the following data are printed on Unit 9.

K — global iteration number.

I — the station number.

S — s, the surface distance.

NITER — the number of iterations at that station.

NITTOT — the total number of station iterations for the global iteration.

TFACT — a primitive convergence criterion U2(15) old - U2(15) new iteration.

DIF — maximum difference for the velocity profiles between station iteration.

(unnamed) — XNS, the current station iteration value of $y_{sh}$.

(unnamed) — CNS, the average of XNS and $y_{sh}$ at the previous station or, if s = 0, from the previous station iteration.

## Unit NTPL Output

After a converged station solution is obtained, the following data are written unformatted on Unit NTPL (13) in Subroutine RESET if KPLTTP $\neq$ 0 for plotting or other purposes appropriate to the user:

| | |
|---|---|
| K | global iteration number. |
| I | station number. |
| XSOL(I) | s, the surface distance of the solution point. |
| XB | $x_w$, axial coordinate of the solution point. |
| RS | $r_w$, radial coordinate of the solution point. |
| XSH | $x_{sh}$, axial coordinate of the shock point. |
| RSH | $r_{sh}$, radial coordinate of the shock point. |
| CNS | $y_{sh}$, shock-layer thickness. |
| CFCH | $C_f$, skin friction coefficient. |
| STAN | St, Stanton number. |
| PWRAT | ratio of $P_w$ to $P_w$ at the stagnation point. |

# APPENDIX A: ANALYSIS

This appendix presents in an abbreviated form the analysis of the viscous, shock-layer problem as given in the companion engineering report. The equations are written for a body oriented coordinate system as shown in Fig. 3. Unless indicated otherwise, variables using a superscript star (*) are dimensional and unstarred variables are nondimensional.

## Governing Equations

The equations for shock-layer flows of multicomponent gases are given below.

Continuity Equation:

$$\frac{\partial}{\partial s}\{(r + y\cos\phi)^j \rho u\} + \frac{\partial}{\partial y}\{(1+\kappa y)(r + y\cos\phi)^j \rho v\} = 0 \qquad (1)$$

s-Momentum Equation:

$$\frac{1}{1+\kappa y}\rho u\frac{\partial u}{\partial s} + \rho v\frac{\partial u}{\partial y} + \rho u v\frac{\kappa}{1+\kappa y} + \frac{1}{1+\kappa y}\frac{\partial P}{\partial s} = \varepsilon^2\frac{\partial}{\partial y}\left[\mu\left(\frac{\partial u}{\partial y} - \frac{\kappa u}{1+\kappa y}\right)\right] +$$

$$\varepsilon^2\mu\left(\frac{2\kappa}{1+\kappa y} + \frac{j\cos\phi}{r + y\cos\phi}\right)\left(\frac{\partial u}{\partial y} - \frac{\kappa u}{1+\kappa y}\right) \qquad (2)$$

y-Momentum Equation:

$$\frac{\partial P}{\partial y} = \frac{\kappa}{1+\kappa y}\rho u^2 - \frac{1}{1+\kappa y}\rho u\frac{\partial v}{\partial s} - \rho v\frac{\partial v}{\partial y} \qquad \text{(FVSL)} \qquad (3a)$$

which becomes

$$\frac{\partial P}{\partial y} = \frac{\kappa}{1+\kappa y}\rho u^2 \qquad \text{(TVSL)} \qquad (3b)$$

if the thin shock-layer approximation is made.

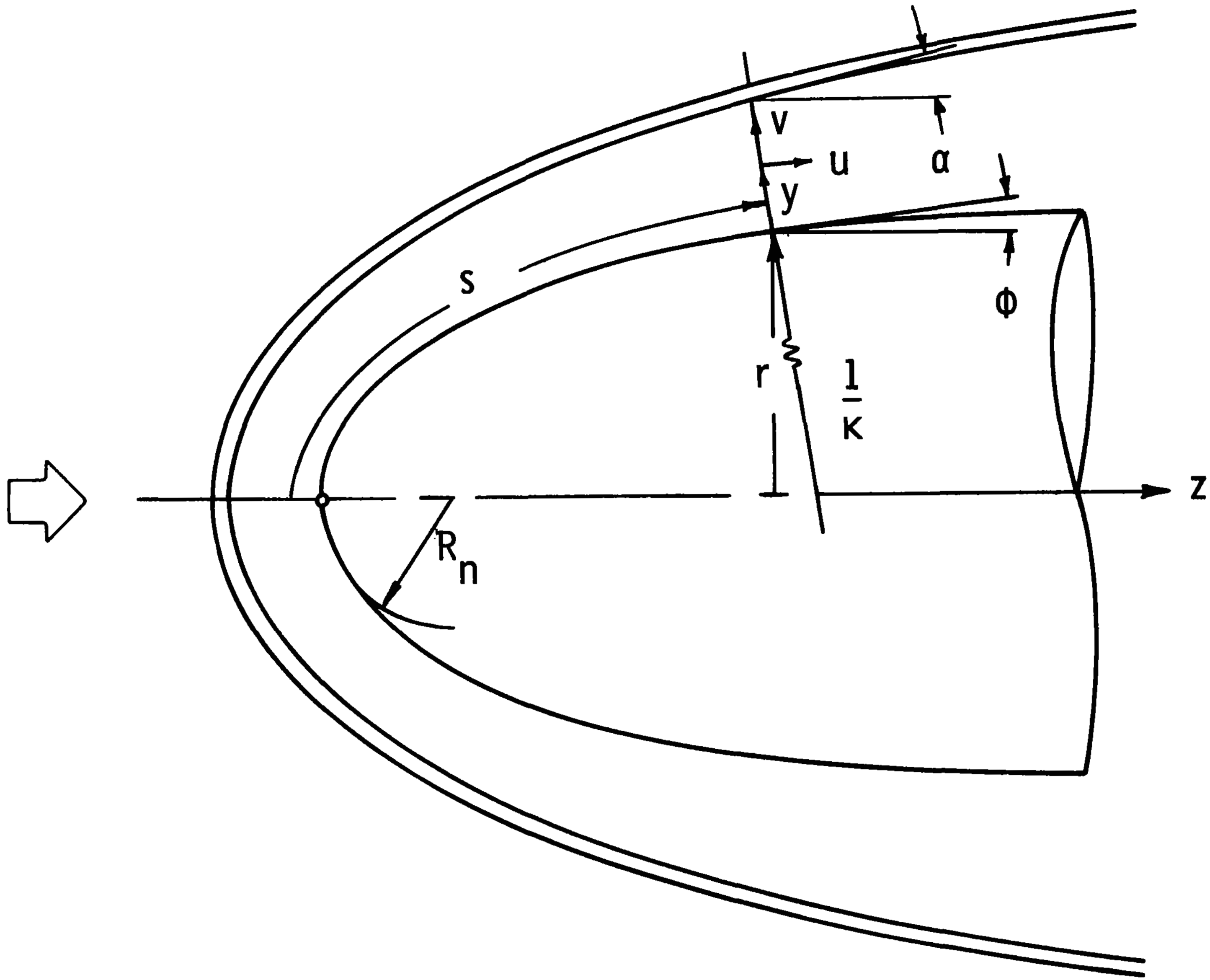


Figure 3. Coordinate System for Viscous Shock-Layer Over Blunt Bodies.

Energy Equation:

$$\frac{1}{1+\kappa y} \rho u \, C_p \frac{\partial T}{\partial s} + \rho v \, C_p \frac{\partial T}{\partial y} - \frac{1}{1+\kappa y} u \frac{\partial P}{\partial s} - v \frac{\partial P}{\partial y} =$$

$$\varepsilon^2 \frac{\partial}{\partial y} \left(k \frac{\partial T}{\partial y}\right) + \varepsilon^2 \left( \frac{\kappa}{1+\kappa y} + \frac{j \cos \phi}{r + y \cos \phi} \right) k \frac{\partial T}{\partial y} - \varepsilon^2 \sum_{i=1}^{ns} J_i \, C_{p_i} \frac{\partial T}{\partial y} +$$

$$\varepsilon^2 \mu \left( \frac{\partial u}{\partial y} - \frac{\kappa u}{1+\kappa y} \right)^2 - \sum_{i=1}^{ns} h_i \, \dot{w}_i \qquad (4)$$

Species Conservation Equations:

$$\frac{1}{1+\kappa y} \rho u \frac{\partial C_i}{\partial s} + \rho v \frac{\partial C_i}{\partial y} = \dot{w}_i - \varepsilon^2 \frac{\partial}{\partial y} (J_i) - \varepsilon^2 \left( \frac{\kappa}{1+\kappa y} + \frac{j \cos \phi}{r + y \cos \phi} \right) J_i \qquad (5)$$

where $J_i$ is the diffusion mass flux term of species i, and

Equation of State:

$$P = \frac{\rho R T}{\overline{M} C^*_{p\infty}} \qquad (6)$$

With binary diffusion only and with constant binary Lewis numbers (all equal), the diffusion mass flux term of the species is given by

$$J_i = - \frac{\mu}{Pr} Le_i \frac{\partial C_i}{\partial y} \qquad (7)$$

The species mass fractions are given by

$$C_i = \rho_i / \rho \qquad (8)$$

The frozen specific heat of the mixture is given by

$$C_p = \sum_{i=1}^{ns} C_i \, C_{p_i} \qquad (9)$$

and the mixture molecular weight is given by

$$\overline{M} = \frac{1}{\sum_{i=1}^{ns} \frac{C_i}{M_i}} \tag{10}$$

The preceding equations are nondimensional. The dimensional equations were nondimensionalized by the following relations:

$$u^* = u\, U_\infty^* \tag{11a}$$

$$v^* = v\, U_\infty^* \tag{11b}$$

$$T^* = T\, T_{ref}^* = T\, U_\infty^{*2}/C_{p\infty}^* \tag{11c}$$

$$P^* = P\, \rho_\infty^*\, U_\infty^{*2} \tag{11d}$$

$$\rho^* = \rho\, \rho_\infty^* \tag{11e}$$

$$\mu^* = \mu\, \mu_{ref}^* \tag{11f}$$

$$k^* = k\, \mu_{ref}^*\, C_{p\infty}^* \tag{11g}$$

$$C_p^* = C_p\, C_{p_\infty}^* \tag{11h}$$

$$h^* = h\, U_\infty^{*2} \tag{11i}$$

$$w_i^* = w_i\, \rho_\infty^*\, U_\infty^*/R_n^* \tag{11j}$$

$$J_i^* = J_i\, \mu_{ref}^*/R_n^* \tag{11k}$$

$$s^* = s\, R_n^* \tag{11l}$$

$$y^* = y\, R_n^* \tag{11m}$$

$$\kappa^* = \kappa\, R_n^* \tag{11n}$$

and

$$r^* = r\, R_n^* \tag{11o}$$

The dimensionless parameters which appear in the shock-layer equations are given by the following relations:

$$Pr = C_p^* \mu^*/k^* \tag{12a}$$

$$\varepsilon = \sqrt{\frac{\mu^*_{ref}}{\rho^*_\infty U^*_\infty R^*_n}} \tag{12b}$$

and

$$Le_i = \rho^* C_p^* D_i^*/k^* \tag{12c}$$

For the finite-difference solution procedure, the shock-layer equations were transformed. The independent and dependent variables (except for the species concentrations) were normalized by their local shock values.

The transformed independent and dependent variables are

$$\eta = y/y_{sh} \tag{13a}$$

$$\xi = s \tag{13b}$$

$$\bar{u} = u/u_{sh} \tag{13c}$$

$$\bar{v} = v/v_{sh} \tag{13d}$$

$$\bar{P} = P/P_{sh} \tag{13e}$$

$$\bar{\rho} = \rho/\rho_{sh} \tag{13f}$$

$$\bar{T} = T/T_{sh} \tag{13g}$$

$$\bar{\mu} = \mu/\mu_{sh} \tag{13h}$$

$$\bar{k} = k/k_{sh} \tag{13i}$$

and

$$\bar{C}_p = C_p/C_{p_{sh}} \tag{13j}$$

The transformations relating the differential expressions are

$$\frac{\partial}{\partial s} = \frac{\partial}{\partial \xi} - \frac{y'_{sh}}{y_{sh}} \eta \frac{\partial}{\partial \eta} \tag{14a}$$

$$\frac{\partial}{\partial y} = \frac{1}{y_{sh}} \frac{\partial}{\partial \eta} \tag{14b}$$

and

$$\frac{\partial^2}{\partial y^2} = \frac{1}{y_{sh}^2} \frac{\partial^2}{\partial \eta^2} \tag{14c}$$

where

$$y'_{sh} = \frac{dy_{sh}}{d\xi} \tag{14d}$$

When written in the transformed $\xi,\eta$ coordinates, the s-momentum, energy and species continuity equations (Eqs. 2, 4 and 5) can be expressed in the following standard form for a parabolic partial differential equation:

$$\frac{\partial^2 W}{\partial \eta^2} + A_1 \frac{\partial W}{\partial \eta} + A_2 W + A_3 + A_4 \frac{\partial W}{\partial \xi} = 0 \tag{15}$$

where W represents $\bar{u}$ in the s momentum equation, $\bar{T}$ in the energy equation and $C_i$ in the species continuity equations. The coefficients $A_1$ through $A_4$ are functions of the independent and dependent variables and may be written as follows:

s-momentum equation

$$A_1 = \frac{1}{\bar{\mu}} \frac{\partial \bar{\mu}}{\partial \eta} + \frac{\kappa y_{sh}}{1+\kappa y_{sn} \eta} + \frac{j\, y_{sh} \cos \phi}{r + y_{sh} \eta \cos \phi} + \frac{y_{sh}\, y'_{sh}\, \rho_{sh}\, u_{sh}}{\varepsilon^2 \mu_{sh} (1+\kappa y_{sh} \eta)} \frac{\overline{\rho u \eta}}{\bar{\mu}}$$

$$- \frac{y_{sh}\, \rho_{sh}\, v_{sh}}{\varepsilon^2 \mu_{sh}} \frac{\overline{\rho v}}{\bar{\mu}} \tag{16a}$$

$$A_2 = - \frac{\kappa y_{sh}}{1+\kappa y_{sh} \eta} \frac{1}{\bar{\mu}} \frac{\partial \bar{\mu}}{\partial \eta} - \frac{\kappa^2 y^2{}_{sh}}{(1+\kappa y_{sh} \eta)^2} - \frac{\kappa y_{sh}^2\, j \cos \phi}{(1+\kappa y_{sh} \eta)\,(r + y_{sh} \eta \cos \phi)} -$$

$$\frac{y_{sh}^2\, \rho_{sh}\, u'_{sh}}{\varepsilon^2 \mu_{sh} (1+\kappa y_{sh} \eta)} \frac{\overline{\rho u}}{\bar{\mu}} - \frac{\kappa y_{sh}^2\, \rho_{sh}\, v_{sh}}{\varepsilon^2 \mu_{sh} (1+\kappa y_{sh} \eta)} \frac{\overline{\rho v}}{\bar{\mu}} \tag{16b}$$

$$A_3 = -\frac{y_{sh}^2}{\varepsilon^2\ \mu_{sh}\ u_{sh}\ (1+\kappa y_{sh}\ \eta)\ \bar{\mu}} \left[\bar{P}\ \frac{\partial P_{sh}}{\partial \xi} + P_{sh}\ \frac{\partial \bar{P}}{\partial \xi} - \eta\ \frac{y'_{sh}}{y_{sh}}\ P_{sh}\ \frac{\partial \bar{P}}{\partial \eta}\right] \tag{16c}$$

$$A_4 = -\frac{y_{sh}^2\ \rho_{sh}\ u_{sh}}{\varepsilon^2\ \mu_{sh}\ (1+\kappa y_{sh}\ \eta)}\ \frac{\overline{\rho u}}{\bar{\mu}} \tag{16d}$$

Energy Equation

$$A_1 = \frac{1}{\bar{k}}\frac{\partial \bar{k}}{\partial \eta} + \frac{\kappa y_{sh}}{1+\kappa y_{sh}\ \eta} + \frac{y_{sh}\ j\ \cos\ \phi}{r + y_{sh}\ \eta\ \cos\ \phi} - \frac{y_{sh}}{k_{sh}\ \bar{k}} \sum_{i=1}^{ns} J_i\ C_{p_i} -$$

$$\frac{y_{sh}\ \rho_{sh}\ C_{p_i}\ \bar{\rho}\ \bar{C}_p}{\varepsilon^2\ k_{sh}\ \bar{k}} \left[v_{sh}\ \bar{v} - \frac{u_{sh}\ y'_{sh}\ \bar{u}\ \eta}{1+\kappa y_{sh}\ \eta}\right] \tag{17a}$$

$$A_2 = A_4\ \frac{1}{T_{sh}}\ \frac{\partial T_{sh}}{\partial \xi} - \frac{y_{sh}^2\ \dot{w}_2}{\varepsilon^2\ k_{sh}\ \bar{k}} \tag{17b}$$

$$A_3 = -\frac{y_{sh}^2\ \dot{w}_1}{\varepsilon^2\ T_{sh}\ k_{sh}\ \bar{k}} + \frac{y_{sh}^2\ \mu_{sh}\ \bar{\mu}}{T_{sh}\ k_{sh}\ \bar{k}} \left[\frac{u_{sh}}{y_{sh}}\ \frac{\partial \bar{u}}{\partial \eta} - \frac{\kappa u_{sh}\ \bar{u}}{1+\kappa y_{sh}\ \eta}\right]^2 +$$

$$\frac{y_{sh}\ u_{sh}\ \bar{u}}{\varepsilon^2\ (1+\kappa y_{sh}\ \eta)\ T_{sh}\ k_{sh}\ \bar{k}} \left[y_{sh}\ \bar{P}\ \frac{\partial P_{sh}}{\partial \xi} + y_{sh}\ P_{sh}\ \frac{\partial \bar{P}}{\partial \xi} - y'_{sh}\ P_{sh}\ \eta\ \frac{\partial \bar{P}}{\partial \eta}\right] +$$

$$\frac{y_{sh}\ P_{sh}\ v_{sh}\ \bar{v}}{\varepsilon^2\ T_{sh}\ k_{sh}\ \bar{k}}\ \frac{\partial \bar{P}}{\partial \eta} \tag{17c}$$

$$A_4 = -\frac{y_{sh}^2\ Cp_{sh}\ \rho_{sh}\ u_{sh}}{\varepsilon^2\ (1+\kappa y_{sh}\ \eta)\ k_{sh}}\ \frac{\bar{C}_p\ \overline{\rho u}}{\bar{k}} \tag{17d}$$

Species Conservation Equation

$$A_1 = \frac{1}{JB}\frac{\partial JB}{\partial \eta} + \frac{y_{sh}\kappa}{1+\kappa y_{sh}\,\eta} + \frac{y_{sh}\; j \cos\phi}{r + y_{sh}\,\eta \cos\phi} - \frac{y_{sh}\,\rho_{sh}\,v_{sh}\,\overline{\rho v}}{\varepsilon^2 JB} +$$

$$\frac{y_{sh}\,y'_{sh}\,\rho_{sh}\,u_{sh}\,\overline{\rho u}\,\eta}{\varepsilon^2\, JB\,(1+\kappa y_{sh}\,\eta)} \tag{18a}$$

$$A_2 = -\frac{y_{sh}^2\,\rho_{sh}\,\bar{\rho}\,w_i^{\,1}}{\varepsilon^2\, JB} \tag{18b}$$

$$A_3 = \frac{y_{sh}^2\,\rho_{sh}\,\bar{\rho}\,w_i^{\,0}}{\varepsilon^2\, JB} \tag{18c}$$

$$A_4 = -\frac{y_{sh}^2\,\rho_{sh}\,u_{sh}\,\overline{\rho u}}{\varepsilon^2\, JB\,(1+\kappa y_{sh}\,\eta)} \tag{18d}$$

where

$$JB = \frac{\mu_{sh}\,\bar{\mu}\,Le_i}{Pr_{sh}\,\overline{Pr}} \tag{18e}$$

In the transformed coordinates the remaining equations are

Continuity Equation

$$\frac{\partial}{\partial \xi}\left[y_{sh}\,(r + y_{sh}\,\eta\cos\phi)^j\,\rho_{sh}\,u_{sh}\,\overline{\rho u}\right] =$$

$$\frac{\partial}{\partial \eta}\left[(r + y_{sh}\,\eta\cos\phi)^j\,\{y'_{sh}\,\rho_{sh}\,u_{sh}\,\overline{\rho u}\eta - (1+\kappa y_{sh}\,\eta)\,\rho_{sh}\,v_{sh}\,\overline{\rho v}\}\right] \tag{19}$$

y-momentum equation

$$\frac{P_{sh}}{y_{sh}\,\rho_{sh}\,u_{sh}\,v_{sh}}\frac{\partial \bar{P}}{\partial \eta} - \frac{\kappa u_{sh}}{v_{sh}\,(1+\kappa y_{sh}\,\eta)}\,\overline{\rho u}^{\,2} + \frac{v_{sh}\,\overline{\rho v}}{y_{sh}\,u_{sh}}\frac{\partial \bar{v}}{\partial \eta} +$$

$$\frac{\overline{\rho u}}{1+\kappa y_{sh}\,\eta}\left[\frac{\partial \bar{v}}{\partial \xi} + \frac{\bar{v}}{v_{sh}}\frac{\partial v_{sh}}{\partial \xi} - \frac{y'_{sh}\,\eta}{y_{sh}}\frac{\partial \bar{v}}{\partial \eta}\right] = 0 \tag{20a}$$

which becomes

$$\frac{\partial \bar{P}}{\partial \eta} = \frac{\kappa y_{sh}\,\rho_{sh}\,u_{sh}^2}{P_{sh}\,(1+\kappa y_{sh}\,\eta)}\,\overline{\rho u}^{\,2} \tag{20b}$$

if the thin shock-layer approximation is made, and

State Equation

$$\bar{P} = \bar{\rho}\,\bar{T}\,\frac{\bar{M}_{sh}}{\bar{M}} \tag{21}$$

The energy and species conservation equations (Eqs. 4 and 5) include the rate of production terms, $\dot{w}_i$, of species i. For the energy equation, the production term is written so that the temperature appears as an unknown as

$$\left(\frac{\dot{w}_i}{\rho}\right)_{k+1} = \left(\frac{\dot{w}_i}{\rho}\right)_k + \left[\frac{\partial}{\partial T}\left(\frac{\dot{w}_i}{\rho}\right)\right]_k \left[T_{k+1} - T_k\right] \tag{22}$$

where k denotes the iteration for which the solution is known and k+1 the iteration for which a solution is sought. The production term in the energy equation (Eq. 4) was rewritten as

$$\sum_{i=1}^{ns} h_i\,\dot{w}_i = \dot{w}_1 + T_{sh}\,\bar{T}\,\dot{w}_2 \tag{23}$$

and the terms $\dot{w}_1$ and $\dot{w}_2$ appear in the energy equation coefficients (Eqs. 17b and 17c). For the species conservation equation, the production term was written so that the species mass fractions appear as an unknown as

$$\frac{\dot{w}_i}{\rho} = \dot{w}_i^{\,0} - C_i\,\dot{w}_i^{\,1} \tag{24}$$

and the terms $\dot{w}_i^{\,0}$ and $\dot{w}_i^{\,1}$ appear in the species conservation equation coefficients (Eqs. 18b and 18c).

The viscous shock layer for nonequilibrium chemistry is described by equations (15) through (21) together with the appropriate boundary conditions and relations for the thermodynamic and transport properties.

## Boundary Conditions

At the body surface, the no slip boundary conditions are imposed. For $\eta = 0$, the surface conditions are

$$\bar{u} = 0 \tag{25a}$$

$$\bar{v} = 0 \tag{25b}$$

and

$$T = T_w \tag{25c}$$

where $T_w$ is either a constant or has a specified variation. For a noncatalytic surface, (NCW), the species boundary conditions are

$$\frac{\partial C_i}{\partial \eta} = 0 \tag{25d}$$

The equilibrium catalytic wall (ECW) conditions are specified by

$$C_i = C_{i_{eq}}\,(T_w) \tag{25e}$$

In the program the ECW condition is approximated by a fully catalytic surface (FCW) condition specified by, for example,

$$C_O = 0,\ C_{O_2} = 0.23456,\ C_{NO} = 0,\ C_N = 0,\ C_{NO^+} = 0 \text{ and } C_{N_2} = 0.76544 \tag{25f}$$

At the shock, the velocity components tangent and normal to the shock are not the same as the components tangent and normal to the body surface. The velocity components tangent and normal to the shock are denoted by $\hat{u}_{sh}$ and $\hat{v}_{sh}$ and the components tangent and normal to the body surface are denoted as $u_{sh}$ and $v_{sh}$. The transformation relating the two sets of shock velocity components is

$$u_{sh} = \hat{u}_{sh} \sin(\alpha + \beta) + \hat{v}_{sh} \cos(\alpha + \beta) \tag{26a}$$

and

$$v_{sh} = -\hat{u}_{sh} \cos(\alpha + \beta) + \hat{v}_{sh} \sin(\alpha + \beta) \tag{26b}$$

where $\beta = \pi/2 - \phi$.

For shocks of finite thickness called shock slip (SS), the shock properties are given by the modified Rankine-Hugoniot relations (see Davis and Cheng) below.

$$\rho_{sh} \hat{v}_{sh} = -\sin\alpha \tag{27a}$$

$$\varepsilon^2 \mu_{sh} \left(\frac{\partial \hat{u}}{\partial y}\right)_{sh} + \sin\alpha\, \hat{u}_{sh} = \sin\alpha \cos\alpha \tag{27b}$$

$$P_{sh} - \sin\alpha\, \hat{v}_{sh} = \frac{P_\infty}{\rho_\infty U_\infty^2} + \sin^2\alpha \tag{27c}$$

$$\varepsilon^2 k_{sh} \left(\frac{\partial T}{\partial y}\right)_{sh} + \sin\alpha \sum_{i=1}^{ns} C_{i_\infty} h_{i_{sh}} - \frac{\sin\alpha}{2} \{(\hat{u}_{sh} - \cos\alpha)^2 + \sin^2\alpha - \hat{v}_{sh}\}$$

$$= \sin\alpha \sum_{i=1}^{ns} C_{i_\infty} h_{i_\infty} \tag{27d}$$

and

$$\varepsilon^2 \frac{\mu_{sh}}{Pr_{sh}} Le_i \frac{\partial C_{i_{sh}}}{\partial y} + \sin\alpha\, C_{i_{sh}} = \sin\alpha\, C_{i_\infty} \tag{27e}$$

With no shock slip (NSS) the Rankine-Hugoniot relations are used to determine the shock values. Eqs. (27a) and (27c) are unchanged. The expressions for $\hat{u}_{sh}$, $T_{sh}$ and $C_{i_{sh}}$ become

$$\hat{u}_{sh} = \cos\alpha \tag{28a}$$

$$\sum_{i=1}^{ns} C_{i_\infty} h_{i_{sh}} - (\hat{u}_{sh} - \cos\alpha)^2/2 + (\sin^2\alpha - \hat{v}_{sh})/2 = \sum_{i=1}^{ns} C_{i_\infty} h_{i_\infty} \quad (28b)$$

and

$$C_{i_{sh}} = C_{i_\infty} \quad (28c)$$

The shock conditions for the dependent variables (at $y = 1$) are

$$\bar{u} = \bar{v} = \bar{\rho} = \bar{P} = \bar{T} = 1 \quad (29a)$$

and

$$C_i = C_{i_{sh}} \quad (29b)$$

## Surface Transport

The surface skin friction and heat transfer rates are given by the skin friction coefficient and Stanton number. The skin friction coefficient is given by

$$C_f = \frac{2\tau_w^*}{\rho_\infty^* U_\infty^{*2}} \quad (30a)$$

where

$$\tau_w^* = \left[\mu^* \frac{\partial u^*}{\partial y^*}\right]_w \quad (30b)$$

In terms of the nondimensionalized variables, the skin friction coefficient is given by

$$C_f = 2\varepsilon^2 \left[\mu \frac{\partial u}{\partial y}\right]_w \quad (30c)$$

The Stanton number is given by the expression

$$St = \frac{q_w^*}{\rho_\infty^* V_\infty^* (H_\infty^* - H_w^*)} \tag{31a}$$

or in the dimensionless variables

$$St = \frac{q_w}{H_\infty - H_w} \tag{31b}$$

where

$$q_w^* = -\left[ k^* \frac{\partial T^*}{\partial y^*} - \sum_{i=1}^{ns} h_i^* J_i^* \right]_w \tag{31c}$$

and

$$q_w = -\varepsilon^2 \left[ k \frac{\partial T}{\partial y} - \sum_{i=1}^{ns} h_i J_i \right]_w \tag{31d}$$

or

$$q_w = -\varepsilon^2 \left[ k \frac{\partial T}{\partial y} + \sum_{i=1}^{ns} \frac{\mu}{Pr} Le_i h_i \frac{\partial C_i}{\partial y} \right]_w \tag{31e}$$

with the restriction of constant and equal Lewis numbers.

## Thermodynamic and Transport Properties

The program has tables of species enthalpy and specific heat in the form

$$\hat{H}_i = \frac{h_i - \Delta h_i^F}{T} \quad ; \quad ft^2/sec^2\text{-}^\circ R \tag{32a}$$

and

$$\hat{C}_{p_i} = C_p \quad ; \quad ft^2/sec^2\text{-}^\circ R \tag{32b}$$

Second order Lagrangian interpolation is used to obtain the values of $\hat{H}_i$ and $\hat{C}_{p_i}$ from the tables. The species enthalpy and specific heat are then calculated from the expressions

$$h_i = T\,\hat{H}_i + \Delta h_i^F ;\ ft^2/sec^2 \tag{33a}$$

and

$$C_{p_i} = \hat{C}_{p_i} ;\ ft^2/sec^2\text{-}^{\circ}R \tag{33b}$$

where $\Delta h_i^F$ is the heat of formation of species i.

The viscosity of each of the individual species is calculated from the curve fit relation

$$\mu_i = \exp\,(C_i)\ T_k^{\ (A_i \ln T_k + B_i)} ;\ \frac{gm}{cm\text{-}sec} \tag{34}$$

where $A_i$, $B_i$ and $C_i$ are the curve fit constants for the species and $T_k$ is the local temperature in degrees Kelvin. The units of the species viscosity are converted to $lbf\text{-}sec/ft^2$.

The thermal conductivity of the individual species is calculated from the expression

$$k_i = \frac{\mu_i R}{M_i}\left(\frac{C_{p_i} M_i}{R} + \frac{5}{4}\right) ;\quad \frac{lbf}{sec\ ^{\circ}R} \tag{35}$$

After the viscosity and thermal conductivity of the individual species are calculated, the viscosity and thermal conductivity of the mixture are calculated using Wilke's semi-empirical relations;

$$\mu = \sum_{i=1}^{ns}\left(\frac{X_i\ \mu_i}{\sum\limits_{j=1}^{ns} X_i\ \Phi_{ij}}\right) ;\ \frac{lbf\text{-}sec}{ft^2} \tag{36}$$

$$k = \sum_{i=1}^{ns}\left(\frac{X_i\ k_i}{\sum\limits_{j=1}^{ns} X_i\ \Phi_{ij}}\right) ;\ \frac{lbf}{sec\text{-}^{\circ}R} \tag{37}$$

where $X_i = C_i\ \overline{M}/M_i$

and $\Phi_{ij} = \left[1 + \left(\frac{\mu_i}{\mu_j}\right)^{1/2}\left(\frac{M_j}{M_i}\right)^{1/4}\right]^2 \left[\sqrt{8}\left(1 + \frac{M_i}{M_j}\right)^{1/2}\right]^{-1}$

In the program, the diffusion model is limited to binary diffusion with the binary diffusion coefficients specified by the Lewis number from Eq. (12c).

$$Le_i = \rho \; Cp \; D_i/k$$

The values of the Lewis numbers used are 1.4.

## Chemical Reaction Model

In the program, the chemical model assumes reactions proceeding at a finite rate, and the rate of production terms, $\dot{w}_i$, of the individual species are needed. The production terms occur in the energy equation (Eq. 4) and the species conservation equations (Eq. 5). For a multicomponent gas with ns distinct chemical species and nr simultaneous chemical reactions, the chemical reaction equations are written in the general stoichiometric form

$$\sum_{i=1}^{nj} \alpha_{ri} X_i \underset{k_{b_r}}{\overset{k_{f_r}}{\rightleftharpoons}} \sum_{i=1}^{nj} \beta_{ri} X_i \tag{38}$$

where r = 1, 2, ... nr and nj is equal to the sum of the species and the catalytic third bodies. The quantities $X_i$ represent the chemical species and the catalytic third bodies, and the $\alpha_{ri}$ and $\beta_{ri}$ are the stoichiometric coefficients for reactants and products. The rates at which the forward and backward reactions occur are specified by the forward and backward rate constants which are given by the equations

$$k_{f_r} = T_k^{C2_r} \exp\left(C0_r - C1_r/T_k\right) \tag{39a}$$

and

$$k_{b_r} = T_k^{D2_r} \exp\left(D0_r - D1_r/T_k\right) \tag{39b}$$

where $T_k$ is the temperature in degrees Kelvin and $C0_r$, $C1_r$, $C2_r$, $D0_r$, $D1_r$, and $D2_r$ are tabular constants.

With the forward and backward reaction rate constants given by Eq. (39) the net mass rate of production of species i per unit volume, $\dot{w}_i$, is given by the equation

$$\frac{\dot{w}_i}{\rho} = M_i \sum_{r=1}^{nr} \left(\beta_{ri} - \alpha_{ri}\right)\left(L_{f_r} - L_{b_r}\right) \tag{40}$$

where

$$\alpha_r = \sum_{j=1}^{nj} \alpha_{rj} - 1$$

$$\beta_r = \sum_{j=1}^{nj} \beta_{rj} - 1$$

$$L_{f_r} = k_{f_r} \bar{\rho}^{\alpha_r} \prod_{j=1}^{nj} (\gamma_j)^{\alpha_{rj}}$$

$$L_{b_r} = k_{b_r} \bar{\rho}^{\beta_r} \prod_{j=1}^{nj} (\gamma_j)^{\beta_{rj}}$$

$$\bar{\rho}\ (\text{gm/cm}^3) = 0.51536\ \rho\ (\text{slugs/ft}^3)$$

For the ns species the mass concentrations $\gamma_j$ are given by the expressions

$$\gamma_j = \frac{C_j}{M_j} \qquad j = 1, 2, \ldots ns$$

whereas for the catalytic third bodies the $\gamma_j$ are given by the following expressions

$$\gamma_j = \sum_{i=1}^{ns} Z_{(j-ns),i}\ \gamma_i \qquad j = (ns+1), \ldots nj$$

The quantity $Z_{(j-ns),i}$ is the third body efficiency relative to argon and is determined from the reaction being considered.

Rewritten so that the species concentrations appear as one of the unknowns, the rate of production terms are given by the expression

$$\frac{\dot{w}_i}{\rho} = \dot{w}_i^0 - \dot{w}_i^1\ C_i \qquad (24)$$

where

$$\dot{w}_i^0 = \mu_i \sum_{r=1}^{nr} (\Gamma_{ri}^{+} L_{f_r} + \Gamma_{ri}^{-} L_{b_r}) \tag{41a}$$

$$\dot{w}_i^1 = \sum_{r=1}^{nr} \{\Gamma_{ri}^{+} (L_{b_r}/\gamma_i) + \Gamma_{ri}^{-} (L_{f_r}/\gamma_i)\} \tag{41b}$$

$$\Gamma_{ri}^{+} = \begin{cases} (\beta_{ri} - \alpha_{ri}) & \text{if } (\beta_{ri} - \alpha_{ri}) > 0 \\ 0 & \text{if } (\beta_{ri} - \alpha_{ri}) \leq 0 \end{cases}$$

$$\Gamma_{ri}^{-} = \begin{cases} 0 & \text{if } (\beta_{ri} - \alpha_{ri}) \geq 0 \\ -(\beta_{ri} - \alpha_{ri}) & \text{if } (\beta_{ri} - \alpha_{ri}) < 0 \end{cases}$$

With temperature in degrees Kelvin, $T_k$, the expression for the derivative of $\dot{w}_i/\rho$ with respect to T is

$$\frac{\partial}{\partial T_k}\left(\frac{\dot{w}_i}{\rho}\right) = \frac{M_i}{T_k} \sum_{r=1}^{nr} (\beta_{ri} - \alpha_{ri}) \{(C2_r + C1_r/T_k - \alpha_r) L_{f_r} - (D2_r + D1_r/T_k - \beta_r) L_{b_r}\} \tag{42}$$

## Method of Solution

A finite-difference method is used to solve the governing differential equations for the viscous shock-layer flows. The solutions for the continuity and n-momentum equations are obtained by integration with the trapezoidal rule. The s-momentum, energy and species conservation equations are expressed in the standard form for a parabolic partial differential equation

$$\frac{\partial^2 W}{\partial \eta^2} + A_1 \frac{\partial W}{\partial \eta} + A_2 W + A_3 + A_4 \frac{\partial W}{\partial \xi} = 0 \tag{15}$$

These equations are solved using the algorithm described by Davis.

Solution for S-Momentum, Energy and Species Conservation Equations

With the finite-difference grid as shown in Fig. 4, Taylor series expansions are used to relate the partial derivatives to the function values at the finite-difference grid points.

With the functions and the partial derivatives evaluated at $(m + \Theta, n)$, the difference quotients are

$$W = \Theta\, W^n_{m+1} + (1 - \Theta)\, W^n_m \tag{43a}$$

$$\frac{\partial W}{\partial \eta} = \Theta\, (a_1\, W^{n+1}_{m+1} + b_1\, W^n_{m+1} + c_1\, W^{n-1}_{m+1}) + (1 - \Theta)\, (a_1\, W^{n+1}_m + b_1\, W^n_m + c_1\, W^{n-1}_m) \tag{43b}$$

$$\frac{\partial^2 W}{\partial \eta^2} = \Theta\, (a_2\, W^{n+1}_{m+1} + b_2\, W^n_{m+1} + c_2\, W^{n-1}_{m+1}) + (1 - \Theta)\, (a_2\, W^{n+1}_m + b_2\, W^n_m + c_2\, W^{n-1}_m) \tag{43c}$$

and

$$\frac{\partial W}{\partial \xi} = \frac{W^n_{m+1} - W^n_m}{\Delta \xi} \tag{43d}$$

where

$$a_1 = \Delta\eta_{n-1}/(\Delta\eta_n\, \Delta\eta_T) \tag{44a}$$

$$b_1 = (\Delta\eta_n - \Delta\eta_{n-1})/(\Delta\eta_n\, \Delta\eta_{n-1}) \tag{44b}$$

$$c_1 = -\,\Delta\eta_n/(\Delta\eta_{n-1}\, \Delta\eta_T) \tag{44c}$$

$$a_2 = 2/(\Delta\eta_n\, \Delta\eta_T) \tag{44d}$$

$$b_2 = -\,2/(\Delta\eta_n\, \Delta\eta_{n-1}) \tag{44e}$$

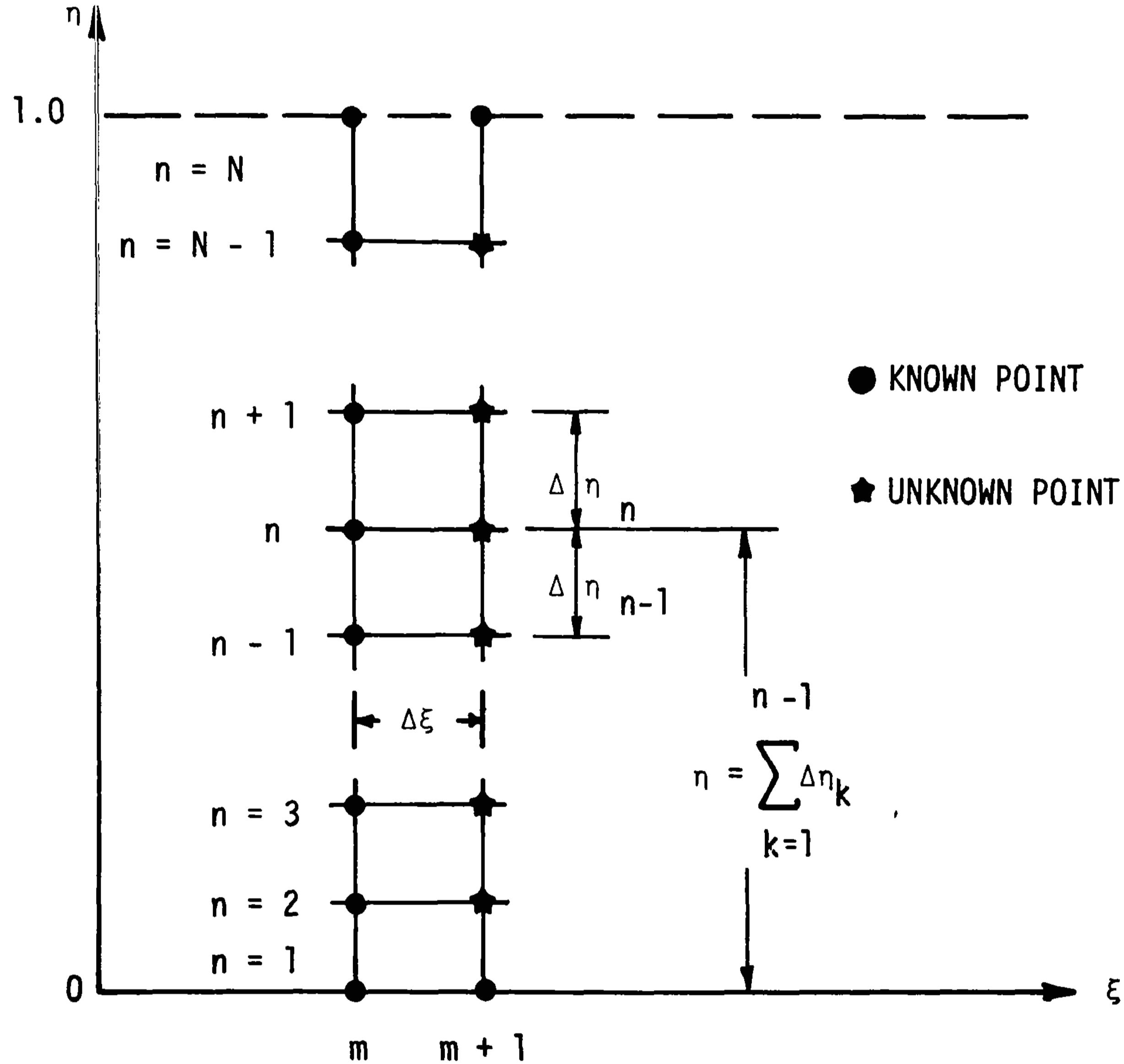


Figure 4. Schematic of Finite-Difference Grid System

$$c_2 = 2/(\Delta\eta_{n-1}\ \Delta\eta_T) \tag{44f}$$

$$\Delta\eta_T = \Delta\eta_n + \Delta\eta_{n-1} \tag{44g}$$

$$\Delta\eta_n = \eta_{n+1} - \eta_n \tag{44h}$$

$$\Delta\eta_{n-1} = \eta_n - \eta_{n-1} \tag{44i}$$

Substitution of Eqs. (43) into Eq. (15) gives the following simultaneous linear algebraic equations involving only W at m + 1.

$$\tilde{A}_n\ W^{n-1}_{m+1} + \tilde{B}_n\ W^n_{m+1} + \tilde{C}_n\ W^{n+1}_{m+1} = \tilde{D}_n \tag{45}$$

where n = 2, 3, ..., N-1. The coefficients for Eq. (45) are given by the following expressions:

$$\tilde{A}_n = (c_2 + A_{1_n}\ c_1)\ \Theta \tag{46a}$$

$$\tilde{B}_n = (b_2 + A_{1_n}\ b_1 + A_{2_n})\ \Theta + A_{4_n}/\Delta\xi \tag{46b}$$

$$\tilde{C}_n = (a_2 + A_{1_n}\ a_1)\ \Theta \tag{46c}$$

and

$$\tilde{D}_n = -\left[\left(\frac{\partial^2 W}{\partial\eta^2}\right)^n_m + A_{1_n}\left(\frac{\partial W}{\partial\eta}\right)^n_m + A_{2_n}\ W^n_m\right](1 - \Theta) - A_{3_n} + A_{4_n}\ W^n_m/\Delta\xi \tag{46d}$$

where $A1_n$, $A2_n$, $A3_n$ and $A4_n$ are the coefficients of Eq. (15) evaluated at the $n^{th}$ grid point and are given by Eqs. (16), (17) and (18) for the s-momentum, energy and species conservation equations.

Assuming that

$$W^n_{m+1} = \tilde{E}_n\ W^{n+1}_{m+1} + \tilde{F}_n \tag{47}$$

is valid through the shock layer then $W_{m+1}^{n-1}$ is given by

$$W_{m+1}^{n-1} = \tilde{E}_{n-1} W_{m+1}^{n} + \tilde{F}_{n-1} \tag{48}$$

Substituting Eq. (48) into Eq. (45) and solving for $W_{m+1}^{n}$ and comparing with Eq. (47) gives the recursion formulas

$$\tilde{E}_n = \frac{-\tilde{C}_n}{\tilde{B}_n + \tilde{A}_n \tilde{E}_{n-1}} \tag{49a}$$

and

$$\tilde{F}_n = \frac{\tilde{D}_n - \tilde{A}_n \tilde{F}_{n-1}}{\tilde{B}_n + \tilde{A}_n \tilde{E}_{n-1}} \tag{49b}$$

At n = 1,

$$\tilde{F}_1 = W_w \text{ and } \tilde{E}_1 = 0, \text{ if } W_{m+1}^{1} = W_w \tag{50a}$$

or

$$\tilde{F}_1 = 0 \text{ and } \tilde{E}_1 = 1, \text{ if } \left(\frac{\partial W}{\partial \eta}\right)_{m+1}^{1} = 0 \tag{50b}$$

For n = N, the value of W is

$$W_{m+1}^{N} = W_{sh} \tag{51}$$

The solution of Eq. (15) is provided by the following algorithm. Starting with Eqs. (50), the $\tilde{E}_n$ and $\tilde{F}_n$ are evaluated with n increasing from 2 to N - 1. Then the $W_{m+1}^{n}$ are evaluated from Eq. (47) with n decreasing from N - 1 to 1.

## Solution for Y-Momentum and Continuity Equations

The normal momentum equation, Eq. (20a), is rewritten so that $\partial\bar{P}/\partial\eta$ may be evaluated directly as

$$\frac{\partial \bar{P}}{\partial \eta} = \frac{\kappa\, y_{sh}\, \rho_{sh}\, u_{sh}^2}{P_{sh}\,(1 + \kappa\, y_{sh}\, \eta)}\ \bar{\rho}\, \bar{u} - \frac{\rho_{sh}\, v_{sh}^2}{P_{sh}}\ \bar{\rho}\, \bar{v}\, \frac{\partial \bar{v}}{\partial \eta} -$$

$$\frac{y_{sh}\, \rho_{sh}\, u_{sh}\, v_{sh}}{P_{sh}\,(1 - \kappa\, y_{sh}\, \eta)}\ \bar{\rho}\, \bar{u} \left( \frac{\partial \bar{v}}{\partial \xi} + \frac{\bar{v}}{v_{sh}}\, \frac{\partial v_{sh}}{\partial \xi} - \frac{y'_{sh}}{y_{sh}}\, \frac{\partial \bar{v}}{\partial \xi} \right) \tag{52}$$

with only the first term on the right side of the equation retained when the thin shock-layer approximation is made, Eq. (20b). With the y-momentum equation written in this form, Eq. (52) or (20b), the pressure derivative with respect to $\eta$ is calculated. With $\bar{P}$ at the shock known, $\bar{P}_{sh} = 1$, integration by the trapezoidal rule from the shock inward gives the solution of the normal momentum equation.

The continuity equation, Eq. (19), when integrated yields both the normal velocity (v) profile and the shock-layer thickness, $y_{sh}$. As given previously, the continuity equation is

$$\frac{\partial}{\partial \xi}\ \{y_{sh}\ (r + y_{sh}\ \eta \cos \phi)^j\ \rho_{sh}\ u_{sh}\ \bar{\rho}\ \bar{u}\ \} =$$

$$\frac{\partial}{\partial \eta}\ \{(r + y_{sh}\ \eta \cos \phi)^j\ \ \{y'_{sh}\ \rho_{sh}\ u_{sh}\ \bar{\rho}\ \bar{u}\ \eta - (1 + \kappa\, y_{sh}\ \eta)\ \rho_{sh}\ v_{sh}\ \bar{\rho}\ \bar{v}\}\} \tag{19}$$

where j = 1 for axisymmetric flow and j = 0 for two-dimensional flow.

The mass flux between the body ($\eta$ = 0) and a given grid point n ($\eta = \eta$) is proportional to $m_n$ (with $m_N$ denoting $\eta$ = 1, the shock) which is given by

$$m_n = \int_0^{\eta} y_{sh}\ (r + y_{sh}\ \eta \cos \phi)^j\ \rho_{sh}\ u_{sh}\ \bar{\rho}\ \bar{u}\ d\eta \tag{53}$$

Integrating Eq. (19) from 0 to $\eta$ and substituting Eq. (53) gives the following form for the continuity equation.

$$\frac{dm_n}{d\xi} = \int_0^{\eta} \frac{\partial}{\partial \eta}\ \{(r + y_{sh}\ \eta \cos \phi)^j\ \ \{y'_{sh}\ \rho_{sh}\ u_{sh}\ \bar{\rho}\ \bar{u}\ \eta -$$

$$(1 + \kappa\, y_{sh}\ \eta)\ \rho_{sh}\ v_{sh}\ \bar{\rho}\ \bar{v}\}\}\ d\eta \tag{54}$$

or equivalently as

$$\frac{dm_\eta}{d\xi} = (r + y_{sh}\, \eta \cos\phi)^j \;\{y'_{sh}\, \rho_{sh}\, u_{sh}\, \bar{\rho}\, \bar{u}\, \eta - (1 + \kappa\, y_{sh}\, \eta)\, \rho_{sh}\, v_{sh}\, \bar{\rho}\, \bar{v}\} \tag{55}$$

The term $dm_\eta/d\xi$ is obtained by evaluating Eq. (53) as s + ds/2 and s - ds/2 and dividing by ds. The normal velocity, v, is then obtained by rearranging Eq. (55).

The shock-layer thickness is obtained by integrating Eqs. (53) and (54) from 0 to 1 instead of from 0 to $\eta$. This gives

$$m_N = y_{sh}\, \rho_{sh}\, u_{sh}\, r^j \int_0^1 \bar{\rho}\, \bar{u}\, d\eta + j\, y_{sh}^2\, \rho_{sh}\, u_{sh} \cos\phi \int_0^1 \bar{\rho}\, \bar{u}\, \eta\, d\eta \tag{56}$$

and

$$\frac{dm_N}{d\xi} = (r + y_{sh} \cos\phi)^j \;\{y'_{sh}\, \rho_{sh}\, u_{sh} - (1 + \kappa\, y_{sh})\, \rho_{sh}\, v_{sh}\} \tag{57}$$

The term $dm_N/d\xi$ could also be evaluated from

$$\frac{dm_N}{d\xi} = \frac{1}{\Delta\xi} \left[ (m_N)_{s + ds/2} - (m_N)_{s - ds/2} \right] \tag{58}$$

Rearranging Eq. (58) gives

$$(m_N)_{s + ds/2} = \Delta\xi \frac{dm_N}{d\xi} + (m_N)_{s - ds/2} \tag{59}$$

First, $dm_N/d\xi$ is evaluated from Eq. (57). Eq. (59) then gives $m_N$ and Eq. (56) is solved for $y_{sh}$.

When written as in Eq. (19), the continuity equation is indeterminate at s = 0. In order to evaluate the continuity equation at the stagnation point the following limit expressions as $\xi \to 0$ are used:

$r \to \xi$, $\cos\phi \to \xi$ and $u_{sh} \to \xi\, u'_{sh}$ where $u'_{sh} = d\, u_{sh}/d\xi$. Also, at s = 0, $y'_{sh} = 0$.

Denoting $r|_{\Delta\xi/2}$ as $r_2$ and $\cos\phi|_{\Delta\xi/2}$ as $\cos\phi_2$, the form of the continuity equation is

$$\frac{\partial}{\partial\eta}\left[(1 + y_{sh}\,\eta)^{j+1}\,\bar{\rho}\,\bar{v}\right] = \left(\frac{2}{\Delta\xi}\right)^{j+1} (j + 1)\, y_{sh}\, (r_2 + y_{sh}\,\eta\cos\phi_2)^j\, \rho_{sh}\, u_{sh}\, \bar{\rho}\,\bar{u} \tag{60}$$

where $\rho_{sh}\, v_{sh} = -\sin\alpha = -1$ at $s = 0$ has been used. Integrating from 0 to $\eta$ and rearranging terms gives the following expression for the normal velocity component.

$$\bar{v} = \left(\frac{2}{\Delta\xi}\right)^{j+1} \frac{(j+1)\, y_{sh}\,\rho_{sh}\, u_{sh}}{\bar{\rho}\,(1 + y_{sh}\,\eta)^{j+1}} \left[r_2^j \int_0^\eta \bar{\rho}\,\bar{u}\, d\eta + j\, y_{sh}\cos\phi_2 \int_0^\eta \bar{\rho}\,\bar{u}\,\eta\, d\eta\right] \tag{61}$$

Integrating Eq. (60) from 0 to 1 gives the following equation

$$(1 + y_{sh})^{j+1} = \left(\frac{2}{\Delta\xi}\right)^{j+1} (j+1)\, y_{sh}\,\rho_{sh}\, u_{sh}\left[r_2^j \int_0^1 \bar{\rho}\,\bar{u}\, d\eta + j\, y_{sh}\cos\phi_2 \int_0^1 \bar{\rho}\,\bar{u}\,\eta\, d\eta\right] \tag{62}$$

which can be solved for the shock-layer thickness, $y_{sh}$, by rearranging terms.

An alternate method for determining the shock-layer thickness, $y_{sh}$, is given in the companion engineering report.

## Solution Procedure

At each s or $\xi$ location the shock-layer equations are solved in the order of species, energy, s-momentum, continuity and y-momentum. At each location the solution is iterated until convergence is obtained for the tangential velocity, temperature and species concentration profiles at all points of the finite-difference grid. The convergence test requires that

$$\left|1 - W_n^{k+1}/W_n^k\right| \leq \delta$$

where n denotes the finite-difference grid point, k denotes the previous iteration value of $W_n$, k + 1 denotes the new iteration value of $W_n$, W represents $\overline{u}$, $\overline{T}$ or $C_i$ and $\delta$ is a small number, typically 0.01. After a converged solution is obtained at a specific location, $\xi$, the profiles are then used as initial profiles for obtaining a new solution at $\xi + \Delta\xi$. In this way the solution procedure marches downstream.

If the governing equations were fully parabolic, only one global iteration (i.e., a solution for the entire length of the body) would be sufficient. However, the equations depend upon $d\,y_{sh}/d\xi$ (and thus the shock angle). Also, the y-momentum equation (in FVSL form) depends upon $\partial\overline{v}/\partial\xi$ which is not known (especially at the stagnation point). The downstream dependence introduces an elliptic nature to the equations. The elliptic effect in the y-momentum equation is resolved by considering TVSL flows for the first global iteration. Subsequent global iterations may then be FVSL using the $\overline{v}$ profiles from the previous global iteration.

The elliptic effect due to $d\,y_{sh}/d\xi$ is resolved by making a suitable approximation for $d\,y_{sh}/d\xi$ for the first global iteration. Subsequent global iterations then use $d\,y_{sh}/d\xi$ as calculated from the previous global iteration.

## List of Symbols

| | |
|---|---|
| $C_i$ | concentration of species i, $\rho_i/\rho$ |
| $C_p$ | specific heat at constant pressure |
| ECW | denotes equilibrium catalytic wall |
| FVSL | denotes fully viscous shock layer |
| h | static enthalpy, $h^*/U_\infty^{*2}$ |
| H | total enthalpy, $H^*/U_\infty^{*2}$ |
| k | thermal conductivity, $k^*/(\mu_{ref}^* C_{p\infty}^*)$ |
| $Le_i$ | Lewis number, $C_p^* \rho^* D_i^*/k^*$ |
| M | Molecular weight |
| $\overline{M}$ | mixture molecular weight, $1/(\sum_i C_i/M_i)$ |
| nj | number of species plus catalytic third bodies, ns + nz |
| ns | number of species |
| nr | number of chemical reaction |
| nz | number of catalytic third bodies |
| NSS | denotes no shock slip |
| NCW | denotes noncatalytic wall |
| P | pressure, $P^*/(\rho_\infty^* U_\infty^{*2})$ |
| Pr | Prandtl number, $C_p^* \mu^*/k^*$ |
| q | heat transfer, $q^*/(\rho_\infty^* U_\infty^{*3})$ |
| r | body radius, $r^*/R_n^*$ |
| R | universal gas constant |
| $R_n^*$ | body nose radius |
| $Re_s$ | shock Reynolds number, $\dfrac{\rho_\infty^* U_\infty^* R_n^*}{\mu_{sh}^*}$ |

| | |
|---|---|
| s | coordinate measured along body surface, $s^*/R_n^*$ |
| St | Stanton number, $q_w/(H_\infty - H_w)$ |
| SS | denotes shock slip |
| T | temperature, $T^*/T_{ref}^*$ |
| $T_{ref}^*$ | reference temperature, $U_\infty^{*2}/C_{p_\infty}^*$ |
| TVSL | denotes thin viscous shock layer |
| u | velocity component tangent to the body surface, $u^*/U_\infty^*$ |
| v | velocity component normal to the body surface, $v^*/U_\infty^*$ |
| y | coordinate measured normal to the body, $y^*/R_n^*$ |
| z | coordinate measured along body axis, $z^*/R_n^*$ |
| $Z_{(j-ns),i}$ | third body catalytic efficiencies relative to argon |
| $\alpha$ | angle between shock tangent and body axis |
| $\alpha_{rj}$ | forward stoichiometric coefficients |
| $\beta_{rj}$ | backward stoichiometric coefficients |
| $\gamma_i$ | species mass concentrations, $C_i/M_i$ |
| $\varepsilon$ | Reynolds number parameter, $\left[\dfrac{\mu_{ref}^*}{\rho_\infty^* U_\infty^* R_n^*}\right]^{1/2}$ |
| $\kappa$ | surface curvature, $\kappa^*/R_n^*$ |
| $\mu$ | coefficient of viscosity, $\mu^*/\mu_{ref}^*$ |
| $\mu_{ref}^*$ | coefficient of viscosity evaluated at $T_{ref}^*$ |
| $\rho$ | density, $\rho^*/\rho_\infty^*$ |
| $\phi$ | angle between body tangent and axis |

Superscripts

| | |
|---|---|
| j | indicator for axisymmetric flow (1) or two-dimensional flow (0) |
| * | dimensional quantities |
| ' | denotes differentiation with respect to $\xi$ |

## Subscripts

| | |
|---|---|
| eq | equilibrium value |
| i | specie i |
| sh | value behind the shock |
| w | wall value |
| $\infty$ | freestream value |

## APPENDIX B: SAMPLE CASES

Input and output data are given for four sample cases; two geometries and two gas chemistries for each geometry. The geometries are a 31° hyperboloid and a curve fit geometry (the 140B orbiter). The gas chemistries are binary gas (dissociating oxygen) and 7-species (multicomponent) air. The Job Control Language (JCL) needed to run the sample cases on the IBM 370/158 computers of the Virginia Polytechnic Institute and State University Computing Center is also listed. The sample cases were run in double precision with the source program and all input data from cards.

### Job Control Language for the 140B Orbiter Sample Cases

```
//B0030VSL JOB 509E3,MINER,MSGLEVEL=(1,1)
/*PRIORITY IDLE
/*MAIN TIME=05,LINES=10,CARDS=0
/*MAIN REGION=238K
// EXEC FORTGCLG
//FORT.SYSIN DD *

          FORTRAN Source Program

/*
//GO.FT01F001 DD SYSOUT=A
//GO.FT03F001 DD SYSOUT=A
//GO.FT08F001 DD SYSOUT=A
//GO.FT09F001 DD SYSOUT=A
//GO.FT15F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),SPACE=(440,(200)),
//    DCB=(RECFM=VS,BLKSIZE=440,LRECL=436)
//GO.FT16F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),SPACE=(440,(200)),
//    DCB=(RECFM=VS,BLKSIZE=440,LRECL=436)
//GO.FT04F001 DD *

          Body Geometry Data

/*
//GO.FT19F001 DD *

          Reaction Rate Data

/*
//GO.FT20F001 DD *

          Shock Shape Data

/*
//GO.SYSIN DD *

          Unit 5 Input Data

/*
//
```

Job Control Language for the 31° Hyperboloid Sample Cases

```
//B0030VSL JOB 509E3,MINER,MSGLEVEL=(1,1)
/*PRIORITY IDLE
/*MAIN TIME=05,LINES=10,CARDS=0
/*MAIN REGION=238K
// EXEC FORTGCLG
//FORT.SYSIN DD *
          FORTRAN Source Program
/*
//GO.FT01F001 DD SYSOUT=A
//GO.FT03F001 DD SYSOUT=A
//GO.FT08F001 DD SYSOUT=A
//GO.FT09F001 DD SYSOUT=A
//GO.FT15F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),SPACE=(440,(200)),
//   DCB=(RECFM=VS,BLKSIZE=440,LRECL=436)
//GO.FT16F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),SPACE=(440,(200)),
//   DCB=(RECFM=VS,BLKSIZE=440,LRECL=436)
//GO.FT19F001 DD *
          Reaction Rate Data
/*
//GO.FT20F001 DD *
          Shock Shape Data
/*
//GO.SYSIN DD *
          Unit 5 Input Data
/*
//
```

Reaction Rate Input Data for all Sample Cases

The same reaction rate data are used for all of the sample cases.

```
LOG  RATES MATCH 6 SPECIE BLOTTNER-SANDIA
  2  2
O   O2
 O2   O2          O     O     O2     3.249E1959400.-1.   2.709E16        -.5
 O2   O           O     O     O      9.025E1959400.-1.   7.525E16        -.5
 10   7   4
O   O2   NO   N    NO+  N2   M1   M2   M3   EL
 O2   M1          O     O     M1      3.61E1859400.-1.    3.01E15        -.5
 N2   M2          N     N     M2      1.92E17113100-.5    1.09E16        -.5
 N2   N           N     N     N       4.15E22113100-1.5   2.32E21        -1.5
 NO   M3          N     O     M3      3.97E2075600.-1.5   1.01E20        -1.5
 NO   O           O2    N              3.18E919700. 1.    9.63E113600.  .5
 N2   O           NO    N             6.75E1337500.       1.50E13
 N    O           NO+   EL             9.03E932400..5     1.80E19        -1.
25.        9.         1.        1.                       2.
1.          1.        1.                               2.5
 20.        1.        20.       20.                  1.
                                             1.
           .23456                                      .76544
           .23456                                      .76544
```

Body Geometry Input Data for the 140B Orbiter Sample Cases

| | | | | |
|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 1.000000E 00 | 1.570800E 00 |
| 2.922039E-06 | 2.418570E-03 | 2.418570E-03 | 9.973460E-01 | 1.569590E 00 |
| 6.723169E-06 | 3.669430E-03 | 3.669430E-03 | 9.959680E-01 | 1.567760E 00 |
| 1.222290E-05 | 4.948780E-03 | 4.948799E-03 | 9.945550E-01 | 1.566500E 00 |
| 1.953149E-05 | 6.257229E-03 | 6.257258E-03 | 9.931059E-01 | 1.565209E 00 |
| 2.876460E-05 | 7.595357E-03 | 7.595427E-03 | 9.916199E-01 | 1.563900E 00 |
| 4.004329E-05 | 8.963808E-03 | 8.963928E-03 | 9.900970E-01 | 1.562550E 00 |
| 5.349469E-05 | 1.036320E-02 | 1.036340E-02 | 9.885350E-01 | 1.561179E 00 |
| 6.925169E-05 | 1.179420E-02 | 1.179440E-02 | 9.869339E-01 | 1.559790E 00 |
| 8.745359E-05 | 1.325730E-02 | 1.325770E-02 | 9.852920E-01 | 1.558359E 00 |
| 1.168470E-04 | 1.473850E-02 | 1.473920E-02 | 1.013370E 00 | 1.550949E 00 |
| 1.505300E-04 | 1.625050E-02 | 1.625160E-02 | 1.011570E 00 | 1.548519E 00 |
| 1.873590E-04 | 1.779640E-02 | 1.779790E-02 | 1.009729E 00 | 1.546980E 00 |
| 2.275070E-04 | 1.937670E-02 | 1.937870E-02 | 1.007850E 00 | 1.545400E 00 |
| 2.711518E-04 | 2.099220E-02 | 2.099480E-02 | 1.005910E 00 | 1.543790E 00 |
| 3.184839E-04 | 2.264370E-02 | 2.264690E-02 | 1.003929E 00 | 1.542139E 00 |
| 3.696978E-04 | 2.433170E-02 | 2.433570E-02 | 1.001900E 00 | 1.540469E 00 |
| 4.250000E-04 | 2.605710E-02 | 2.606200E-02 | 9.998159E-01 | 1.538759E 00 |
| 4.846030E-04 | 2.782050E-02 | 2.782640E-02 | 9.976820E-01 | 1.537009E 00 |
| 5.487299E-04 | 2.962280E-02 | 2.962990E-02 | 9.954939E-01 | 1.535230E 00 |
| 6.176129E-04 | 3.146470E-02 | 3.147300E-02 | 9.932520E-01 | 1.533420E 00 |
| 6.914949E-04 | 3.334690E-02 | 3.335670E-02 | 9.909550E-01 | 1.531560E 00 |
| 7.706280E-04 | 3.527030E-02 | 3.528170E-02 | 9.886020E-01 | 1.529679E 00 |
| 8.646848E-04 | 3.721940E-02 | 3.723310E-02 | 1.014429E 00 | 1.522579E 00 |
| 9.681918E-04 | 3.920490E-02 | 3.922130E-02 | 1.011849E 00 | 1.518709E 00 |
| 1.078080E-03 | 4.123340E-02 | 4.125280E-02 | 1.009219E 00 | 1.516680E 00 |
| 1.194660E-03 | 4.330590E-02 | 4.332860E-02 | 1.006510E 00 | 1.514609E 00 |
| 1.318240E-03 | 4.542310E-02 | 4.544930E-02 | 1.003750E 00 | 1.512489E 00 |
| 1.449140E-03 | 4.758590E-02 | 4.761610E-02 | 1.000910E 00 | 1.510340E 00 |
| 1.587720E-03 | 4.979510E-02 | 4.982960E-02 | 9.980110E-01 | 1.508149E 00 |
| 1.734330E-03 | 5.205160E-02 | 5.209090E-02 | 9.950390E-01 | 1.505919E 00 |
| 1.889340E-03 | 5.435640E-02 | 5.440090E-02 | 9.919960E-01 | 1.503639E 00 |
| 2.053130E-03 | 5.671030E-02 | 5.676050E-02 | 9.888800E-01 | 1.501329E 00 |
| 2.229920E-03 | 5.910760E-02 | 5.916430E-02 | 1.012190E 00 | 1.497180E 00 |
| 2.428080E-03 | 6.153550E-02 | 6.160030E-02 | 1.008789E 00 | 1.489360E 00 |
| 2.636620E-03 | 6.401455E-02 | 6.408817E-02 | 1.005309E 00 | 1.486879E 00 |
| 2.856000E-03 | 6.654596E-02 | 6.662905E-02 | 1.001750E 00 | 1.484349E 00 |
| 3.086700E-03 | 6.913060E-02 | 6.922400E-02 | 9.981010E-01 | 1.481779E 00 |
| 3.329190E-03 | 7.176936E-02 | 7.187378E-02 | 9.943710E-01 | 1.479159E 00 |
| 3.583980E-03 | 7.446319E-02 | 7.457978E-02 | 9.905550E-01 | 1.476500E 00 |
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| 4.132599E-03 | 8.002067E-02 | 8.016419E-02 | 9.826620E-01 | 1.471029E 00 |
| 4.435159E-03 | 8.287299E-02 | 8.303237E-02 | 1.003059E 00 | 1.465110E 00 |
| 4.762709E-03 | 8.576638E-02 | 8.594429E-02 | 9.987150E-01 | 1.458070E 00 |
| 5.105790E-03 | 8.871937E-02 | 8.891720E-02 | 9.942740E-01 | 1.455130E 00 |
| 5.465049E-03 | 9.173298E-02 | 9.195209E-02 | 9.897360E-01 | 1.452149E 00 |
| 5.841140E-03 | 9.480846E-02 | 9.505045E-02 | 9.850990E-01 | 1.449109E 00 |
| 6.234739E-03 | 9.794658E-02 | 9.821337E-02 | 9.803620E-01 | 1.446030E 00 |
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| 7.077307E-03 | 1.044160E-01 | 1.047380E-01 | 9.705840E-01 | 1.439710E 00 |
| 7.542837E-03 | 1.077240E-01 | 1.080779E-01 | 9.877980E-01 | 1.430960E 00 |
| 8.034170E-03 | 1.110890E-01 | 1.114790E-01 | 9.824430E-01 | 1.425830E 00 |
| 8.547239E-03 | 1.145220E-01 | 1.149499E-01 | 9.769790E-01 | 1.422460E 00 |
| 9.082880E-03 | 1.180249E-01 | 1.184930E-01 | 9.714040E-01 | 1.419029E 00 |
| 9.641968E-03 | 1.215970E-01 | 1.221090E-01 | 9.657180E-01 | 1.415549E 00 |
| 1.022540E-02 | 1.252410E-01 | 1.257989E-01 | 9.599200E-01 | 1.412029E 00 |
| 1.083410E-02 | 1.289570E-01 | 1.295649E-01 | 9.540100E-01 | 1.408449E 00 |
| 1.148910E-02 | 1.327130E-01 | 1.333770E-01 | 9.679510E-01 | 1.398109E 00 |
| 1.217370E-02 | 1.365390E-01 | 1.372640E-01 | 9.615780E-01 | 1.393769E 00 |
| 1.288700E-02 | 1.404409E-01 | 1.412309E-01 | 9.550860E-01 | 1.389990E 00 |
| 1.363000E-02 | 1.444200E-01 | 1.452790E-01 | 9.484770E-01 | 1.386169E 00 |
| 1.440400E-02 | 1.484770E-01 | 1.494090E-01 | 9.417490E-01 | 1.382290E 00 |
| 1.521000E-02 | 1.526130E-01 | 1.536230E-01 | 9.349020E-01 | 1.378360E 00 |
| 1.606600E-02 | 1.568020E-01 | 1.578979E-01 | 9.456690E-01 | 1.369200E 00 |
| 1.696350E-02 | 1.610600E-01 | 1.622500E-01 | 9.383290E-01 | 1.363050E 00 |
| 1.789720E-02 | 1.654000E-01 | 1.666890E-01 | 9.308670E-01 | 1.358919E 00 |
| 1.886830E-02 | 1.698250E-01 | 1.712199E-01 | 9.232849E-01 | 1.354750E 00 |
| 1.987820E-02 | 1.743349E-01 | 1.758420E-01 | 9.155830E-01 | 1.350519E 00 |
| 2.092860E-02 | 1.789320E-01 | 1.805570E-01 | 9.234329E-01 | 1.346149E 00 |
| 2.204520E-02 | 1.835750E-01 | 1.853319E-01 | 9.152240E-01 | 1.334749E 00 |
| 2.320530E-02 | 1.883060E-01 | 1.902030E-01 | 9.068960E-01 | 1.330339E 00 |
| 2.441050E-02 | 1.931280E-01 | 1.951730E-01 | 8.984480E-01 | 1.325870E 00 |
| 2.566230E-02 | 1.980420E-01 | 2.002439E-01 | 8.898840E-01 | 1.321360E 00 |
| 2.696220E-02 | 2.030489E-01 | 2.054180E-01 | 8.812050E-01 | 1.316810E 00 |
| 2.833080E-02 | 2.081190E-01 | 2.106690E-01 | 8.857329E-01 | 1.307159E 00 |

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|---|---|---|---|---|
| 2.975870E-02 | 2.132730E-01 | 2.160169E-01 | 8.765520E-01 | 1.300489E 00 |
| 3.124040E-02 | 2.185240E-01 | 2.214730E-01 | 8.672619E-01 | 1.295759E 00 |
| 3.277780E-02 | 2.238740E-01 | 2.270390E-01 | 8.578629E-01 | 1.290979E 00 |
| 3.437260E-02 | 2.293240E-01 | 2.327180E-01 | 8.483599E-01 | 1.286160E 00 |
| 3.604730E-02 | 2.348419E-01 | 2.384850E-01 | 8.500270E-01 | 1.276099E 00 |
| 3.779050E-02 | 2.404510E-01 | 2.443590E-01 | 8.400480E-01 | 1.269500E 00 |
| 3.959760E-02 | 2.461660E-01 | 2.503520E-01 | 8.299720E-01 | 1.264520E 00 |
| 4.147070E-02 | 2.519870E-01 | 2.564670E-01 | 8.198040E-01 | 1.259489E 00 |
| 4.341410E-02 | 2.579130E-01 | 2.627040E-01 | 8.191280E-01 | 1.253920E 00 |
| 4.545380E-02 | 2.639050E-01 | 2.690340E-01 | 8.085200E-01 | 1.242680E 00 |
| 4.756670E-02 | 2.700080E-01 | 2.754920E-01 | 7.978320E-01 | 1.237510E 00 |
| 4.975510E-02 | 2.762250E-01 | 2.820820E-01 | 7.870700E-01 | 1.232309E 00 |
| 5.202140E-02 | 2.825560E-01 | 2.888070E-01 | 7.762380E-01 | 1.227070E 00 |
| 5.274590E-02 | 2.918150E-01 | 2.980940E-01 | 6.544350E-01 | 1.492709E 00 |
| 5.478100E-02 | 2.990659E-01 | 3.056250E-01 | 6.464400E-01 | 1.297179E 00 |
| 5.689330E-02 | 3.064530E-01 | 3.133079E-01 | 6.383880E-01 | 1.292259E 00 |
| 5.908550E-02 | 3.139780E-01 | 3.211460E-01 | 6.302820E-01 | 1.287310E 00 |
| 6.158730E-02 | 3.212489E-01 | 3.288360E-01 | 5.711100E-01 | 1.239440E 00 |
| 6.374609E-02 | 3.294050E-01 | 3.372729E-01 | 5.640219E-01 | 1.312030E 00 |
| 6.598818E-02 | 3.377140E-01 | 3.458790E-01 | 5.568939E-01 | 1.307230E 00 |
| 6.831628E-02 | 3.461780E-01 | 3.546570E-01 | 5.497280E-01 | 1.302389E 00 |
| 7.147789E-02 | 3.535120E-01 | 3.626429E-01 | 5.528400E-01 | 1.163759E 00 |
| 7.403809E-02 | 3.622070E-01 | 3.717080E-01 | 5.453650E-01 | 1.284439E 00 |
| 7.669437E-02 | 3.710639E-01 | 3.809550E-01 | 5.378600E-01 | 1.279440E 00 |
| 7.940406E-02 | 3.801650E-01 | 3.904510E-01 | 5.421460E-01 | 1.281420E 00 |
| 8.232319E-02 | 3.892490E-01 | 3.999910E-01 | 5.342979E-01 | 1.259850E 00 |
| 8.534908E-02 | 3.985000E-01 | 4.097250E-01 | 5.264300E-01 | 1.254700E 00 |
| 8.848506E-02 | 4.079240E-01 | 4.196570E-01 | 5.185460E-01 | 1.249530E 00 |
| 9.173477E-02 | 4.175220E-01 | 4.297900E-01 | 5.106490E-01 | 1.244329E 00 |
| 9.510165E-02 | 4.272970E-01 | 4.401290E-01 | 5.027420E-01 | 1.239100E 00 |
| 9.858948E-02 | 4.372530E-01 | 4.506789E-01 | 4.948300E-01 | 1.233850E 00 |
| 1.022020E-01 | 4.473940E-01 | 4.614429E-01 | 4.869159E-01 | 1.228580E 00 |
| 1.059430E-01 | 4.577219E-01 | 4.724280E-01 | 4.790030E-01 | 1.223280E 00 |
| 1.098160E-01 | 4.682400E-01 | 4.836370E-01 | 4.710950E-01 | 1.217970E 00 |
| 1.138260E-01 | 4.789529E-01 | 4.950750E-01 | 4.631950E-01 | 1.212629E 00 |
| 1.179760E-01 | 4.898630E-01 | 5.067490E-01 | 4.553080E-01 | 1.207279E 00 |
| 1.222720E-01 | 5.009750E-01 | 5.186620E-01 | 4.474360E-01 | 1.201909E 00 |
| 1.267170E-01 | 5.122920E-01 | 5.308200E-01 | 4.395840E-01 | 1.196529E 00 |
| 1.313159E-01 | 5.238169E-01 | 5.432290E-01 | 4.317549E-01 | 1.191130E 00 |
| 1.360739E-01 | 5.355549E-01 | 5.558950E-01 | 4.239520E-01 | 1.185710E 00 |
| 1.409950E-01 | 5.475100E-01 | 5.688230E-01 | 4.161800E-01 | 1.180289E 00 |
| 1.460840E-01 | 5.596850E-01 | 5.820180E-01 | 4.084400E-01 | 1.174850E 00 |
| 1.513470E-01 | 5.720840E-01 | 5.954880E-01 | 4.007379E-01 | 1.169410E 00 |
| 1.567880E-01 | 5.847120E-01 | 6.092390E-01 | 3.930759E-01 | 1.163960E 00 |
| 1.624129E-01 | 5.975730E-01 | 6.232760E-01 | 3.854570E-01 | 1.158489E 00 |
| 1.684440E-01 | 6.102970E-01 | 6.373560E-01 | 3.872679E-01 | 1.128180E 00 |
| 1.745920E-01 | 6.233950E-01 | 6.518260E-01 | 3.793640E-01 | 1.131940E 00 |
| 1.809440E-01 | 6.367350E-01 | 6.666009E-01 | 3.715190E-01 | 1.126400E 00 |
| 1.875049E-01 | 6.503209E-01 | 6.816880E-01 | 3.637379E-01 | 1.120850E 00 |
| 1.942829E-01 | 6.641560E-01 | 6.970950E-01 | 3.560230E-01 | 1.115299E 00 |
| 2.012820E-01 | 6.782460E-01 | 7.128280E-01 | 3.483770E-01 | 1.109759E 00 |
| 2.085100E-01 | 6.925970E-01 | 7.288949E-01 | 3.408030E-01 | 1.104219E 00 |
| 2.159719E-01 | 7.072110E-01 | 7.453049E-01 | 3.333049E-01 | 1.098689E 00 |
| 2.236770E-01 | 7.220960E-01 | 7.620650E-01 | 3.258840E-01 | 1.093160E 00 |
| 2.316300E-01 | 7.372560E-01 | 7.791840E-01 | 3.185440E-01 | 1.087640E 00 |
| 2.398390E-01 | 7.526950E-01 | 7.966710E-01 | 3.112860E-01 | 1.082129E 00 |
| 2.483110E-01 | 7.684210E-01 | 8.145330E-01 | 3.041130E-01 | 1.076630E 00 |
| 2.570540E-01 | 7.844369E-01 | 8.327810E-01 | 2.970279E-01 | 1.071139E 00 |
| 2.660750E-01 | 8.007510E-01 | 8.514220E-01 | 2.900330E-01 | 1.065660E 00 |
| 2.743730E-01 | 8.191150E-01 | 8.715740E-01 | 2.890390E-01 | 1.146410E 00 |
| 2.841840E-01 | 8.356780E-01 | 8.908250E-01 | 2.818840E-01 | 1.036019E 00 |
| 2.943020E-01 | 8.525470E-01 | 9.104960E-01 | 2.748350E-01 | 1.030530E 00 |
| 3.047349E-01 | 8.697300E-01 | 9.305980E-01 | 2.678930E-01 | 1.025069E 00 |
| 3.154939E-01 | 8.872310E-01 | 9.511420E-01 | 2.610590E-01 | 1.019629E 00 |
| 3.265859E-01 | 9.050580E-01 | 9.721380E-01 | 2.543350E-01 | 1.014199E 00 |
| 3.380210E-01 | 9.232170E-01 | 9.935970E-01 | 2.477220E-01 | 1.008809E 00 |
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| 3.619580E-01 | 9.605570E-01 | 1.037950E 00 | 2.348329E-01 | 9.980820E-01 |
| 3.744810E-01 | 9.797519E-01 | 1.060869E 00 | 2.285579E-01 | 9.927590E-01 |
| 3.875329E-01 | 9.990500E-01 | 1.084169E 00 | 2.240019E-01 | 9.761310E-01 |
| 4.009970E-01 | 1.018680E 00 | 1.107969E 00 | 2.178020E-01 | 9.697180E-01 |
| 4.148670E-01 | 1.038690E 00 | 1.132319E 00 | 2.117220E-01 | 9.644750E-01 |
| 4.291570E-01 | 1.059070E 00 | 1.157200E 00 | 2.057640E-01 | 9.592640E-01 |
| 4.438760E-01 | 1.079829E 00 | 1.182659E 00 | 1.999280E-01 | 9.540850E-01 |
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|---|---|---|---|---|
| 4.746520E-01 | 1.122530E 00 | 1.235299E 00 | 1.886179E-01 | 9.438290E-01 |
| 4.907320E-01 | 1.144489E 00 | 1.262509E 00 | 1.831450E-01 | 9.387529E-01 |
| 5.072920E-01 | 1.166869E 00 | 1.290350E 00 | 1.777910E-01 | 9.337119E-01 |
| 5.243430E-01 | 1.189670E 00 | 1.318820E 00 | 1.725570E-01 | 9.287060E-01 |
| 5.418990E-01 | 1.212910E 00 | 1.347950E 00 | 1.674410E-01 | 9.237379E-01 |
| 5.599740E-01 | 1.236589E 00 | 1.377729E 00 | 1.624430E-01 | 9.188060E-01 |
| 5.785810E-01 | 1.260719E 00 | 1.408210E 00 | 1.575609E-01 | 9.139130E-01 |
| 5.977350E-01 | 1.285310E 00 | 1.439380E 00 | 1.527960E-01 | 9.090570E-01 |
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| 6.382710E-01 | 1.334999E 00 | 1.503519E 00 | 1.435710E-01 | 8.690880E-01 |
| 6.593660E-01 | 1.360680E 00 | 1.536750E 00 | 1.390750E-01 | 8.829800E-01 |
| 6.810730E-01 | 1.386840E 00 | 1.570740E 00 | 1.346940E-01 | 8.783060E-01 |
| 7.034079E-01 | 1.413520E 00 | 1.605530E 00 | 1.304269E-01 | 8.736740E-01 |
| 7.263890E-01 | 1.440709E 00 | 1.641129E 00 | 1.262720E-01 | 8.690839E-01 |
| 7.500319E-01 | 1.468419E 00 | 1.677569E 00 | 1.222270E-01 | 8.645360E-01 |
| 7.743559E-01 | 1.496679E 00 | 1.714849E 00 | 1.182910E-01 | 8.600320E-01 |
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| 8.251160E-01 | 1.554850E 00 | 1.792049E 00 | 1.107390E-01 | 8.511530E-01 |
| 8.515910E-01 | 1.584789E 00 | 1.832020E 00 | 1.071180E-01 | 8.467780E-01 |
| 8.788210E-01 | 1.615319E 00 | 1.872930E 00 | 1.035990E-01 | 8.424470E-01 |
| 9.070800E-01 | 1.646009E 00 | 1.914650E 00 | 9.962797E-02 | 8.265700E-01 |
| 9.361240E-01 | 1.677329E 00 | 1.957359E 00 | 9.627569E-02 | 8.230830E-01 |
| 9.659890E-01 | 1.709270E 00 | 2.001080E 00 | 9.302217E-02 | 8.189220E-01 |
| 9.966969E-01 | 1.741830E 00 | 2.045850E 00 | 8.986509E-02 | 8.148070E-01 |
| 1.028270E 00 | 1.775049E 00 | 2.091669E 00 | 8.680248E-02 | 8.107370E-01 |
| 1.060730E 00 | 1.808920E 00 | 2.138590E 00 | 8.383238E-02 | 8.067120E-01 |
| 1.094100E 00 | 1.843470E 00 | 2.186629E 00 | 8.095247E-02 | 8.027329E-01 |
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| 1.163670E 00 | 1.914660E 00 | 2.286160E 00 | 7.545537E-02 | 7.949089E-01 |
| 1.199929E 00 | 1.951320E 00 | 2.337720E 00 | 7.283396E-02 | 7.910640E-01 |
| 1.237189E 00 | 1.988720E 00 | 2.390510E 00 | 7.029456E-02 | 7.872640E-01 |
| 1.275479E 00 | 2.026870E 00 | 2.444570E 00 | 6.783527E-02 | 7.835090E-01 |
| 1.314850E 00 | 2.065800E 00 | 2.499929E 00 | 6.545389E-02 | 7.797980E-01 |
| 1.355300E 00 | 2.105510E 00 | 2.556620E 00 | 6.314880E-02 | 7.761320E-01 |
| 1.396870E 00 | 2.146020E 00 | 2.614659E 00 | 6.091760E-02 | 7.725100E-01 |
| 1.440499E 00 | 2.185789E 00 | 2.673699E 00 | 5.786620E-02 | 7.392580E-01 |
| 1.484759E 00 | 2.227340E 00 | 2.734409E 00 | 5.577590E-02 | 7.537200E-01 |
| 1.530239E 00 | 2.269739E 00 | 2.796590E 00 | 5.375530E-02 | 7.502930E-01 |
| 1.576969E 00 | 2.313000E 00 | 2.860270E 00 | 5.180250E-02 | 7.469110E-01 |
| 1.624980E 00 | 2.357149E 00 | 2.925489E 00 | 4.991550E-02 | 7.435720E-01 |
| 1.674299E 00 | 2.402209E 00 | 2.992299E 00 | 4.809250E-02 | 7.402779E-01 |
| 1.724970E 00 | 2.448199E 00 | 3.060730E 00 | 4.633160E-02 | 7.370260E-01 |
| 1.777020E 00 | 2.495139E 00 | 3.130819E 00 | 4.463090E-02 | 7.338180E-01 |
| 1.830489E 00 | 2.543059E 00 | 3.202609E 00 | 4.298870E-02 | 7.306520E-01 |
| 1.885420E 00 | 2.591960E 00 | 3.276159E 00 | 4.140320E-02 | 7.275280E-01 |
| 1.941830E 00 | 2.641890E 00 | 3.351489E 00 | 3.987260E-02 | 7.244460E-01 |
| 1.999769E 00 | 2.692849E 00 | 3.428659E 00 | 3.839540E-02 | 7.214070E-01 |
| 2.061090E 00 | 2.741770E 00 | 3.507090E 00 | 3.610550E-02 | 6.733590E-01 |
| 2.122649E 00 | 2.794129E 00 | 3.587910E 00 | 3.474170E-02 | 7.048550E-01 |
| 2.185869E 00 | 2.847600E 00 | 3.670699E 00 | 3.342680E-02 | 7.020130E-01 |
| 2.250790E 00 | 2.902189E 00 | 3.755529E 00 | 3.215930E-02 | 6.992120E-01 |
| 2.317450E 00 | 2.957939E 00 | 3.842429E 00 | 3.093750E-02 | 6.964509E-01 |
| 2.385900E 00 | 3.014870E 00 | 3.931459E 00 | 2.976000E-02 | 6.937300E-01 |
| 2.456189E 00 | 3.073000E 00 | 4.022679E 00 | 2.862540E-02 | 6.910480E-01 |
| 2.528359E 00 | 3.132370E 00 | 4.116130E 00 | 2.753220E-02 | 6.884050E-01 |
| 2.603330E 00 | 3.191520E 00 | 4.211619E 00 | 2.537840E-02 | 6.679699E-01 |
| 2.680070E 00 | 3.252310E 00 | 4.309520E 00 | 2.438620E-02 | 6.698890E-01 |
| 2.758860E 00 | 3.314400E 00 | 4.409840E 00 | 2.343140E-02 | 6.674719E-01 |
| 2.839740E 00 | 3.377830E 00 | 4.512620E 00 | 2.251270E-02 | 6.650929E-01 |
| 2.922759E 00 | 3.442639E 00 | 4.617940E 00 | 2.162880E-02 | 6.627510E-01 |
| 3.007990E 00 | 3.508840E 00 | 4.725860E 00 | 2.077840E-02 | 6.604450E-01 |
| 3.095469E 00 | 3.576480E 00 | 4.836450E 00 | 1.996050E-02 | 6.581750E-01 |
| 3.185269E 00 | 3.645590E 00 | 4.949759E 00 | 1.917370E-02 | 6.559409E-01 |
| 3.278589E 00 | 3.714230E 00 | 5.065599E 00 | 1.746840E-02 | 6.341460E-01 |
| 3.373879E 00 | 3.785199E 00 | 5.184420E 00 | 1.676550E-02 | 6.401320E-01 |
| 3.471680E 00 | 3.857730E 00 | 5.306170E 00 | 1.609010E-02 | 6.381159E-01 |
| 3.572049E 00 | 3.931849E 00 | 5.430949E 00 | 1.544130E-02 | 6.361319E-01 |
| 3.675050E 00 | 4.007609E 00 | 5.558809E 00 | 1.481800E-02 | 6.341820E-01 |
| 3.780749E 00 | 4.085050E 00 | 5.689850E 00 | 1.421930E-02 | 6.322640E-01 |
| 3.889640E 00 | 4.163489E 00 | 5.824039E 00 | 1.293700E-02 | 6.242540E-01 |
| 4.001550E 00 | 4.243360E 00 | 5.961539E 00 | 1.240560E-02 | 6.199009E-01 |
| 4.116380E 00 | 4.325029E 00 | 6.102440E 00 | 1.189560E-02 | 6.181740E-01 |
| 4.234200E 00 | 4.408520E 00 | 6.246849E 00 | 1.140620E-02 | 6.164780E-01 |
| 4.355100E 00 | 4.493879E 00 | 6.394839E 00 | 1.093650E-02 | 6.148100E-01 |
| 4.479309E 00 | 4.580870E 00 | 6.546479E 00 | 9.965908E-03 | 6.109580E-01 |

| | | | | |
|---|---|---|---|---|
| 4.607080E 00 | 4.669240E 00 | 6.701839E 00 | 9.550169E-03 | 6.050740E-01 |
| 4.738170E 00 | 4.759609E 00 | 6.861050E 00 | 9.151500E-03 | 6.035730E-01 |
| 4.872649E 00 | 4.852030E 00 | 7.024240E 00 | 8.769218E-03 | 6.020970E-01 |
| 5.010619E 00 | 4.946549E 00 | 7.191480E 00 | 8.402657E-03 | 6.006490E-01 |
| 5.153000E 00 | 5.041770E 00 | 7.362760E 00 | 7.638928E-03 | 5.894300E-01 |
| 5.298670E 00 | 5.139819E 00 | 7.538360E 00 | 7.315997E-03 | 5.924670E-01 |
| 5.448739E 00 | 5.239030E 00 | 7.718260E 00 | 6.608158E-03 | 5.841110E-01 |
| 5.602759E 00 | 5.340369E 00 | 7.902630E 00 | 5.886339E-03 | 5.819899E-01 |
| 5.761080E 00 | 5.443469E 00 | 8.091559E 00 | 5.379148E-03 | 5.772009E-01 |
| 5.923739E 00 | 5.548479E 00 | 8.285170E 00 | 4.988506E-03 | 5.732610E-01 |
| 6.090810E 00 | 5.655530E 00 | 8.483589E 00 | 4.578840E-03 | 5.698510E-01 |
| 6.262309E 00 | 5.764799E 00 | 8.686939E 00 | 4.239608E-03 | 5.672830E-01 |
| 6.438490E 00 | 5.876120E 00 | 8.895350E 00 | 3.833990E-03 | 5.635310E-01 |
| 6.619380E 00 | 5.989710E 00 | 9.108939E 00 | 3.481260E-03 | 5.607100E-01 |
| 6.805059E 00 | 6.105659E 00 | 9.327860E 00 | 3.171240E-03 | 5.582120E-01 |
| 6.995780E 00 | 6.223829E 00 | 9.552219E 00 | 2.796320E-03 | 5.547100E-01 |
| 7.191600E 00 | 6.344390E 00 | 9.782169E 00 | 2.491480E-03 | 5.518349E-01 |
| 7.392449E 00 | 6.467719E 00 | 1.001790E 01 | 2.209980E-03 | 5.507140E-01 |
| 7.598740E 00 | 6.593410E 00 | 1.025940E 01 | 2.109600E-03 | 5.472220E-01 |
| 7.810149E 00 | 6.722300E 00 | 1.050700E 01 | 2.014450E-03 | 5.474910E-01 |
| 8.026890E 00 | 6.854340E 00 | 1.076080E 01 | 1.988210E-03 | 5.471660E-01 |
| 8.249129E 00 | 6.989550E 00 | 1.102100E 01 | 1.898000E-03 | 5.465630E-01 |
| 8.477039E 00 | 7.127930E 00 | 1.128760E 01 | 1.860710E-03 | 5.456730E-01 |
| 8.710569E 00 | 7.269899E 00 | 1.156090E 01 | 1.776380E-03 | 5.462450E-01 |
| 8.950000E 00 | 7.415310E 00 | 1.184100E 01 | 1.695850E-03 | 5.457529E-01 |
| 9.195499E 00 | 7.564230E 00 | 1.212820E 01 | 1.618950E-03 | 5.452720E-01 |
| 9.446870E 00 | 7.717310E 00 | 1.242250E 01 | 1.635870E-03 | 5.470020E-01 |
| 9.704720E 00 | 7.873890E 00 | 1.272410E 01 | 1.561920E-03 | 5.457259E-01 |
| 9.969100E 00 | 8.034260E 00 | 1.303330E 01 | 1.491310E-03 | 5.452490E-01 |
| 1.024020E 01 | 8.198500E 00 | 1.335030E 01 | 1.423860E-03 | 5.447820E-01 |
| 1.051750E 01 | 8.367680E 00 | 1.367520E 01 | 1.452850E-03 | 5.477050E-01 |
| 1.080220E 01 | 8.540440E 00 | 1.400810E 01 | 1.387420E-03 | 5.454880E-01 |
| 1.139310E 01 | 8.898820E 00 | 1.469930E 01 | 1.364680E-03 | 5.464930E-01 |
| 1.169960E 01 | 9.085030E 00 | 1.505790E 01 | 1.303540E-03 | 5.460100E-01 |
| 1.201380E 01 | 9.275749E 00 | 1.542540E 01 | 1.245120E-03 | 5.455360E-01 |
| 1.233590E 01 | 9.471080E 00 | 1.580220E 01 | 1.189320E-03 | 5.450730E-01 |
| 1.266610E 01 | 9.671340E 00 | 1.618829E 01 | 1.211860E-03 | 5.452130E-01 |
| 1.300440E 01 | 9.876820E 00 | 1.658420E 01 | 1.157820E-03 | 5.458170E-01 |
| 1.335130E 01 | 1.008730E 01 | 1.698990E 01 | 1.106190E-03 | 5.453530E-01 |
| 1.370690E 01 | 1.030280E 01 | 1.740569E 01 | 1.056840E-03 | 5.448980E-01 |
| 1.407150E 01 | 1.052360E 01 | 1.783199E 01 | 1.009700E-03 | 5.444530E-01 |
| 1.444470E 01 | 1.075080E 01 | 1.826889E 01 | 1.015710E-03 | 5.469060E-01 |
| 1.482770E 01 | 1.098290E 01 | 1.871669E 01 | 9.705969E-04 | 5.448720E-01 |
| 1.522030E 01 | 1.122060E 01 | 1.917569E 01 | 9.274799E-04 | 5.444320E-01 |
| 1.562290E 01 | 1.146420E 01 | 1.964619E 01 | 8.862719E-04 | 5.440010E-01 |
| 1.603519E 01 | 1.171430E 01 | 2.012839E 01 | 9.086698E-04 | 5.453990E-01 |
| 1.645789E 01 | 1.197060E 01 | 2.062279E 01 | 8.685738E-04 | 5.449330E-01 |
| 1.689130E 01 | 1.223300E 01 | 2.112939E 01 | 8.302419E-04 | 5.444980E-01 |
| 1.733559E 01 | 1.250180E 01 | 2.164879E 01 | 7.935958E-04 | 5.440720E-01 |
| 1.779070E 01 | 1.277810E 01 | 2.218109E 01 | 8.065440E-04 | 5.455640E-01 |
| 1.825729E 01 | 1.306080E 01 | 2.272670E 01 | 7.711819E-04 | 5.448200E-01 |
| 1.873569E 01 | 1.335050E 01 | 2.328600E 01 | 7.373649E-04 | 5.443940E-01 |
| 1.922589E 01 | 1.364770E 01 | 2.385919E 01 | 7.439549E-04 | 5.450079E-01 |
| 1.972839E 01 | 1.395230E 01 | 2.444679E 01 | 7.115440E-04 | 5.449980E-01 |
| 2.024350E 01 | 1.426430E 01 | 2.504909E 01 | 6.805419E-04 | 5.445750E-01 |
| 2.077150E 01 | 1.458420E 01 | 2.566640E 01 | 6.825628E-04 | 5.448260E-01 |
| 2.131259E 01 | 1.491230E 01 | 2.629919E 01 | 6.530120E-04 | 5.450570E-01 |
| 2.186729E 01 | 1.524830E 01 | 2.694769E 01 | 6.247358E-04 | 5.446380E-01 |
| 2.243579E 01 | 1.559290E 01 | 2.761249E 01 | 6.235340E-04 | 5.448750E-01 |
| 2.301849E 01 | 1.594620E 01 | 2.829390E 01 | 5.967019E-04 | 5.450180E-01 |
| 2.361589E 01 | 1.630800E 01 | 2.899239E 01 | 5.710218E-04 | 5.446060E-01 |
| 2.422809E 01 | 1.667920E 01 | 2.970830E 01 | 5.681140E-04 | 5.451300E-01 |
| 2.485559E 01 | 1.705959E 01 | 3.044209E 01 | 5.438149E-04 | 5.449250E-01 |
| 2.549889E 01 | 1.744930E 01 | 3.119429E 01 | 5.388530E-04 | 5.447090E-01 |
| 2.615810E 01 | 1.784909E 01 | 3.196519E 01 | 5.159448E-04 | 5.451609E-01 |
| 2.683400E 01 | 1.825859E 01 | 3.275549E 01 | 4.940080E-04 | 5.447590E-01 |
| 2.752669E 01 | 1.867839E 01 | 3.356540E 01 | 4.858158E-04 | 5.447740E-01 |
| 2.823669E 01 | 1.910869E 01 | 3.439569E 01 | 4.652629E-04 | 5.447870E-01 |
| 2.896469E 01 | 1.954939E 01 | 3.524669E 01 | 4.540388E-04 | 5.444230E-01 |
| 2.971078E 01 | 2.000130E 01 | 3.611890E 01 | 4.349009E-04 | 5.445930E-01 |
| 3.047549E 01 | 2.046449E 01 | 3.701299E 01 | 4.236810E-04 | 5.445810E-01 |
| 3.125949E 01 | 2.093909E 01 | 3.792940E 01 | 4.058848E-04 | 5.443590E-01 |
| 3.206339E 01 | 2.142490E 01 | 3.886870E 01 | 3.781149E-04 | 5.435579E-01 |
| 3.288820E 01 | 2.192139E 01 | 3.983150E 01 | 3.187228E-04 | 5.418670E-01$ |

Shock Shape Input Data for the 140B
Orbiter Sample Cases

| | | |
|---|---|---|
| 0.0 | 0.0 | 1.166000E-01 |
| 2.418570E-03 | 0.0 | 1.166000E-01 |
| 3.669430E-03 | 0.0 | 1.166000E-01 |
| 4.948799E-03 | 0.0 | 1.166000E-01 |
| 6.257258E-03 | 0.0 | 1.166000E-01 |
| 7.595427E-03 | 0.0 | 1.166000E-01 |
| 8.963928E-03 | 0.0 | 1.166000E-01 |
| 1.036340E-02 | 0.0 | 1.166000E-01 |
| 1.179440E-02 | 0.0 | 1.166000E-01 |
| 1.325770E-02 | 0.0 | 1.166000E-01 |
| 1.473920E-02 | 0.0 | 1.166000E-01 |
| 1.625160E-02 | 0.0 | 1.166000E-01 |
| 1.779790E-02 | 0.0 | 1.166000E-01 |
| 1.937870E-02 | 0.0 | 1.166000E-01 |
| 2.099480E-02 | 0.0 | 1.166000E-01 |
| 2.264690E-02 | 0.0 | 1.166000E-01 |
| 2.433570E-02 | 0.0 | 1.166000E-01 |
| 2.606200E-02 | 0.0 | 1.166000E-01 |
| 2.782640E-02 | 0.0 | 1.166000E-01 |
| 2.962990E-02 | 0.0 | 1.166000E-01 |
| 3.147300E-02 | 0.0 | 1.166000E-01 |
| 3.335670E-02 | 0.0 | 1.166000E-01 |
| 3.528170E-02 | 0.0 | 1.166000E-01 |
| 3.723310E-02 | 0.0 | 1.166000E-01 |
| 3.922130E-02 | 0.0 | 1.166000E-01 |
| 4.125280E-02 | 0.0 | 1.166000E-01 |
| 4.332860E-02 | 0.0 | 1.166000E-01 |
| 4.544930E-02 | 0.0 | 1.166000E-01 |
| 4.761610E-02 | 0.0 | 1.166000E-01 |
| 4.982960E-02 | 0.0 | 1.166000E-01 |
| 5.209090E-02 | 0.0 | 1.166000E-01 |
| 5.440090E-02 | 0.0 | 1.166000E-01 |
| 5.676050E-02 | 0.0 | 1.166000E-01 |
| 5.916430E-02 | 0.0 | 1.166000E-01 |
| 6.160030E-02 | 0.0 | 1.166000E-01 |
| 6.408817E-02 | 0.0 | 1.166000E-01 |
| 6.662905E-02 | 0.0 | 1.166000E-01 |
| 6.922400E-02 | 0.0 | 1.166000E-01 |
| 7.187378E-02 | 0.0 | 1.166000E-01 |
| 7.457978E-02 | 0.0 | 1.166000E-01 |
| 7.734287E-02 | 0.0 | 1.166000E-01 |
| 8.016419E-02 | 0.0 | 1.166000E-01 |
| 8.303237E-02 | 0.0 | 1.166000E-01 |
| 8.594429E-02 | 0.0 | 1.166000E-01 |
| 8.891720E-02 | 0.0 | 1.166000E-01 |
| 9.195215E-02 | 0.0 | 1.166000E-01 |
| 9.505045E-02 | 0.0 | 1.166000E-01 |
| 9.821337E-02 | 0.0 | 1.166000E-01 |
| 1.014420E-01 | 0.0 | 1.166000E-01 |
| 1.047380E-01 | 0.0 | 1.166000E-01 |
| 1.080779E-01 | 0.0 | 1.166000E-01 |
| 1.114790E-01 | 0.0 | 1.166000E-01 |
| 1.149499E-01 | 0.0 | 1.166000E-01 |
| 1.184930E-01 | 0.0 | 1.166000E-01 |
| 1.221090E-01 | 0.0 | 1.166000E-01 |
| 1.257989E-01 | 0.0 | 1.166000E-01 |
| 1.295649E-01 | 0.0 | 1.166000E-01 |
| 1.333770E-01 | 0.0 | 1.166000E-01 |
| 1.372640E-01 | 0.0 | 1.166000E-01 |
| 1.412309E-01 | 0.0 | 1.166000E-01 |
| 1.452790E-01 | 0.0 | 1.166000E-01 |
| 1.494090E-01 | 0.0 | 1.166000E-01 |
| 1.536230E-01 | 0.0 | 1.166000E-01 |
| 1.578979E-01 | 0.0 | 1.166000E-01 |
| 1.622500E-01 | 0.0 | 1.166000E-01 |
| 1.666890E-01 | 0.0 | 1.166000E-01 |
| 1.712199E-01 | 0.0 | 1.166000E-01 |
| 1.758420E-01 | 0.0 | 1.166000E-01 |
| 1.805570E-01 | 0.0 | 1.166000E-01 |
| 1.853319E-01 | 0.0 | 1.166000E-01 |
| 1.902030E-01 | 0.0 | 1.166000E-01 |
| 1.951730E-01 | 0.0 | 1.166000E-01 |
| 2.002439E-01 | 0.0 | 1.166000E-01 |
| 2.054180E-01 | 0.0 | 1.166000E-01 |
| 2.106690E-01 | 0.0 | 1.166000E-01 |

| | | |
|---|---|---|
| 2.160169E-01 | 0.0 | 1.166000E-01 |
| 2.214730E-01 | 0.0 | 1.166000E-01 |
| 2.270390E-01 | 0.0 | 1.166000E-01 |
| 2.327180E-01 | 0.0 | 1.166000E-01 |
| 2.384850E-01 | 0.0 | 1.166000E-01 |
| 2.443590E-01 | 0.0 | 1.166000E-01 |
| 2.503520E-01 | 0.0 | 1.166000E-01 |
| 2.564670E-01 | 0.0 | 1.166000E-01 |
| 2.627040E-01 | 0.0 | 1.166000E-01 |
| 2.690340E-01 | 0.0 | 1.166000E-01 |
| 2.754920E-01 | 0.0 | 1.166000E-01 |
| 2.820820E-01 | 0.0 | 1.166000E-01 |
| 2.888070E-01 | 0.0 | 1.166000E-01 |
| 2.980940E-01 | 0.0 | 1.166000E-01 |
| 3.056250E-01 | 0.0 | 1.166000E-01 |
| 3.133079E-01 | 0.0 | 1.166000E-01 |
| 3.211460E-01 | 0.0 | 1.166000E-01 |
| 3.288360E-01 | 0.0 | 1.166000E-01 |
| 3.372729E-01 | 0.0 | 1.166000E-01 |
| 3.458790E-01 | 0.0 | 1.166000E-01 |
| 3.546570E-01 | 0.0 | 1.166000E-01 |
| 3.626429E-01 | 0.0 | 1.166000E-01 |
| 3.717080E-01 | 0.0 | 1.166000E-01 |
| 3.809550E-01 | 0.0 | 1.166000E-01 |
| 3.904510E-01 | 0.0 | 1.166000E-01 |
| 3.999910E-01 | 0.0 | 1.166000E-01 |
| 4.097250E-01 | 0.0 | 1.166000E-01 |
| 4.196570E-01 | 0.0 | 1.166000E-01 |
| 4.297900E-01 | 0.0 | 1.166000E-01 |
| 4.401290E-01 | 0.0 | 1.166000E-01 |
| 4.506789E-01 | 0.0 | 1.166000E-01 |
| 4.614429E-01 | 0.0 | 1.166000E-01 |
| 4.724280E-01 | 0.0 | 1.166000E-01 |
| 4.836370E-01 | 0.0 | 1.166000E-01 |
| 4.950750E-01 | 0.0 | 1.166000E-01 |
| 5.067490E-01 | 0.0 | 1.166000E-01 |
| 5.186620E-01 | 0.0 | 1.166000E-01 |
| 5.308200E-01 | 0.0 | 1.166000E-01 |
| 5.432290E-01 | 0.0 | 1.166000E-01 |
| 5.558950E-01 | 0.0 | 1.166000E-01 |
| 5.688230E-01 | 0.0 | 1.166000E-01 |
| 5.820180E-01 | 0.0 | 1.166000E-01 |
| 5.954880E-01 | 0.0 | 1.166000E-01 |
| 6.092390E-01 | 0.0 | 1.166000E-01 |
| 6.232760E-01 | 0.0 | 1.166000E-01 |
| 6.373560E-01 | 0.0 | 1.166000E-01 |
| 6.518260E-01 | 0.0 | 1.166000E-01 |
| 6.666009E-01 | 0.0 | 1.166000E-01 |
| 6.816880E-01 | 0.0 | 1.166000E-01 |
| 6.970950E-01 | 0.0 | 1.166000E-01 |
| 7.128280E-01 | 0.0 | 1.166000E-01 |
| 7.288949E-01 | 0.0 | 1.166000E-01 |
| 7.453049E-01 | 0.0 | 1.166000E-01 |
| 7.620650E-01 | 0.0 | 1.166000E-01 |
| 7.791840E-01 | 0.0 | 1.166000E-01 |
| 7.966710E-01 | 0.0 | 1.166000E-01 |
| 8.145330E-01 | 0.0 | 1.166000E-01 |
| 8.327810E-01 | 0.0 | 1.166000E-01 |
| 8.514220E-01 | 0.0 | 1.166000E-01 |
| 8.715740E-01 | 0.0 | 1.166000E-01 |
| 8.908250E-01 | 0.0 | 1.166000E-01 |
| 9.104960E-01 | 0.0 | 1.166000E-01 |
| 9.305980E-01 | 0.0 | 1.166000E-01 |
| 9.511420E-01 | 0.0 | 1.166000E-01 |
| 9.721380E-01 | 0.0 | 1.166000E-01 |
| 9.935970E-01 | 0.0 | 1.166000E-01 |
| 1.015530E 00 | 0.0 | 1.166000E-01 |
| 1.037950E 00 | 0.0 | 1.166000E-01 |
| 1.060869E 00 | 0.0 | 1.166000E-01 |
| 1.084169E 00 | 0.0 | 1.166000E-01 |
| 1.107969E 00 | 0.0 | 1.166000E-01 |
| 1.132319E 00 | 0.0 | 1.166000E-01 |
| 1.157200E 00 | 0.0 | 1.166000E-01 |
| 1.182659E 00 | 0.0 | 1.166000E-01 |
| 1.208679E 00 | 0.0 | 1.166000E-01 |

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| 1.235299E 00 | 0.0 | 1.166000E-01 |
| 1.262509E 00 | 0.0 | 1.166000E-01 |
| 1.290350E 00 | 0.0 | 1.166000E-01 |
| 1.318820E 00 | 0.0 | 1.166000E-01 |
| 1.347950E 00 | 0.0 | 1.166000E-01 |
| 1.377729E 00 | 0.0 | 1.166000E-01 |
| 1.408210E 00 | 0.0 | 1.166000E-01 |
| 1.439380E 00 | 0.0 | 1.166000E-01 |
| 1.471270E 00 | 0.0 | 1.166000E-01 |
| 1.503519E 00 | 0.0 | 1.166000E-01 |
| 1.536750E 00 | 0.0 | 1.166000E-01 |
| 1.570740E 00 | 0.0 | 1.166000E-01 |
| 1.605530E 00 | 0.0 | 1.166000E-01 |
| 1.641129E 00 | 0.0 | 1.166000E-01 |
| 1.677569E 00 | 0.0 | 1.166000E-01 |
| 1.714849E 00 | 0.0 | 1.166000E-01 |
| 1.752999E 00 | 0.0 | 1.166000E-01 |
| 1.792049E 00 | 0.0 | 1.166000E-01 |
| 1.832020E 00 | 0.0 | 1.166000E-01 |
| 1.872930E 00 | 0.0 | 1.166000E-01 |
| 1.914650E 00 | 0.0 | 1.166000E-01 |
| 1.957359E 00 | 0.0 | 1.166000E-01 |
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| 2.045850E 00 | 0.0 | 1.166000E-01 |
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| 2.186629E 00 | 0.0 | 1.166000E-01 |
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| 2.286160E 00 | 0.0 | 1.166000E-01 |
| 2.337720E 00 | 0.0 | 1.166000E-01 |
| 2.390510E 00 | 0.0 | 1.166000E-01 |
| 2.444570E 00 | 0.0 | 1.166000E-01 |
| 2.499929E 00 | 0.0 | 1.166000E-01 |
| 2.556620E 00 | 0.0 | 1.166000E-01 |
| 2.614659E 00 | 0.0 | 1.166000E-01 |
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| 2.734409E 00 | 0.0 | 1.166000E-01 |
| 2.796590E 00 | 0.0 | 1.166000E-01 |
| 2.860270E 00 | 0.0 | 1.166000E-01 |
| 2.925489E 00 | 0.0 | 1.166000E-01 |
| 2.992299E 00 | 0.0 | 1.166000E-01 |
| 3.060730E 00 | 0.0 | 1.166000E-01 |
| 3.130819E 00 | 0.0 | 1.166000E-01 |
| 3.202609E 00 | 0.0 | 1.166000E-01 |
| 3.276159E 00 | 0.0 | 1.166000E-01 |
| 3.351489E 00 | 0.0 | 1.166000E-01 |
| 3.428659E 00 | 0.0 | 1.166000E-01 |
| 3.507090E 00 | 0.0 | 1.166000E-01 |
| 3.587910E 00 | 0.0 | 1.166000E-01 |
| 3.670699E 00 | 0.0 | 1.166000E-01 |
| 3.755529E 00 | 0.0 | 1.166000E-01 |
| 3.842429E 00 | 0.0 | 1.166000E-01 |
| 3.931459E 00 | 0.0 | 1.166000E-01 |
| 4.022679E 00 | 0.0 | 1.166000E-01 |
| 4.116130E 00 | 0.0 | 1.166000E-01 |
| 4.211619E 00 | 0.0 | 1.166000E-01 |
| 4.309520E 00 | 0.0 | 1.166000E-01 |
| 4.409840E 00 | 0.0 | 1.166000E-01 |
| 4.512620E 00 | 0.0 | 1.166000E-01 |
| 4.617940E 00 | 0.0 | 1.166000E-01 |
| 4.725860E 00 | 0.0 | 1.166000E-01 |
| 4.836450E 00 | 0.0 | 1.166000E-01 |
| 4.949759E 00 | 0.0 | 1.166000E-01 |
| 5.065599E 00 | 0.0 | 1.166000E-01 |
| 5.184420E 00 | 0.0 | 1.166000E-01 |
| 5.306170E 00 | 0.0 | 1.166000E-01 |
| 5.430949E 00 | 0.0 | 1.166000E-01 |
| 5.558809E 00 | 0.0 | 1.166000E-01 |
| 5.689850E 00 | 0.0 | 1.166000E-01 |
| 5.824039E 00 | 0.0 | 1.166000E-01 |
| 5.961539E 00 | 0.0 | 1.166000E-01 |
| 6.102440E 00 | 0.0 | 1.166000E-01 |
| 6.246849E 00 | 0.0 | 1.166000E-01 |
| 6.394839E 00 | 0.0 | 1.166000E-01 |
| 6.546479E 00 | 0.0 | 1.166000E-01 |

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|---|---|---|
| 6.701839E 00 | 0.0 | 1.166000E-01 |
| 6.861050E 00 | 0.0 | 1.166000E-01 |
| 7.024240E 00 | 0.0 | 1.166000E-01 |
| 7.191480E 00 | 0.0 | 1.166000E-01 |
| 7.362760E 00 | 0.0 | 1.166000E-01 |
| 7.538360E 00 | 0.0 | 1.166000E-01 |
| 7.718260E 00 | 0.0 | 1.166000E-01 |
| 7.902630E 00 | 0.0 | 1.166000E-01 |
| 8.091559E 00 | 0.0 | 1.166000E-01 |
| 8.285170E 00 | 0.0 | 1.166000E-01 |
| 8.483589E 00 | 0.0 | 1.166000E-01 |
| 8.686939E 00 | 0.0 | 1.166000E-01 |
| 8.895350E 00 | 0.0 | 1.166000E-01 |
| 9.108939E 00 | 0.0 | 1.166000E-01 |
| 9.327860E 00 | 0.0 | 1.166000E-01 |
| 9.552219E 00 | 0.0 | 1.166000E-01 |
| 9.782169E 00 | 0.0 | 1.166000E-01 |
| 1.001790E 01 | 0.0 | 1.166000E-01 |
| 1.025940E 01 | 0.0 | 1.166000E-01 |
| 1.050700E 01 | 0.0 | 1.166000E-01 |
| 1.076080E 01 | 0.0 | 1.166000E-01 |
| 1.102100E 01 | 0.0 | 1.166000E-01 |
| 1.128760E 01 | 0.0 | 1.166000F-01 |
| 1.156090E 01 | 0.0 | 1.166000E-01 |
| 1.184100E 01 | 0.0 | 1.166000E-01 |
| 1.212820E 01 | 0.0 | 1.166000E-01 |
| 1.242250E 01 | 0.0 | 1.166000E-01 |
| 1.272410E 01 | 0.0 | 1.166000E-01 |
| 1.303330E 01 | 0.0 | 1.166000E-01 |
| 1.335030E 01 | 0.0 | 1.166000E-01 |
| 1.367520E 01 | 0.0 | 1.166000E-01 |
| 1.400810E 01 | 0.0 | 1.166000E-01 |
| 1.434940E 01 | 0.0 | 1.166000F-01 |
| 1.469930E 01 | 0.0 | 1.166000E-01 |
| 1.505790E 01 | 0.0 | 1.166000E-01 |
| 1.542540E 01 | 0.0 | 1.166000E-01 |
| 1.580220E 01 | 0.0 | 1.166000E-01 |
| 1.618829E 01 | 0.0 | 1.166000E-01 |
| 1.658420E 01 | 0.0 | 1.166000E-01 |
| 1.698990E 01 | 0.0 | 1.166000E-01 |
| 1.740569E 01 | 0.0 | 1.166000E-01 |
| 1.783199E 01 | 0.0 | 1.166000E-01 |
| 1.826889E 01 | 0.0 | 1.166000E-01 |
| 1.871669E 01 | 0.0 | 1.166000E-01 |
| 1.917569E 01 | 0.0 | 1.166000E-01 |
| 1.964619E 01 | 0.0 | 1.166000E-01 |
| 2.012839E 01 | 0.0 | 1.166000E-01 |
| 2.062279E 01 | 0.0 | 1.166000E-01 |
| 2.112939E 01 | 0.0 | 1.166000F-01 |
| 2.164879E 01 | 0.0 | 1.166000E-01 |
| 2.218109E 01 | 0.0 | 1.166000E-01 |
| 2.272670E 01 | 0.0 | 1.166000E-01 |
| 2.328600E 01 | 0.0 | 1.166000E-01 |
| 2.385919E 01 | 0.0 | 1.166000E-01 |
| 2.444679E 01 | 0.0 | 1.166000E-01 |
| 2.504909E 01 | 0.0 | 1.166000E-01 |
| 2.566640E 01 | 0.0 | 1.166000E-01 |
| 2.629919E 01 | 0.0 | 1.166000E-01 |
| 2.694769E 01 | 0.0 | 1.166000E-01 |
| 2.761249E 01 | 0.0 | 1.166000E-01 |
| 2.829390E 01 | 0.0 | 1.166000E-01 |
| 2.899239E 01 | 0.0 | 1.166000E-01 |
| 2.970830E 01 | 0.0 | 1.166000E-01 |
| 3.044209E 01 | 0.0 | 1.166000E-01 |
| 3.119429E 01 | 0.0 | 1.166000E-01 |
| 3.196519E 01 | 0.0 | 1.166000E-01 |
| 3.275549E 01 | 0.0 | 1.166000E-01 |
| 3.356540E 01 | 0.0 | 1.166000E-01 |
| 3.439569E 01 | 0.0 | 1.166000E-01 |
| 3.524669E 01 | 0.0 | 1.166000E-01 |
| 3.611890E 01 | 0.0 | 1.166000E-01 |
| 3.701299E 01 | 0.0 | 1.166000E-01 |
| 3.792940E 01 | 0.0 | 1.166000E-01 |
| 3.886870E 01 | 0.0 | 1.166000E-01 |
| 3.983150E 01 | 0.0 | 1.166000E-01* |

## Unit 5 Input Data for the 140B Orbiter

## Binary-Gas Sample Case

```
FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS
 &INPUT
 ALT=245000.0,
 BRAD=2.360833,
 DS=0.2,
 DSMAX=1.0,
 RINF=.867251028D-07,
 SEND=35.0,
 TB=2460.0,
 THINI=-1.,
 TINF=361.48,
 UINF=25100.0,
 XKETA=1.05,
 IEND=6,
 IGEOM=3,
 KEND=1,
 NAN=-2,
 NDATA=1,
 NS=2,
 NSI=2,
 NTSH=20,
 &END
           .23456                                     .76544
           .23456                                     .76544
```

# Unit 5 Input Data for the 140B Orbiter

## 7-Species Sample Case

```
FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES
 &INPUT
 ALT=245C00.0,
 BRAD=2.360833,
 DS=0.2,
 DSMAX=1.0,
 RINF=.867251028D-07,
 SEND=35.0,
 TB=2460.0,
 THINI=-1.,
 TINF=361.48,
 UINF=25100.0,
 XKETA=1.05,
 IEND=6,
 IGECM=3,
 KEND=1,
 NAN=-2,
 NDATA=1,
 NS=6,
 NSI=6,
 NTSH=20,
 &END
           .23456                                       .76544
           .23456                                       .76544
```

## Shock Shape Input Data for the 31° Hyperboloid Sample Cases

| | | |
|---|---|---|
| 0.0 | 0.0 | 1.166000E-01 |
| 2.943361E-02 | 0.0 | 1.166000E-01 |
| 5.886861E-02 | 0.0 | 1.166000E-01 |
| 8.830637E-02 | 0.0 | 1.166000E-01 |
| 1.177483E-01 | 0.0 | 1.166000E-01 |
| 1.471957E-01 | 0.0 | 1.166000E-01 |
| 1.766500E-01 | 0.0 | 1.166000E-01 |
| 2.061127E-01 | 0.0 | 1.166000E-01 |
| 2.355852E-01 | 0.0 | 1.166000E-01 |
| 2.650688E-01 | 0.0 | 1.166000E-01 |
| 2.945648E-01 | 0.0 | 1.166000E-01 |
| 3.240746E-01 | 0.0 | 1.166000E-01 |
| 3.535998E-01 | 0.0 | 1.166000E-01 |
| 3.831417E-01 | 0.0 | 1.166000E-01 |
| 4.127015E-01 | 0.0 | 1.166000E-01 |
| 4.422811E-01 | 0.0 | 1.166000E-01 |
| 4.718814E-01 | 0.0 | 1.166000E-01 |
| 5.015042E-01 | 0.0 | 1.166000E-01 |
| 5.311506E-01 | 0.0 | 1.166000E-01 |
| 5.608222E-01 | 0.0 | 1.166000E-01 |
| 5.905204E-01 | 0.0 | 1.166000E-01 |
| 6.202466E-01 | 0.0 | 1.166000E-01 |
| 6.500025E-01 | 0.0 | 1.166000E-01 |
| 6.797891E-01 | 0.0 | 1.166000E-01 |
| 7.096082E-01 | 0.0 | 1.166000E-01 |
| 7.394611E-01 | 0.0 | 1.166000E-01 |
| 7.693492E-01 | 0.0 | 1.166000E-01 |
| 7.992741E-01 | 0.0 | 1.166000E-01 |
| 8.292373E-01 | 0.0 | 1.166000E-01 |
| 8.592403E-01 | 0.0 | 1.166000E-01 |
| 8.892844E-01 | 0.0 | 1.166000E-01 |
| 9.193712E-01 | 0.0 | 1.166000E-01 |
| 9.495023E-01 | 0.0 | 1.166000E-01 |
| 9.796793E-01 | 0.0 | 1.166000E-01 |
| 1.009903E 00 | 0.0 | 1.166000E-01 |
| 1.040175E 00 | 0.0 | 1.166000E-01 |
| 1.070499E 00 | 0.0 | 1.166000E-01 |
| 1.100875E 00 | 0.0 | 1.166000E-01 |
| 1.131304E 00 | 0.0 | 1.166000E-01 |
| 1.161786E 00 | 0.0 | 1.166000E-01 |
| 1.192327E 00 | 0.0 | 1.166000E-01 |
| 1.222926E 00 | 0.0 | 1.166000E-01 |
| 1.253585E 00 | 0.0 | 1.166000E-01 |
| 1.284305E 00 | 0.0 | 1.166000E-01 |
| 1.315087E 00 | 0.0 | 1.166000E-01 |
| 1.345936E 00 | 0.0 | 1.166000E-01 |
| 1.376850E 00 | 0.0 | 1.166000E-01 |
| 1.407832E 00 | 0.0 | 1.166000E-01 |
| 1.438885E 00 | 0.0 | 1.166000E-01 |
| 1.470009E 00 | 0.0 | 1.166000E-01 |
| 1.501205E 00 | 0.0 | 1.166000E-01 |
| 1.532476E 00 | 0.0 | 1.166000E-01 |
| 1.563826E 00 | 0.0 | 1.166000E-01 |
| 1.595253E 00 | 0.0 | 1.166000E-01 |
| 1.626760E 00 | 0.0 | 1.166000E-01 |
| 1.658348E 00 | 0.0 | 1.166000E-01 |
| 1.690022E 00 | 0.0 | 1.166000E-01 |
| 1.721781E 00 | 0.0 | 1.166000E-01 |
| 1.753627E 00 | 0.0 | 1.166000E-01 |
| 1.785562E 00 | 0.0 | 1.166000E-01 |
| 1.817589E 00 | 0.0 | 1.166000E-01 |
| 1.849709E 00 | 0.0 | 1.166000E-01 |
| 1.881924E 00 | 0.0 | 1.166000E-01 |
| 1.914235E 00 | 0.0 | 1.166000E-01 |
| 1.946647E 00 | 0.0 | 1.166000E-01 |
| 1.979158E 00 | 0.0 | 1.166000E-01 |
| 2.011773E 00 | 0.0 | 1.166000E-01 |
| 2.044494E 00 | 0.0 | 1.166000E-01 |
| 2.077320E 00 | 0.0 | 1.166000E-01 |
| 2.110257E 00 | 0.0 | 1.166000E-01 |
| 2.143305E 00 | 0.0 | 1.166000E-01 |
| 2.176466E 00 | 0.0 | 1.166000E-01 |
| 2.209742E 00 | 0.0 | 1.166000E-01 |
| 2.243136E 00 | 0.0 | 1.166000E-01 |
| 2.276650E 00 | 0.0 | 1.166000E-01 |

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| 2.344047E 00 | 0.0 | 1.166000E-01 |
| 2.377934E 00 | 0.0 | 1.166000E-01 |
| 2.411950E 00 | 0.0 | 1.166000E-01 |
| 2.446098E 00 | 0.0 | 1.166000E-01 |
| 2.480379E 00 | 0.0 | 1.166000E-01 |
| 2.514797E 00 | 0.0 | 1.166000E-01 |
| 2.549354E 00 | 0.0 | 1.166000E-01 |
| 2.584050E 00 | 0.0 | 1.166000E-01 |
| 2.618892E 00 | 0.0 | 1.166000E-01 |
| 2.653878E 00 | 0.0 | 1.166000E-01 |
| 2.689014E 00 | 0.0 | 1.166000E-01 |
| 2.724301E 00 | 0.0 | 1.166000E-01 |
| 2.759743E 00 | 0.0 | 1.166000E-01 |
| 2.795340E 00 | 0.0 | 1.166000E-01 |
| 2.831097E 00 | 0.0 | 1.166000E-01 |
| 2.867016E 00 | 0.0 | 1.166000E-01 |
| 2.903099E 00 | 0.0 | 1.166000E-01 |
| 2.939351E 00 | 0.0 | 1.166000E-01 |
| 2.975775E 00 | 0.0 | 1.166000E-01 |
| 3.012370E 00 | 0.0 | 1.166000E-01 |
| 3.049144E 00 | 0.0 | 1.166000E-01 |
| 3.086096E 00 | 0.0 | 1.166000E-01 |
| 3.123231E 00 | 0.0 | 1.166000E-01 |
| 3.160551E 00 | 0.0 | 1.166000E-01 |
| 3.198062E 00 | 0.0 | 1.166000E-01 |
| 3.235764E 00 | 0.0 | 1.166000E-01 |
| 3.273661E 00 | 0.0 | 1.166000E-01 |
| 3.311756E 00 | 0.0 | 1.166000E-01 |
| 3.350056E 00 | 0.0 | 1.166000E-01 |
| 3.388559E 00 | 0.0 | 1.166000E-01 |
| 3.427273E 00 | 0.0 | 1.166000E-01 |
| 3.466198E 00 | 0.0 | 1.166000E-01 |
| 3.505340E 00 | 0.0 | 1.166000E-01 |
| 3.544702E 00 | 0.0 | 1.166000E-01 |
| 3.584287E 00 | 0.0 | 1.166000E-01 |
| 3.624100E 00 | 0.0 | 1.166000E-01 |
| 3.664144E 00 | 0.0 | 1.166000E-01 |
| 3.704423E 00 | 0.0 | 1.166000E-01 |
| 3.744941E 00 | 0.0 | 1.166000E-01 |
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| 3.826712E 00 | 0.0 | 1.166000E-01 |
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| 4.121061E 00 | 0.0 | 1.166000E-01 |
| 4.164207E 00 | 0.0 | 1.166000E-01 |
| 4.207641E 00 | 0.0 | 1.166000E-01 |
| 4.251368E 00 | 0.0 | 1.166000E-01 |
| 4.295391E 00 | 0.0 | 1.166000E-01 |
| 4.339720E 00 | 0.0 | 1.166000E-01 |
| 4.384356E 00 | 0.0 | 1.166000E-01 |
| 4.429307E 00 | 0.0 | 1.166000E-01 |
| 4.474577E 00 | 0.0 | 1.166000E-01 |
| 4.520170E 00 | 0.0 | 1.166000E-01 |
| 4.566095E 00 | 0.0 | 1.166000E-01 |
| 4.612356E 00 | 0.0 | 1.166000E-01 |
| 4.658960E 00 | 0.0 | 1.166000E-01 |
| 4.705913E 00 | 0.0 | 1.166000E-01 |
| 4.753219E 00 | 0.0 | 1.166000E-01 |
| 4.800885E 00 | 0.0 | 1.166000E-01 |
| 4.848920E 00 | 0.0 | 1.166000E-01 |
| 4.897327E 00 | 0.0 | 1.166000E-01 |
| 4.946115E 00 | 0.0 | 1.166000E-01 |
| 4.995291E 00 | 0.0 | 1.166000E-01 |
| 5.044860E 00 | 0.0 | 1.166000E-01 |
| 5.094831E 00 | 0.0 | 1.166000E-01 |
| 5.145209E 00 | 0.0 | 1.166000E-01 |
| 5.196005E 00 | 0.0 | 1.166000E-01 |
| 5.247223E 00 | 0.0 | 1.166000E-01 |
| 5.298873E 00 | 0.0 | 1.166000E-01 |
| 5.350962E 00 | 0.0 | 1.166000E-01 |

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|---|---|---|
| 5.403499E 00 | 0.0 | 1.166000E-01 |
| 5.456491E 00 | 0.0 | 1.166000E-01 |
| 5.509947E 00 | 0.0 | 1.166000E-01 |
| 5.563875E 00 | 0.0 | 1.166000E-01 |
| 5.618285E 00 | 0.0 | 1.166000E-01 |
| 5.673186E 00 | 0.0 | 1.166000E-01 |
| 5.728588E 00 | 0.0 | 1.166000E-01 |
| 5.784498E 00 | 0.0 | 1.166000E-01 |
| 5.840928E 00 | 0.0 | 1.166000E-01 |
| 5.897887E 00 | 0.0 | 1.166000E-01 |
| 5.955386E 00 | 0.0 | 1.166000E-01 |
| 6.013434E 00 | 0.0 | 1.166000E-01 |
| 6.072043E 00 | 0.0 | 1.166000E-01 |
| 6.131224E 00 | 0.0 | 1.166000E-01 |
| 6.190987E 00 | 0.0 | 1.166000E-01 |
| 6.251345E 00 | 0.0 | 1.166000E-01 |
| 6.312307E 00 | 0.0 | 1.166000E-01 |
| 6.373889E 00 | 0.0 | 1.166000E-01 |
| 6.436101E 00 | 0.0 | 1.166000E-01 |
| 6.498956E 00 | 0.0 | 1.166000E-01 |
| 6.562467E 00 | 0.0 | 1.166000E-01 |
| 6.626647E 00 | 0.0 | 1.166000E-01 |
| 6.691510E 00 | 0.0 | 1.166000E-01 |
| 6.757072E 00 | 0.0 | 1.166000E-01 |
| 6.823345E 00 | 0.0 | 1.166000E-01 |
| 6.890345E 00 | 0.0 | 1.166000E-01 |
| 6.958087E 00 | 0.0 | 1.166000E-01 |
| 7.026586E 00 | 0.0 | 1.166000E-01 |
| 7.095858E 00 | 0.0 | 1.166000E-01 |
| 7.165919E 00 | 0.0 | 1.166000E-01 |
| 7.236790E 00 | 0.0 | 1.166000E-01 |
| 7.308482E 00 | 0.0 | 1.166000E-01 |
| 7.381019E 00 | 0.0 | 1.166000E-01 |
| 7.454415E 00 | 0.0 | 1.166000E-01 |
| 7.528691E 00 | 0.0 | 1.166000E-01 |
| 7.603867E 00 | 0.0 | 1.166000E-01 |
| 7.679960E 00 | 0.0 | 1.166000E-01 |
| 7.756994E 00 | 0.0 | 1.166000E-01 |
| 7.834990E 00 | 0.0 | 1.166000E-01 |
| 7.913967E 00 | 0.0 | 1.166000E-01 |
| 7.993950E 00 | 0.0 | 1.166000E-01 |
| 8.074961E 00 | 0.0 | 1.166000E-01 |
| 8.157023E 00 | 0.0 | 1.166000E-01 |
| 8.240164E 00 | 0.0 | 1.166000E-01 |
| 8.324406E 00 | 0.0 | 1.166000E-01 |
| 8.409776E 00 | 0.0 | 1.166000E-01 |
| 8.496301E 00 | 0.0 | 1.166000E-01 |
| 8.584008E 00 | 0.0 | 1.166000E-01 |
| 8.672928E 00 | 0.0 | 1.166000E-01 |
| 8.763088E 00 | 0.0 | 1.166000E-01 |
| 8.854520E 00 | 0.0 | 1.166000E-01 |
| 8.947254E 00 | 0.0 | 1.166000E-01 |
| 9.041325E 00 | 0.0 | 1.166000E-01 |
| 9.136765E 00 | 0.0 | 1.166000E-01 |
| 9.233607E 00 | 0.0 | 1.166000E-01 |
| 9.331889E 00 | 0.0 | 1.166000E-01 |
| 9.431649E 00 | 0.0 | 1.166000E-01 |
| 9.532924E 00 | 0.0 | 1.166000E-01 |
| 9.635753E 00 | 0.0 | 1.166000E-01 |
| 9.740177E 00 | 0.0 | 1.166000E-01 |
| 9.846241E 00 | 0.0 | 1.166000E-01 |
| 9.953984E 00 | 0.0 | 1.166000E-01 |
| 1.006346E 01 | 0.0 | 1.166000E-01 |
| 1.017471E 01 | 0.0 | 1.166000E-01 |
| 1.028778E 01 | 0.0 | 1.166000E-01 |
| 1.040272E 01 | 0.0 | 1.166000E-01 |
| 1.051959E 01 | 0.0 | 1.166000E-01 |
| 1.063845E 01 | 0.0 | 1.166000E-01 |
| 1.075934E 01 | 0.0 | 1.166000E-01 |
| 1.088233E 01 | 0.0 | 1.166000E-01 |
| 1.100747E 01 | 0.0 | 1.166000E-01 |
| 1.113484E 01 | 0.0 | 1.166000E-01 |
| 1.126449E 01 | 0.0 | 1.166000E-01 |
| 1.139650E 01 | 0.0 | 1.166000E-01 |
| 1.153093E 01 | 0.0 | 1.166000E-01 |

| | | |
|---|---|---|
| 1.166787E 01 | 0.0 | 1.166000E-01 |
| 1.180738E 01 | 0.0 | 1.166000E-01 |
| 1.194955E 01 | 0.0 | 1.166000E-01 |
| 1.209446E 01 | 0.0 | 1.166000E-01 |
| 1.224220E 01 | 0.0 | 1.166000E-01 |
| 1.239286E 01 | 0.0 | 1.166000E-01 |
| 1.254653E 01 | 0.0 | 1.166000E-01 |
| 1.270331E 01 | 0.0 | 1.166000E-01 |
| 1.286331E 01 | 0.0 | 1.166000E-01 |
| 1.302663E 01 | 0.0 | 1.166000E-01 |
| 1.319339E 01 | 0.0 | 1.166000E-01 |
| 1.336370E 01 | 0.0 | 1.166000E-01 |
| 1.353769E 01 | 0.0 | 1.166000E-01 |
| 1.371548E 01 | 0.0 | 1.166000E-01 |
| 1.389721E 01 | 0.0 | 1.166000E-01 |
| 1.408302E 01 | 0.0 | 1.166000E-01 |
| 1.427307E 01 | 0.0 | 1.166000E-01 |
| 1.446749E 01 | 0.0 | 1.166000E-01 |
| 1.466647E 01 | 0.0 | 1.166000E-01 |
| 1.487016E 01 | 0.0 | 1.166000E-01 |
| 1.507875E 01 | 0.0 | 1.166000E-01 |
| 1.529243E 01 | 0.0 | 1.166000E-01 |
| 1.551140E 01 | 0.0 | 1.166000E-01 |
| 1.573586E 01 | 0.0 | 1.166000E-01 |
| 1.596604E 01 | 0.0 | 1.166000E-01 |
| 1.620216E 01 | 0.0 | 1.166000E-01 |
| 1.644449E 01 | 0.0 | 1.166000E-01 |
| 1.669325E 01 | 0.0 | 1.166000E-01 |
| 1.694875E 01 | 0.0 | 1.166000E-01 |
| 1.721127E 01 | 0.0 | 1.166000E-01 |
| 1.748111E 01 | 0.0 | 1.166000E-01 |
| 1.775859E 01 | 0.0 | 1.166000E-01 |
| 1.804407E 01 | 0.0 | 1.166000E-01 |
| 1.833788E 01 | 0.0 | 1.166000E-01 |
| 1.864044E 01 | 0.0 | 1.166000E-01 |
| 1.895215E 01 | 0.0 | 1.166000E-01 |
| 1.927344E 01 | 0.0 | 1.166000E-01 |
| 1.960478E 01 | 0.0 | 1.166000E-01 |
| 1.994667E 01 | 0.0 | 1.166000E-01 |
| 2.029964E 01 | 0.0 | 1.166000E-01 |
| 2.066425E 01 | 0.0 | 1.166000E-01 |
| 2.104109E 01 | 0.0 | 1.166000E-01 |
| 2.143082E 01 | 0.0 | 1.166000E-01 |
| 2.183414E 01 | 0.0 | 1.166000E-01 |
| 2.225177E 01 | 0.0 | 1.166000E-01 |
| 2.268454E 01 | 0.0 | 1.166000E-01 |
| 2.313326E 01 | 0.0 | 1.166000E-01 |
| 2.359889E 01 | 0.0 | 1.166000E-01 |
| 2.408243E 01 | 0.0 | 1.166000E-01 |
| 2.458493E 01 | 0.0 | 1.166000E-01 |
| 2.510757E 01 | 0.0 | 1.166000E-01 |
| 2.565161E 01 | 0.0 | 1.166000E-01 |
| 2.621843E 01 | 0.0 | 1.166000E-01 |
| 2.680949E 01 | 0.0 | 1.166000E-01 |
| 2.742644E 01 | 0.0 | 1.166000E-01 |
| 2.807103E 01 | 0.0 | 1.166000E-01 |
| 2.874519E 01 | 0.0 | 1.166000E-01 |
| 2.945105E 01 | 0.0 | 1.166000E-01 |
| 3.019095E 01 | 0.0 | 1.166000E-01 |
| 3.096741E 01 | 0.0 | 1.166000E-01 |
| 3.178326E 01 | 0.0 | 1.166000E-01 |
| 3.264165E 01 | 0.0 | 1.166000E-01 |
| 3.354601E 01 | 0.0 | 1.166000E-01 |
| 3.450018E 01 | 0.0 | 1.166000E-01 |
| 3.550845E 01 | 0.0 | 1.166000E-01 |
| 3.657561E 01 | 0.0 | 1.166000E-01 |
| 3.770702E 01 | 0.0 | 1.166000E-01 |
| 3.890871E 01 | 0.0 | 1.166000E-01 |
| 4.018752E 01 | 0.0 | 1.166000E-01 |
| 4.155119E 01 | 0.0 | 1.166000E-01 |
| 4.300851E 01 | 0.0 | 1.166000E-01 |
| 4.456956E 01 | 0.0 | 1.166000E-01 |
| 4.624590E 01 | 0.0 | 1.166000E-01 |
| 4.805089E 01 | 0.0 | 1.166000E-01 |
| 5.000000E 01 | 0.0 | 1.166000E-01$ |

## Unit 5 Input Data for the $31^{\circ}$ Hyperboloid Binary-Gas Sample Case

```
FREE FLIGHT 31DEG HYPER  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS
 &INPUT
 ALT=245000.0,
 BRAD=2.360833,
 DS=0.2,
 DSMAX=3.0,
 HANGLE=31.0,
 RINF=.867251028D-07,
 SEND=43.0,
 TB=2460.0,
 THINI=-1.,
 TINF=361.48,
 UINF=25100.0,
 XKETA=1.05,
 IEND=6,
 IGECM=1,
 KEND=1,
 NAN=1,
 NDATA=1,
 NS=2,
 NSI=2,
 NTSH=20,
 &END
           .23456                                      .76544
           .23456                                      .76544
```

## Unit 5 Input Data for the 31° Hyperboloid
## 7-Species Sample Case

```
FREE FLIGHT 31DEG HYPER  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES
 &INPUT
 ALT=245000.0,
 BRAD=2.360833,
 DS=0.2,
 DSMAX=3.0,
 HANGLE=31.0,
 RINF=.867251028D-07,
 SEND=43.0,
 TB=2460.0,
 THINI=-1.,
 TINF=361.48,
 UINF=25100.0,
 XKETA=1.05,
 IEND=6,
 IGEOM=1,
 KEND=1,
 NAN=1,
 NDATA=1,
 NS=6,
 NSI=6,
 NTSH=20,
 &END
           .23456                                   .76544
           .23456                                   .76544
```

<u>Listing of the Unit 6 Output Data for the 140B Orbiter Binary-Gas Sample Case</u>

```
                     FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS


&INPUT
ALT=  245000.0000000000     ,BRAD=  2.360833000000000     ,CAINF= 0.0                          ,CAT=  1.000000000000000     ,CAW=
 0.0                        ,CCFAC= 0.0                   ,CONVRG= 0.9999997913837432D-02,DS= 0.2000000000000000     ,DSMAX=
  1.000000000000000         ,HANGLE=  10.00000000000000     ,PRNTCI= 0.0                   ,RINF= 0.8672510279999999D-07,SEND=
  35.00000000000000         ,SIGM= 0.6999999880790710     ,SITEST= 0.9999999019782990D-04,SMALLT= 0.9999994290410541D-06,SSFAC=
 -1.000000000000000         ,SWFAC= -1.000000000000000     ,TB=  2460.000000000000      ,THINI= -1.000000000000000     ,TINF=
  361.4800000000000         ,UFAC= 0.5000000000000000     ,UINF=  25100.00000000000      ,WVFAC= 0.2500000000000000     ,XKETA=
  1.050000000000000         ,XLE=  1.399999618530273     ,XNSO= 0.1165999770164490     ,IE=            51,IEND=          6,IGEOM=        3,
IUN=          19,JFAC=           1,KEND=           1,KPLTTP=           0,KTWAL=           0,NAN=          -2,NDATA=           1,NITMAX=
      9999,NITMIN=           3,NITMNI=           3,NS=           2,NSI=           2,NSPRF=           0,NTSH=          20,NTTWA=
         5
&END


LOG  RATES MATCH 6 SPECIE BLOTTNER-SANDIA

NR               REACTION                   CRO        EXP(CRO)       CR1       CR2       DRO        EXP(DRO)          DR1      DR2
 1   O2    O2       =O     O     O2      44.9274640  0.3249D 20     59400.0    -1.0     37.8379411  0.2709D 17         0.0     -0.5
 2   O2    O        =O     O     O       45.9491153  0.9025D 20     59400.0    -1.0     38.8595923  0.7525D 17         0.0     -0.5

                   ALPHSB( 2, 2)
NR    ALSUB        NR       O     O2
 1     1.0          1       0.    2.
 2     1.0          2       1.    1.

                   BETASB( 2, 2)
NR   BETSUB        NR      O     O2
 1     2.0          1      2.    1.
 2     2.0          2      3.    0.

   GAMMPL( 2, 2)
 1     2.     0.
 2     2.     0.

   GAMMMI( 2, 2)
 1     0.     1.
 2     0.     1.

VSREF =  0.19332065D-04

  VSINF =  0.46451309D-06
```

```
K =1, I =  1, S =  0.0  , NITER =  1, DIFI = 3.900D 01 2.544D 00 0.0       1.000D 00
K =1, I =  1, S =  0.0  , NITER =  2, DIFI = 4.802D-01 1.944D 00 4.395D-01 1.073D 04
K =1, I =  1, S =  0.0  , NITER =  3, DIFI = 3.722D-01 2.615D-01 2.169D-01 3.553D 01
K =1, I =  1, S =  0.0  , NITER =  4, DIFI = 9.725D-02 3.613D-01 7.576D-02 1.696D 01
K =1, I =  1, S =  0.0  , NITER =  5, DIFI = 1.280D-01 3.756D-01 3.625D-01 4.820D 01
K =1, I =  1, S =  0.0  , NITER =  6, DIFI = 8.850D-02 2.793D-01 3.368D-01 5.120D 00
K =1, I =  1, S =  0.0  , NITER =  7, DIFI = 5.875D-02 5.058D-02 1.091D-01 1.686D 00
K =1, I =  1, S =  0.0  , NITER =  8, DIFI = 5.028D-02 5.279D-02 4.782D-02 1.537D 00
K =1, I =  1, S =  0.0  , NITER =  9, DIFI = 6.379D-02 4.067D-02 8.176D-02 1.463D 00
K =1, I =  1, S =  0.0  , NITER = 10, DIFI = 5.112D-02 2.960D-02 6.005D-02 1.075D 00
K =1, I =  1, S =  0.0  , NITER = 11, DIFI = 4.192D-02 2.444D-02 4.478D-02 7.984D-01
K =1, I =  1, S =  0.0  , NITER = 12, DIFI = 3.646D-02 2.144D-02 3.907D-02 6.252D-01
K =1, I =  1, S =  0.0  , NITER = 13, DIFI = 3.159D-02 1.835D-02 3.485D-02 4.929D-01
K =1, I =  1, S =  0.0  , NITER = 14, DIFI = 2.693D-02 1.538D-02 3.009D-02 3.877D-01
K =1, I =  1, S =  0.0  , NITER = 15, DIFI = 2.280D-02 1.286D-02 2.554D-02 3.071D-01
K =1, I =  1, S =  0.0  , NITER = 16, DIFI = 1.928D-02 1.077D-02 2.165D-02 2.458D-01
K =1, I =  1, S =  0.0  , NITER = 17, DIFI = 1.627D-02 9.005D-03 1.835D-02 1.979D-01
K =1, I =  1, S =  0.0  , NITER = 18, DIFI = 1.370D-02 7.512D-03 1.551D-02 1.600D-01
K =1, I =  1, S =  0.0  , NITER = 19, DIFI = 1.150D-02 6.252D-03 1.305D-02 1.297D-01
K =1, I =  1, S =  0.0  , NITER = 20, DIFI = 9.628D-03 5.197D-03 1.096D-02 1.057D-01
K =1, I =  1, S =  0.0  , NITER = 21, DIFI = 8.052D-03 4.316D-03 9.180D-03 8.646D-02
K =1, I =  1, S =  0.0  , NITER = 22, DIFI = 6.665D-03 3.580D-03 7.678D-03 7.086D-02
K =1, I =  1, S =  0.0  , NITER = 23, DIFI = 5.142D-03 2.716D-03 5.377D-03 5.106D-02
K =1, I =  1, S =  0.0  , NITER = 24, DIFI = 4.770D-03 2.645D-03 4.939D-03 4.738D-02
K =1, I =  1, S =  0.0  , NITER = 25, DIFI = 4.136D-03 2.311D-03 4.616D-03 4.233D-02
K =1, I =  1, S =  0.0  , NITER = 26, DIFI = 3.444D-03 1.902D-03 4.017D-03 3.590D-02
K =1, I =  1, S =  0.0  , NITER = 27, DIFI = 2.842D-03 1.548D-03 3.393D-03 2.982D-02
K =1, I =  1, S =  0.0  , NITER = 28, DIFI = 2.350D-03 1.259D-03 2.843D-03 2.458D-02
K =1, I =  1, S =  0.0  , NITER = 29, DIFI = 1.946D-03 1.019D-03 2.369D-03 2.013D-02
K =1, I =  1, S =  0.0  , NITER = 30, DIFI = 1.608D-03 8.193D-04 1.963D-03 1.636D-02
K =1, I =  1, S =  0.0  , NITER = 31, DIFI = 1.324D-03 6.552D-04 1.618D-03 1.323D-02
K =1, I =  1, S =  0.0  , NITER = 32, DIFI = 1.085D-03 5.221D-04 1.327D-03 1.067D-02
K =1, I =  1, S =  0.0  , NITER = 33, DIFI = 8.858D-04 4.152D-04 1.084D-03 8.580D-03

   UINF        PINF          TINF          CAINF        TB           BRAD          PR          LE          YSH           ALT
 C.251D 05   0.48676D-01   0.36148D 03   C.0         0.2460D 04   0.2361D 01   0.70D 00   0.14D 01   0.4354D-01   0.245D 06

 THIN SHOCK LAYER  NO WALL SLIP  NC SHOCK SLIP     CAT WALL NC STEPS IN Y= 51 NO STFPS IN S=  6 S STEP SIZE=0.200

 TW/TS    EPS      REYINF       REYSH        TREF         UREF        RREF         PREF       ITER
0.0638   0.0613   0.1106D 05   0.6611D 03   0.1147D 06   0.2510D 05   0.8673D-07   0.5464D 02   1


 ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS             ****


    S          X            R            YSH        YSHP          XSH          RSH      NO ITER    NITTOT    NTOT    I    K
  0.0        0.0          0.0         0.043541     0.0        -0.043541     0.0         33         33        33    1    1

    DS         CF          HEAT         STAN        CDF          CDP          CDTOT       PWALL      TWALL          PW/PO
  0.200000   0.0         0.043937     0.091651     0.0        1.751458     1.751458    0.875729 2460.000000    1.000000

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.0       0.000000      0.0         1.444297     1.444297    1.000000    0.977685

      USH          VSH          TSH          RSH          PSH         VPG
     0.0        -0.105425     0.331071     9.409600     0.880391     0.0
          0.0    -2646.17     37963.65
                              21090.92
```

| N | Y/YSH | U/USH | V/VSH | T/TSH | R/RSH | P/PSH(APPR) | P/PSH | CA | CAEQ | XM | T DEG R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.064799 | 15.350654 | 0.994705 | 1.064659 | 0.0 | 0.000002 | 0.0 | 2460.00 |
| 2 | 0.004777 | 0.035621 | 0.000088 | 0.080200 | 11.723069 | 0.994705 | 1.064659 | 0.058053 | 0.000164 | 0.000102 | 3044.68 |
| 3 | 0.009792 | 0.068436 | 0.000398 | 0.093896 | 9.530513 | 0.994706 | 1.064660 | 0.111651 | 0.002262 | 0.000421 | 3564.62 |
| 4 | 0.015059 | 0.099311 | 0.000961 | 0.106465 | 8.039284 | 0.994708 | 1.064662 | 0.162270 | 0.013942 | 0.000938 | 4041.81 |
| 5 | 0.020586 | 0.128733 | 0.001804 | 0.118217 | 6.950163 | 0.994712 | 1.064665 | 0.210750 | 0.053291 | 0.001644 | 4487.97 |
| 6 | 0.026394 | 0.157008 | 0.002956 | 0.129342 | 6.115703 | 0.994718 | 1.064668 | 0.257606 | 0.146813 | 0.002531 | 4910.28 |
| 7 | 0.032491 | 0.184334 | 0.004443 | 0.139960 | 5.454101 | 0.994725 | 1.064672 | 0.303172 | 0.312377 | 0.003597 | 5313.38 |
| 8 | 0.038892 | 0.210848 | 0.006295 | 0.150153 | 4.915986 | 0.994734 | 1.064675 | 0.347667 | 0.529330 | 0.004840 | 5700.36 |
| 9 | 0.045614 | 0.236643 | 0.008540 | 0.159977 | 4.469627 | 0.994746 | 1.064677 | 0.391234 | 0.732473 | 0.006259 | 6073.30 |
| 10 | 0.052671 | 0.261784 | 0.011207 | 0.169468 | 4.093570 | 0.994759 | 1.064678 | 0.433968 | 0.867856 | 0.007856 | 6433.63 |
| 11 | 0.060081 | 0.286314 | 0.014326 | 0.178657 | 3.772693 | 0.994775 | 1.064675 | 0.475917 | 0.937851 | 0.009633 | 6782.46 |
| 12 | 0.067862 | 0.310261 | 0.017927 | 0.187567 | 3.495974 | 0.994793 | 1.064668 | 0.517092 | 0.970129 | 0.011593 | 7120.73 |
| 13 | 0.076032 | 0.333641 | 0.022040 | 0.196226 | 3.255124 | 0.994814 | 1.064656 | 0.557465 | 0.984880 | 0.013737 | 7449.46 |
| 14 | 0.084610 | 0.356459 | 0.026697 | 0.204665 | 3.043756 | 0.994837 | 1.064637 | 0.596971 | 0.991893 | 0.016070 | 7769.83 |
| 15 | 0.093617 | 0.378715 | 0.031931 | 0.212921 | 2.856861 | 0.994863 | 1.064609 | 0.635512 | 0.995415 | 0.018594 | 8083.25 |
| 16 | 0.103075 | 0.400401 | 0.037776 | 0.221037 | 2.690448 | 0.994892 | 1.064570 | 0.672951 | 0.997282 | 0.021318 | 8391.39 |
| 17 | 0.113006 | 0.421506 | 0.044269 | 0.229065 | 2.541303 | 0.994923 | 1.064519 | 0.709125 | 0.998324 | 0.024246 | 8696.14 |
| 18 | 0.123433 | 0.442017 | 0.051448 | 0.237060 | 2.406812 | 0.994958 | 1.064453 | 0.743841 | 0.998932 | 0.027384 | 8999.66 |
| 19 | 0.134381 | 0.461919 | 0.059352 | 0.245081 | 2.284858 | 0.994995 | 1.064369 | 0.776887 | 0.999300 | 0.030743 | 9304.17 |
| 20 | 0.145877 | 0.481201 | 0.068024 | 0.253185 | 2.173736 | 0.995036 | 1.064264 | 0.808039 | 0.999531 | 0.034330 | 9611.83 |
| 21 | 0.157947 | 0.499853 | 0.077503 | 0.261423 | 2.072092 | 0.995081 | 1.064135 | 0.837076 | 0.999680 | 0.038158 | 9924.57 |
| 22 | 0.170621 | 0.517873 | 0.087828 | 0.269833 | 1.978870 | 0.995129 | 1.063978 | 0.863787 | 0.999778 | 0.042231 | 10243.86 |
| 23 | 0.183929 | 0.535264 | 0.099032 | 0.278437 | 1.893275 | 0.995180 | 1.063789 | 0.887994 | 0.999844 | 0.046558 | 10570.48 |
| 24 | 0.197902 | 0.552039 | 0.111137 | 0.287229 | 1.814733 | 0.995235 | 1.063564 | 0.909559 | 0.999888 | 0.051145 | 10904.26 |
| 25 | 0.212574 | 0.568221 | 0.124156 | 0.296175 | 1.742855 | 0.995294 | 1.063300 | 0.928407 | 0.999919 | 0.055998 | 11243.89 |
| 26 | 0.227980 | 0.583843 | 0.138082 | 0.305207 | 1.677393 | 0.995356 | 1.062992 | 0.944532 | 0.999940 | 0.061118 | 11586.75 |
| 27 | 0.244155 | 0.598950 | 0.152891 | 0.314220 | 1.618194 | 0.995423 | 1.062639 | 0.958004 | 0.999955 | 0.066501 | 11928.94 |
| 28 | 0.261140 | 0.613597 | 0.168538 | 0.323083 | 1.565160 | 0.995494 | 1.062235 | 0.968973 | 0.999966 | 0.072142 | 12265.41 |
| 29 | 0.278974 | 0.627850 | 0.184961 | 0.331641 | 1.518198 | 0.995570 | 1.061781 | 0.977655 | 0.999973 | 0.078034 | 12590.29 |
| 30 | 0.297699 | 0.641786 | 0.202088 | 0.339729 | 1.477185 | 0.995651 | 1.061273 | 0.984321 | 0.999978 | 0.084168 | 12897.37 |
| 31 | 0.317361 | 0.655490 | 0.219841 | 0.347193 | 1.441940 | 0.995737 | 1.060711 | 0.989273 | 0.999982 | 0.090536 | 13180.73 |
| 32 | 0.338006 | 0.669053 | 0.238152 | 0.353901 | 1.412201 | 0.995829 | 1.060094 | 0.992819 | 0.999985 | 0.097136 | 13435.39 |
| 33 | 0.359683 | 0.682575 | 0.256970 | 0.359760 | 1.387618 | 0.995928 | 1.059418 | 0.995255 | 0.999987 | 0.103966 | 13657.81 |
| 34 | 0.382443 | 0.696158 | 0.276275 | 0.364726 | 1.367755 | 0.996035 | 1.058682 | 0.996841 | 0.999988 | 0.111040 | 13846.34 |
| 35 | 0.406342 | 0.709908 | 0.296085 | 0.368808 | 1.352100 | 0.996149 | 1.057881 | 0.997791 | 0.999989 | 0.118378 | 14001.29 |
| 36 | 0.431436 | 0.723930 | 0.316460 | 0.372066 | 1.340078 | 0.996273 | 1.057005 | 0.998271 | 0.999990 | 0.126013 | 14124.97 |
| 37 | 0.457785 | 0.738327 | 0.337506 | 0.374604 | 1.331071 | 0.996406 | 1.056046 | 0.998391 | 0.999990 | 0.133985 | 14221.32 |
| 38 | 0.485451 | 0.753196 | 0.359374 | 0.376562 | 1.324439 | 0.996551 | 1.054987 | 0.998208 | 0.999991 | 0.142350 | 14295.68 |
| 39 | 0.514500 | 0.768627 | 0.382257 | 0.378107 | 1.319534 | 0.996709 | 1.053809 | 0.997727 | 0.999991 | 0.151170 | 14354.34 |
| 40 | 0.545002 | 0.784699 | 0.406389 | 0.379424 | 1.315711 | 0.996881 | 1.052489 | 0.996897 | 0.999991 | 0.160520 | 14404.33 |
| 41 | 0.577029 | 0.801479 | 0.432048 | 0.380719 | 1.312324 | 0.997068 | 1.050993 | 0.995595 | 0.999992 | 0.170488 | 14453.50 |
| 42 | 0.610657 | 0.819019 | 0.459572 | 0.382231 | 1.308697 | 0.997272 | 1.049282 | 0.993599 | 0.999992 | 0.181176 | 14510.89 |
| 43 | 0.645966 | 0.837357 | 0.489384 | 0.384262 | 1.304062 | 0.997495 | 1.047303 | 0.990537 | 0.999992 | 0.192714 | 14587.99 |
| 44 | 0.683041 | 0.856509 | 0.522067 | 0.387241 | 1.297431 | 0.997739 | 1.044980 | 0.985780 | 0.999993 | 0.205275 | 14701.08 |
| 45 | 0.721970 | 0.876466 | 0.558495 | 0.391851 | 1.287380 | 0.998005 | 1.042201 | 0.978240 | 0.999993 | 0.219108 | 14876.09 |
| 46 | 0.762845 | 0.897171 | 0.600120 | 0.399294 | 1.271638 | 0.998293 | 1.038778 | 0.965931 | 0.999994 | 0.234625 | 15158.65 |
| 47 | 0.805764 | 0.918500 | 0.649600 | 0.411920 | 1.246322 | 0.998606 | 1.034361 | 0.944943 | 0.999995 | 0.252582 | 15637.99 |
| 48 | 0.850829 | 0.940190 | 0.712337 | 0.434937 | 1.204448 | 0.998939 | 1.028224 | 0.906630 | 0.999997 | 0.274480 | 16511.80 |
| 49 | 0.898148 | 0.961722 | 0.800273 | 0.482026 | 1.133606 | 0.999288 | 1.018843 | 0.828441 | 0.999998 | 0.303756 | 18299.47 |
| 50 | 0.947832 | 0.982097 | 0.935987 | 0.598451 | 1.020715 | 0.999640 | 1.007360 | 0.636124 | 0.999999 | 0.349042 | 22719.37 |
| 51 | 1.000000 | 1.000000 | 1.003332 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 0.0 | 1.000000 | 0.360816 | 37963.65 |

```
K =1, I =  2. S =  0.200, NITER =  1, DIFI = 8.794D-01 6.982D-03 1.600D-03 3.006D-02
K =1, I =  2, S =  0.200, NITER =  2, DIFI = 2.570D-01 6.164D-02 6.792D-02 3.987D-01
K =1, I =  2, S =  0.200, NITER =  3, DIFI = 4.065D-02 4.281D-02 1.572D-02 5.424D-02
K =1, I =  2, S =  0.200, NITER =  4, DIFI = 2.154D-02 1.554D-02 1.051D-02 6.452D-02
K =1, I =  2, S =  0.200, NITER =  5, DIFI = 9.136D-03 2.956D-03 4.462D-03 3.101D-02
K =1, I =  2, S =  0.200, NITER =  6, DIFI = 2.133D-03 1.013D-03 1.018D-03 4.739D-03


  ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS            ****


      S          X          R          YSH        YSHP        XSH        RSH     NO ITER    NITTOT    NTOT    I     K
   0.200000   0.025602   0.197806   0.054988   0.114469  -0.027687   0.211368     6          39        39     2     1

      DS         CF        HEAT        STAN        CDF        CDP       CDTOT      PWALL       TWALL        PW/PO
   0.200000   0.010448   0.034649   0.072278   0.002606   1.707200   1.709805   0.871149 2460.000000   0.994770

  YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
   0.000000   0.000000   0.114469   1.425378   1.425378   0.890295   0.652402

        USH         VSH          TSH          RSH          PSH         VPG
      0.135534   -0.105267    0.330158     9.411532     0.878142     0.0
       3401.91     -2642.21    37858.90
                               21032.73


K =1, I =  3, S =  0.400, NITER =  1, DIFI = 3.602D-01 1.241D-01 3.697D-02 1.790D-01
K =1, I =  3, S =  0.400, NITER =  2, DIFI = 5.619D-01 3.323D-02 8.844D-02 5.757D-01
K =1, I =  3, S =  0.400, NITER =  3, DIFI = 3.217D-02 4.539D-02 3.013D-02 3.683D-01
K =1, I =  3, S =  0.400, NITER =  4, DIFI = 6.342D-03 8.854D-03 4.399D-03 1.037D-02
K =1, I =  3, S =  0.400, NITER =  5, DIFI = 2.035D-03 4.739D-04 1.997D-03 5.523D-03


  ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS            ****


      S          X          R          YSH        YSHP        XSH        RSH     NO ITER    NITTOT    NTOT    I     K
   0.400000   0.082326   0.389258   0.078699   0.122640   0.007402   0.413337     5          44        44     3     1

      DS         CF        HEAT        STAN        CDF        CDP       CDTOT      PWALL       TWALL        PW/PO
   0.200000   0.015368   0.026732   0.055763   0.003762   1.670689   1.674451   0.806482 2460.000000   0.920926

  YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
   0.000000   0.000000   0.122640   1.210361   1.210361   0.534291   0.459847

        USH         VSH          TSH          RSH          PSH         VPG
      0.248794   -0.101984    0.311164     9.439457     0.829947     0.0
       6244.73     -2559.80    35680.91
                               19822.74
```

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K =1, I =   4, S =   0.600, NITER =   1, DIFI = 1.714D-01 1.488D-01 1.192D-01 6.824D 00
K =1, I =   4, S =   0.600, NITER =   2, DIFI = 2.419D-01 7.362D-02 8.662D-02 8.276D-01
K =1, I =   4, S =   0.600, NITER =   3, DIFI = 4.620D-02 3.360D-02 2.573D-02 2.228D-01
K =1, I =   4, S =   0.600, NITER =   4, DIFI = 6.560D-03 1.078D-02 8.346D-03 6.401D-02
K =1, I =   4, S =   0.600, NITER =   5, DIFI = 5.032D-04 1.579D-03 3.338D-03 2.963D-02
K =1, I =   4, S =   0.600, NITER =   6, DIFI = 7.847D-04 4.359D-04 3.215D-04 6.574D-03


   ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS              ****


     S           X          R          YSH        YSHP        XSH        RSH     NO ITER    NITTOT    NTOT   I    K
  0.600000    0.153125   0.576231   0.088778   -0.021844   0.071465   0.611063    6          50        50    4    1

     DS          CF        HEAT        STAN        CDF         CDP       CDTOT       PWALL      TWALL        PW/PO
  0.200000    0.020365   0.024787   0.051705    0.005592   1.578926   1.584518   0.714939 2460.000000   0.816393

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
   0.000000    0.000000  -0.021844   1.114267    1.114267    0.398202    0.354594

        USH         VSH          TSH          RSH          PSH          VPG
      0.396758   -0.096824    0.281341     9.467410     0.752737     0.0
       9958.63    -2430.28    32261.11
                              17922.85


K =1, I =   5, S =   0.800, NITER =   1, DIFI = 6.070D-02 9.228D-02 8.195D-02 1.811D 00
K =1, I =   5, S =   0.800, NITER =   2, DIFI = 4.188D-02 1.895D-02 2.770D-02 6.622D-01
K =1, I =   5, S =   0.800, NITER =   3, DIFI = 8.250D-03 6.639D-03 5.127D-03 3.967D-02
K =1, I =   5, S =   0.800, NITER =   4, DIFI = 2.078D-03 1.051D-03 3.184D-03 3.860D-02
K =1, I =   5, S =   0.800, NITER =   5, DIFI = 1.527D-04 2.603D-04 1.767D-04 6.526D-03


   ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS              ****


     S           X          R          YSH        YSHP        XSH        RSH     NO ITER    NITTOT    NTOT   I    K
  0.800000    0.241411   0.755630   0.090974    0.043798   0.161130   0.798420    5          55        55    5    1

     DS          CF        HEAT        STAN        CDF         CDP       CDTOT       PWALL      TWALL        PW/PO
  0.200000    0.021500   0.022818   0.047597    0.007541   1.486205   1.493747   0.647636 2460.000000   0.739540

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  -0.000000    0.000000    0.043798   1.033441    1.033441    0.309931    0.278565

        USH         VSH          TSH          RSH          PSH          VPG
      0.476350   -0.092866    0.258557     9.457766     0.691116     0.0
      11956.40    -2330.94    29648.52
                              16471.41
```

```
K =1, I =  6, S =  1.000, NITER =  1, DIFI = 6.021D-02 9.231D-02 1.695D-01 4.716D 00
K =1, I =  6, S =  1.000, NITER =  2, DIFI = 3.743D-02 1.860D-02 4.096D-02 2.068D-01
K =1, I =  6, S =  1.000, NITER =  3, DIFI = 1.595D-02 1.215D-02 2.216D-02 1.831D-01
K =1, I =  6, S =  1.000, NITER =  4, DIFI = 2.516D-03 2.946D-03 3.298D-03 1.299D-02
K =1, I =  6, S =  1.000, NITER =  5, DIFI = 2.186D-03 1.043D-03 3.069D-03 1.765D-02
K =1, I =  6, S =  1.000, NITER =  6, DIFI = 1.597D-04 2.706D-04 9.332D-05 1.541D-03
```

**** FREE FLIGHT 140B ORBITER ALT=245K FT. M=26.9 ALPHA=30, BINARY-GAS ****

| S | X | R | YSH | YSHP | XSH | RSH | NO ITER | NITTOT | NTOT | I | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.000000 | 0.341452 | 0.928623 | 0.098907 | 0.035535 | 0.257841 | 0.981461 | 6 | 61 | 61 | 6 | 1 |

| DS | CF | HEAT | STAN | CDF | CDP | CDTOT | PWALL | TWALL | PW/PO |
|---|---|---|---|---|---|---|---|---|---|
| 0.200000 | 0.021800 | 0.020432 | 0.042621 | 0.009274 | 1.397999 | 1.407273 | 0.586682 | 2460.000000 | 0.669935 |

| YSHP ( S | YSHP ( S+DS/2 | NEW YSHP | ALPHA(S+DS/2 | PHI(S+DS/2 | KAPPA(S | KAPPA(S+DS/2 |
|---|---|---|---|---|---|---|
| 0.000000 | 0.000000 | 0.035535 | 0.971723 | 0.971723 | 0.245798 | 0.219850 |

| USH | VSH | TSH | RSH | PSH | VPG |
|---|---|---|---|---|---|
| 0.537871 | -0.089376 | 0.238586 | 9.425669 | 0.635587 | 0.0 |
| 13500.57 | -2243.34 | 27358.40 | | | |
| | | 15199.12 | | | |

| N | Y/YSH | U/USH | V/VSH | T/TSH | R/RSH | P/PSH(APPR) | P/PSH | CA | CAEQ | XM | T DEG R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.090044 | 10.267920 | 0.923055 | 1.001704 | 0.0 | 0.000003 | 0.0 | 2463.45 |
| 2 | 0.004777 | 0.038203 | 0.000064 | 0.112695 | 7.726415 | 0.923058 | 1.001707 | 0.060766 | 0.000249 | 0.225582 | 3083.16 |
| 3 | 0.009792 | 0.073332 | 0.000290 | 0.131926 | 6.264774 | 0.923070 | 1.001719 | 0.116635 | 0.003323 | 0.392782 | 3609.29 |
| 4 | 0.015059 | 0.106442 | 0.000704 | 0.148902 | 5.296664 | 0.923095 | 1.001744 | 0.169391 | 0.018828 | 0.526678 | 4073.71 |
| 5 | 0.020588 | 0.138091 | 0.001327 | 0.164228 | 4.600746 | 0.923138 | 1.001786 | 0.219994 | 0.065467 | 0.638621 | 4493.03 |
| 6 | 0.026394 | 0.168605 | 0.002185 | 0.178272 | 4.072950 | 0.923200 | 1.001846 | 0.269009 | 0.164526 | 0.734689 | 4877.25 |
| 7 | 0.032491 | 0.198184 | 0.003301 | 0.191271 | 3.657324 | 0.923283 | 1.001925 | 0.316786 | 0.323319 | 0.818604 | 5232.87 |
| 8 | 0.038892 | 0.226951 | 0.004702 | 0.203387 | 3.320843 | 0.923388 | 1.002026 | 0.363538 | 0.518159 | 0.892756 | 5564.34 |
| 9 | 0.045614 | 0.254976 | 0.006414 | 0.214738 | 3.042615 | 0.923518 | 1.002150 | 0.409392 | 0.700111 | 0.958919 | 5874.89 |
| 10 | 0.052671 | 0.282299 | 0.008465 | 0.225416 | 2.808680 | 0.923673 | 1.002296 | 0.454407 | 0.831198 | 1.018385 | 6167.02 |
| 11 | 0.060081 | 0.308929 | 0.010884 | 0.235498 | 2.609282 | 0.923857 | 1.002468 | 0.498591 | 0.908798 | 1.072045 | 6442.85 |
| 12 | 0.067862 | 0.334859 | 0.013701 | 0.245058 | 2.437350 | 0.924069 | 1.002665 | 0.541902 | 0.950272 | 1.120594 | 6704.39 |
| 13 | 0.076032 | 0.360067 | 0.016947 | 0.254168 | 2.287604 | 0.924312 | 1.002888 | 0.584253 | 0.971929 | 1.164633 | 6953.63 |
| 14 | 0.084610 | 0.384522 | 0.020654 | 0.262906 | 2.155999 | 0.924588 | 1.003138 | 0.625516 | 0.983476 | 1.204400 | 7192.70 |
| 15 | 0.093617 | 0.408183 | 0.024858 | 0.271355 | 2.039379 | 0.924898 | 1.003414 | 0.665525 | 0.989874 | 1.240207 | 7423.84 |
| 16 | 0.103075 | 0.431012 | 0.029596 | 0.279600 | 1.935253 | 0.925244 | 1.003718 | 0.704079 | 0.993574 | 1.272323 | 7649.41 |
| 17 | 0.113006 | 0.452966 | 0.034906 | 0.287728 | 1.841646 | 0.925626 | 1.004049 | 0.740952 | 0.995802 | 1.300995 | 7871.77 |
| 18 | 0.123433 | 0.474014 | 0.040829 | 0.295819 | 1.756998 | 0.926047 | 1.004407 | 0.775899 | 0.997191 | 1.326477 | 8093.15 |
| 19 | 0.134381 | 0.494129 | 0.047406 | 0.303946 | 1.680092 | 0.926508 | 1.004790 | 0.808671 | 0.998084 | 1.349174 | 8315.49 |
| 20 | 0.145877 | 0.513299 | 0.054679 | 0.312163 | 1.610001 | 0.927009 | 1.005198 | 0.839024 | 0.998672 | 1.369264 | 8540.28 |
| 21 | 0.157947 | 0.531531 | 0.062683 | 0.320499 | 1.546047 | 0.927551 | 1.005628 | 0.866737 | 0.999066 | 1.387096 | 8768.33 |
| 22 | 0.170621 | 0.548845 | 0.071452 | 0.328950 | 1.487766 | 0.928137 | 1.006080 | 0.891627 | 0.999334 | 1.403080 | 8999.54 |
| 23 | 0.183929 | 0.565284 | 0.081005 | 0.337473 | 1.434875 | 0.928766 | 1.006551 | 0.913567 | 0.999518 | 1.417684 | 9232.73 |
| 24 | 0.197902 | 0.580908 | 0.091351 | 0.345980 | 1.387241 | 0.929442 | 1.007041 | 0.932498 | 0.999645 | 1.431424 | 9465.46 |
| 25 | 0.212574 | 0.595797 | 0.102480 | 0.354335 | 1.344838 | 0.930166 | 1.007548 | 0.948446 | 0.999733 | 1.444929 | 9694.04 |
| 26 | 0.227980 | 0.610046 | 0.114365 | 0.362362 | 1.307702 | 0.930941 | 1.008072 | 0.961520 | 0.999794 | 1.458686 | 9913.65 |
| 27 | 0.244155 | 0.623763 | 0.126959 | 0.369857 | 1.275890 | 0.931770 | 1.008613 | 0.971917 | 0.999837 | 1.473224 | 10118.69 |
| 28 | 0.261140 | 0.637069 | 0.140203 | 0.376604 | 1.249434 | 0.932659 | 1.009174 | 0.979900 | 0.999867 | 1.489085 | 10303.27 |
| 29 | 0.278974 | 0.650089 | 0.154036 | 0.382405 | 1.228300 | 0.933613 | 1.009758 | 0.985784 | 0.999887 | 1.506754 | 10461.98 |
| 30 | 0.297699 | 0.662956 | 0.168402 | 0.387102 | 1.212362 | 0.934640 | 1.010368 | 0.989902 | 0.999901 | 1.526642 | 10590.50 |
| 31 | 0.317361 | 0.675801 | 0.183265 | 0.390603 | 1.201381 | 0.935747 | 1.011009 | 0.992579 | 0.999910 | 1.549069 | 10686.29 |
| 32 | 0.338006 | 0.688753 | 0.198621 | 0.392891 | 1.195006 | 0.936947 | 1.011686 | 0.994104 | 0.999915 | 1.574259 | 10748.88 |
| 33 | 0.359683 | 0.701936 | 0.214506 | 0.394028 | 1.192782 | 0.938250 | 1.012403 | 0.994710 | 0.999918 | 1.602341 | 10779.96 |
| 34 | 0.382443 | 0.715461 | 0.230996 | 0.394142 | 1.194173 | 0.939671 | 1.013166 | 0.994562 | 0.999918 | 1.633359 | 10783.11 |
| 35 | 0.406342 | 0.729423 | 0.248209 | 0.393416 | 1.198595 | 0.941224 | 1.013975 | 0.993754 | 0.999916 | 1.667287 | 10763.24 |
| 36 | 0.431436 | 0.743900 | 0.266293 | 0.392058 | 1.205451 | 0.942926 | 1.014833 | 0.992309 | 0.999913 | 1.704046 | 10726.08 |
| 37 | 0.457785 | 0.758948 | 0.285418 | 0.390283 | 1.214164 | 0.944798 | 1.015739 | 0.990180 | 0.999908 | 1.743527 | 10677.53 |
| 38 | 0.485451 | 0.774600 | 0.305770 | 0.388301 | 1.224206 | 0.946859 | 1.016690 | 0.987254 | 0.999903 | 1.785605 | 10623.30 |
| 39 | 0.514500 | 0.790865 | 0.327538 | 0.386308 | 1.235104 | 0.949132 | 1.017682 | 0.983353 | 0.999897 | 1.830152 | 10568.77 |
| 40 | 0.545002 | 0.807730 | 0.350921 | 0.384491 | 1.246422 | 0.951642 | 1.018706 | 0.978229 | 0.999891 | 1.877033 | 10519.07 |
| 41 | 0.577029 | 0.825161 | 0.376134 | 0.383045 | 1.257732 | 0.954415 | 1.019750 | 0.971557 | 0.999886 | 1.926093 | 10479.50 |
| 42 | 0.610657 | 0.843101 | 0.403428 | 0.382190 | 1.268552 | 0.957478 | 1.020796 | 0.962921 | 0.999883 | 1.977130 | 10456.11 |
| 43 | 0.645966 | 0.861471 | 0.433124 | 0.382209 | 1.278272 | 0.960861 | 1.021816 | 0.951782 | 0.999882 | 2.029851 | 10456.63 |
| 44 | 0.683041 | 0.880166 | 0.465666 | 0.383495 | 1.286045 | 0.964591 | 1.022764 | 0.937430 | 0.999885 | 2.083814 | 10491.80 |
| 45 | 0.721970 | 0.899051 | 0.501727 | 0.386643 | 1.290601 | 0.968694 | 1.023562 | 0.918871 | 0.999893 | 2.138323 | 10577.95 |
| 46 | 0.762845 | 0.917951 | 0.542417 | 0.392653 | 1.289906 | 0.973188 | 1.024073 | 0.894580 | 0.999908 | 2.192255 | 10742.35 |
| 47 | 0.805764 | 0.936643 | 0.589768 | 0.403395 | 1.280431 | 0.978080 | 1.024018 | 0.861893 | 0.999929 | 2.243710 | 11036.25 |
| 48 | 0.850829 | 0.954823 | 0.648037 | 0.422976 | 1.255431 | 0.983344 | 1.022761 | 0.815262 | 0.999955 | 2.289098 | 11571.94 |
| 49 | 0.898148 | 0.972043 | 0.727746 | 0.462565 | 1.200636 | 0.988891 | 1.018596 | 0.740087 | 0.999979 | 2.320998 | 12655.05 |
| 50 | 0.947832 | 0.987544 | 0.858754 | 0.564260 | 1.086472 | 0.994491 | 1.010363 | 0.582548 | 0.999996 | 2.325834 | 15437.24 |
| 51 | 1.000000 | 1.000000 | 0.986765 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 0.0 | 1.000000 | 2.363807 | 27358.40 |

## Listing of the Unit 6 Output Data for the 140B Orbiter 7-Species Sample Case

FREE FLIGHT 140B ORBITER ALT=245K FT. M=26.9 ALPHA=30, 7-SPECIES

```
&INPUT
ALT=  245000.0000000000     ,BRAD=  2.3608330C0000000     ,CAINF= 0.0                        ,CAT=  1.000000000000000     ,CAW=
 0.0                     ,CCFAC= 0.0                       ,CONVRG= 0.99999979138374320-02,DS= 0.2000000000000000      ,DSMAX=
  1.000000000000000      ,HANGLE=  10.00000000000000      ,PRNTCI= 0.0                      ,RINF= 0.8672510279999999D-07,SEND=
  35.00000000000000      ,SIGM= 0.6999999880790710      ,SITEST= 0.9999999019782990D-04,SMALLT= 0.9999994290410541D-06,SSFAC=
 -1.000000000000000      ,SWFAC= -1.000000000000000      ,TB=  246C.000000000000      ,THINI= -1.000000000000000      ,TINF=
  361.4800000000000      ,UFAC= 0.5000000000000000      ,UINF=  25100.00000000000      ,WVFAC= 0.2500000000000000      ,XKETA=
  1.050000000000000      ,XLE=  1.399999618530273     ,XNSO= 0.1165999770164490     ,IE=          51,IEND=          6,IGEOM=          3,
IUN=         19,JFAC=          1,KEND=          1,KPLTTP=          0,KTWAL=          0,NAN=          -2,NDATA=          1,NITMAX=
      9999,NITMIN=          3,NITMNI=          3,NS=          6,NSI=          6,NSPRF=          0,NTSH=          20,NTTWA=
     5
&END
```

LOG RATES MATCH 6 SPECIE BLOTTNER-SANDIA

| NR | | | REACTION | | | CRO | EXP(CRO) | CR1 | CR2 | DRO | EXP(DRO) | DR1 | DR2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | O2 | M1 | =O | O | M1 | 42.7302394 | 0.3610D 19 | 59400.0 | -1.0 | 35.6407165 | 0.3010D 16 | 0.0 | -0.5 |
| 2 | N2 | M2 | =N | N | M2 | 39.7962718 | 0.1920D 18 | 113100.0 | -0.5 | 36.9275392 | 0.1090D 17 | 0.0 | -0.5 |
| 3 | N2 | N | =N | N | N | 52.0799804 | 0.4150D 23 | 113100.0 | -1.5 | 49.1958541 | 0.2320D 22 | 0.0 | -1.5 |
| 4 | NO | M3 | =N | O | M3 | 47.4304680 | 0.3970D 21 | 75600.0 | -1.5 | 46.0616522 | 0.1010D 21 | 0.0 | -1.5 |
| 5 | NO | O | =O2 | N | | 21.8801470 | 0.3180D 10 | 19700.0 | 1.0 | 27.5933192 | 0.9630D 12 | 3600.0 | 0.5 |
| 6 | N2 | O | =NO | N | | 31.8431487 | 0.6750D 14 | 37500.0 | 0.0 | 30.3390713 | 0.1500D 14 | 0.0 | 0.0 |
| 7 | N | O | =NO+ | EL | | 22.9238182 | 0.9030D 10 | 32400.0 | 0.5 | 44.3369034 | 0.1800D 20 | 0.0 | -1.0 |

ALPHSB( 7,10)

| NR | ALSUB | NR | O | O2 | NO | N | NO+ | N2 | M1 | M2 | M3 | EL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 1 | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. |
| 2 | 1.0 | 2 | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 0. | 0. |
| 3 | 1.0 | 3 | 0. | 0. | 0. | 1. | 0. | 1. | 0. | 0. | 0. | 0. |
| 4 | 1.0 | 4 | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 1. | 0. |
| 5 | 1.0 | 5 | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 1.0 | 6 | 1. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 0. |
| 7 | 1.0 | 7 | 1. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. |

| NR | BETSUB |
|---|---|
| 1 | 2.0 |
| 2 | 2.0 |
| 3 | 2.0 |
| 4 | 2.0 |
| 5 | 1.0 |
| 6 | 1.0 |
| 7 | 1.0 |

BETASB( 7,10)

| NR | O | O2 | NO | N | NO+ | N2 | M1 | M2 | M3 | EL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 2. | 0. | 0. | 0. | 1. | 0. | 0. |
| 3 | 0. | 0. | 0. | 3. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4 | 1. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 0. |
| 5 | 0. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. |
| 7 | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 1. |

ZSUB( 4, 6)

| | O | O2 | NO | N | NO+ | N2 |
|---|---|---|---|---|---|---|
| M1 | 25.0 | 9.0 | 1.0 | 1.0 | 0.0 | 2.0 |
| M2 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 2.5 |
| M3 | 20.0 | 1.0 | 20.0 | 20.0 | 0.0 | 1.0 |
| EL | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 |

GAMMPL( 7, 6)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2. | 0. | 0. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 2. | 0. | 0. |
| 3 | 0. | 0. | 0. | 2. | 0. | 0. |
| 4 | 1. | 0. | 0. | 1. | 0. | 0. |
| 5 | 0. | 1. | 0. | 1. | 0. | 0. |
| 6 | 0. | 0. | 1. | 1. | 0. | 0. |
| 7 | 0. | 0. | 0. | 0. | 1. | 0. |

GAMMMI( 7, 6)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0. | 1. | 0. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 0. | 0. | 1. |
| 3 | 0. | 0. | 0. | 0. | 0. | 1. |
| 4 | 0. | 0. | 1. | 0. | 0. | 0. |
| 5 | 1. | 0. | 1. | 0. | 0. | 0. |
| 6 | 1. | 0. | 0. | 0. | 0. | 1. |
| 7 | 1. | 0. | 0. | 1. | 0. | 0. |

VSREF = 0.23353999D-04

VSINF = 0.35867911D-06

```
K =1, I =   1, S =  0.0   , NITER =  1, DIFI = 3.663D 01 5.011D 00 0.0       1.000D 00 0.0       0.0       0.0       7.525D-01
K =1, I =   1, S =  0.0   , NITER =  2, DIFI = 6.127D-01 2.739D-01 8.846D-01 6.091D 02 8.642D 16 3.844D 17 7.587D 35 1.422D 00
K =1, I =   1, S =  0.0   , NITER =  3, DIFI = 4.105D-01 9.870D-01 2.643D 01 3.278D 03 1.772D 00 9.699D-01 9.915D-01 1.365D 02
K =1, I =   1, S =  0.0   , NITER =  4, DIFI = 3.107D 00 7.267D 00 9.507D-01 1.468D 02 9.006D 02 4.872D 00 1.541D 01 2.006D 01
K =1, I =   1, S =  0.0   , NITER =  5, DIFI = 2.103D-01 3.671D 01 1.017D 00 1.097D 38 2.496D 01 4.694D 02 2.764D 16 7.547D 00
K =1, I =   1, S =  0.0   , NITER =  6, DIFI = 3.982D-01 3.658D 00 2.895D 01 4.831D 00 4.442D-01 4.957D 10 2.768D 00 1.214D 00
K =1, I =   1, S =  0.0   , NITER =  7, DIFI = 4.068D-01 4.761D 00 2.391D 00 1.000D 40 7.515D 01 1.905D 00 1.531D 09 6.690D 00
K =1, I =   1, S =  0.0   , NITER =  8, DIFI = 2.562D-01 7.693D-01 1.000D 00 1.000D 00 7.744D 01 4.140D 02 1.000D 00 5.028D 00
K =1, I =   1, S =  0.0   , NITER =  9, DIFI = 5.501D-01 8.295D-01 3.891D 39 7.213D 38 1.000D 00 1.000D 00 3.929D 03 6.124D 01
K =1, I =   1, S =  0.0   , NITER = 10, DIFI = 9.707D-01 4.751D-01 9.946D-01 1.000D 40 5.642D 05 7.773D 02 2.405D 00 3.528D 00
K =1, I =   1, S =  0.0   , NITER = 11, DIFI = 2.073D-01 1.865D 00 4.082D 02 1.000D 00 7.527D-01 9.983D-01 8.810D 02 3.228D 00
K =1, I =   1, S =  0.0   , NITER = 12, DIFI = 4.104D-01 4.447D-01 9.629D-01 1.000D 40 9.861D-01 4.810D 01 9.441D-01 2.375D 01
K =1, I =   1, S =  0.0   , NITER = 13, DIFI = 2.281D-01 2.819D 01 2.447D 01 9.852D-01 4.878D 01 1.183D 03 4.422D 01 5.526D 01
K =1, I =   1, S =  0.0   , NITER = 14, DIFI = 7.485D-01 3.563D-01 8.672D-01 2.252D 01 9.938D-01 1.641D 01 3.594D 00 2.083D 01
K =1, I =   1, S =  0.0   , NITER = 15, DIFI = 2.136D-01 3.295D-01 2.683D-01 8.885D-01 2.356D 01 5.963D-01 7.557D-01 8.177D-01
K =1, I =   1, S =  0.0   , NITER = 16, DIFI = 2.152D-01 9.855D-02 2.002D-01 2.442D 00 6.986D-01 8.064D-01 5.149D-01 3.382D-01
K =1, I =   1, S =  0.0   , NITER = 17, DIFI = 4.475D-02 4.866D-01 5.062D-01 5.042D-01 4.066D-01 1.956D 00 6.929D-01 2.224D-01
K =1, I =   1, S =  0.0   , NITER = 18, DIFI = 1.302D-01 9.790D-02 2.369D-01 3.009D-01 9.414D-01 7.761D-01 7.632D-01 4.791D-02
K =1, I =   1, S =  0.0   , NITER = 19, DIFI = 3.152D-02 5.841D-02 2.134D-01 2.729D-01 1.165D-01 2.455D-01 3.633D-01 7.078D-02
K =1, I =   1, S =  0.0   , NITER = 20, DIFI = 3.342D-02 7.238D-02 1.003D-01 5.311D-02 2.124D-01 2.048D-01 3.108D-01 2.608D-02
K =1, I =   1, S =  0.0   , NITER = 21, DIFI = 2.192D-02 3.453D-02 3.704D-02 1.488D-01 1.287D-01 1.882D-01 8.508D-02 3.740D-02
K =1, I =   1, S =  0.0   , NITER = 22, DIFI = 9.107D-03 3.443D-02 4.826D-02 1.136D-01 7.914D-02 1.011D-01 8.121D-02 2.083D-02
K =1, I =   1, S =  0.0   , NITER = 23, DIFI = 1.327D-02 2.710D-02 5.150D-02 5.375D-02 7.930D-02 4.259D-02 2.680D-02 1.399D-02
K =1, I =   1, S =  0.0   , NITER = 24, DIFI = 6.872D-03 4.961D-03 1.686D-02 6.082D-02 2.098D-02 8.727D-02 3.961D-02 7.945D-03
K =1, I =   1, S =  0.0   , NITER = 25, DIFI = 1.663D-03 7.358D-03 2.877D-02 5.274D-02 3.861D-02 6.922D-03 1.376D-02 6.154D-03
K =1, I =   1, S =  0.0   , NITER = 26, DIFI = 2.496D-03 2.685D-03 2.234D-03 1.719D-02 2.478D-02 1.242D-02 9.460D-03 1.640D-03
K =1, I =   1, S =  0.0   , NITER = 27, DIFI = 4.292D-04 1.615D-03 5.955D-03 2.115D-02 9.451D-03 2.088D-02 6.700D-03 1.983D-03
K =1, I =   1, S =  0.0   , NITER = 28, DIFI = 5.542D-04 2.650D-03 4.474D-03 2.049D-02 8.707D-03 1.397D-03 9.238D-03 1.783D-03
K =1, I =   1, S =  0.0   , NITER = 29, DIFI = 1.030D-03 8.778D-04 2.919D-03 1.096D-02 9.192D-03 3.899D-03 3.069D-03 9.956D-04
K =1, I =   1, S =  0.0   , NITER = 30, DIFI = 1.235D-04 5.622D-04 2.456D-03 9.694D-03 4.543D-03 7.481D-03 1.003D-03 5.496D-04

   UINF        PINF          TINF          CAINF        TB           BRAD         PR          LE          YSH           ALT
 0.251D 05  0.53938D-01  0.36148D 03  0.0         0.2460D 04  0.2361D 01  0.70D 00  0.14D 01  0.4542D-01  0.245D 06

 THIN SHOCK LAYER  NO WALL SLIP  NO SHOCK SLIP    CAT WALL NO STEPS IN Y= 51 NO STEPS IN S=  6 S STEP SIZE=0.200

 TW/TS    EPS      REYINF       REYSH        TREF         UREF         RREF          PREF       ITER
0.0742   0.0674   0.1433D 05   0.6594D 03   0.1045D 06   0.2510D 05   0.8673D-07   0.5464D 02   1


  ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                  ****


   S           X           R           YSH         YSHP          XSH         RSH      NO ITER    NITTOT    NTOT   I    K
 0.0         0.0         0.0         0.045418    0.0        -0.045418    0.0         30          30       30    1    1

  DS          CF          HEAT        STAN        CDF          CDP         CDTOT       PWALL       TWALL         PW/PO
 0.200000    0.0         0.039920    0.083507    0.0          1.762960    1.762960    0.881480 2460.000000    1.000000

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.0        0.000000     0.0          1.444297    1.444297    1.000000    0.977685

     USH          VSH          TSH          RSH          PSH         VPG
     0.0       -0.099716     0.312089     9.948308     0.886151     0.0
         0.0   -2502.88      32616.88
                             18120.50
```

| N | Y/YSH | U/USH | V/VSH | T/TSH | R/RSH | P/PSH(APPR) | P/PSH | CA | CAEQ | XM | T DEG R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.075421 | 13.189015 | 0.994730 | 1.058007 | 0.0 | 0.000002 | 0.0 | 2460.00 |
| 2 | 0.004777 | 0.040336 | 0.000110 | 0.114092 | 8.460444 | 0.994730 | 1.058007 | 0.030433 | 0.004301 | 0.000105 | 3721.33 |
| 3 | 0.009792 | 0.073752 | 0.000503 | 0.145062 | 6.492926 | 0.994731 | 1.058008 | 0.055497 | 0.094627 | 0.000425 | 4731.48 |
| 4 | 0.015059 | 0.103470 | 0.001185 | 0.171896 | 5.362561 | 0.994733 | 1.058010 | 0.077268 | 0.452639 | 0.000916 | 5606.72 |
| 5 | 0.020588 | 0.130812 | 0.002165 | 0.195933 | 4.613281 | 0.994736 | 1.058012 | 0.096576 | 0.835184 | 0.001557 | 6390.74 |
| 6 | 0.026394 | 0.156480 | 0.003455 | 0.217827 | 4.074532 | 0.994740 | 1.058014 | 0.113843 | 0.962140 | 0.002340 | 7104.84 |
| 7 | 0.032491 | 0.180901 | 0.005065 | 0.237943 | 3.666306 | 0.994745 | 1.058016 | 0.129321 | 0.989461 | 0.003259 | 7760.97 |
| 8 | 0.038892 | 0.204355 | 0.007011 | 0.256510 | 3.345440 | 0.994752 | 1.058018 | 0.143174 | 0.996269 | 0.004315 | 8366.56 |
| 9 | 0.045614 | 0.227037 | 0.009306 | 0.273683 | 3.086328 | 0.994760 | 1.058020 | 0.155523 | 0.998400 | 0.005510 | 8926.67 |
| 10 | 0.052671 | 0.249086 | 0.011966 | 0.289577 | 2.872676 | 0.994769 | 1.058020 | 0.166468 | 0.999206 | 0.006847 | 9445.10 |
| 11 | 0.060081 | 0.270605 | 0.015008 | 0.304288 | 2.693534 | 0.994780 | 1.058018 | 0.176099 | 0.999558 | 0.008332 | 9924.94 |
| 12 | 0.067862 | 0.291667 | 0.018449 | 0.317902 | 2.541233 | 0.994793 | 1.058014 | 0.184506 | 0.999731 | 0.009973 | 10368.97 |
| 13 | 0.076032 | 0.312327 | 0.022308 | 0.330497 | 2.410216 | 0.994807 | 1.058007 | 0.191780 | 0.999825 | 0.011776 | 10779.78 |
| 14 | 0.084610 | 0.332623 | 0.026608 | 0.342149 | 2.296351 | 0.994824 | 1.057996 | 0.198016 | 0.999879 | 0.013750 | 11159.83 |
| 15 | 0.093617 | 0.352580 | 0.031369 | 0.352931 | 2.196499 | 0.994843 | 1.057980 | 0.203313 | 0.999912 | 0.015906 | 11511.50 |
| 16 | 0.103075 | 0.372215 | 0.036616 | 0.362914 | 2.108229 | 0.994864 | 1.057958 | 0.207770 | 0.999934 | 0.018253 | 11837.14 |
| 17 | 0.113006 | 0.391534 | 0.042376 | 0.372170 | 2.029630 | 0.994888 | 1.057930 | 0.211485 | 0.999948 | 0.020803 | 12139.02 |
| 18 | 0.123433 | 0.410539 | 0.048675 | 0.380765 | 1.959184 | 0.994914 | 1.057892 | 0.214553 | 0.999959 | 0.023567 | 12419.36 |
| 19 | 0.134381 | 0.429229 | 0.055543 | 0.388765 | 1.895677 | 0.994943 | 1.057845 | 0.217063 | 0.999966 | 0.026558 | 12680.31 |
| 20 | 0.145877 | 0.447597 | 0.063011 | 0.396234 | 1.838129 | 0.994976 | 1.057785 | 0.219097 | 0.999972 | 0.029787 | 12923.92 |
| 21 | 0.157947 | 0.465639 | 0.071110 | 0.403230 | 1.785750 | 0.995012 | 1.057711 | 0.220728 | 0.999976 | 0.033267 | 13152.11 |
| 22 | 0.170621 | 0.483350 | 0.079873 | 0.409810 | 1.737895 | 0.995051 | 1.057621 | 0.222023 | 0.999979 | 0.037011 | 13366.72 |
| 23 | 0.183929 | 0.500729 | 0.089333 | 0.416026 | 1.694042 | 0.995095 | 1.057511 | 0.223037 | 0.999982 | 0.041030 | 13569.47 |
| 24 | 0.197902 | 0.517779 | 0.099525 | 0.421928 | 1.653760 | 0.995143 | 1.057379 | 0.223819 | 0.999984 | 0.045337 | 13761.98 |
| 25 | 0.212574 | 0.534510 | 0.110481 | 0.427563 | 1.616696 | 0.995195 | 1.057222 | 0.224408 | 0.999986 | 0.049948 | 13945.77 |
| 26 | 0.227980 | 0.550938 | 0.122239 | 0.432975 | 1.582557 | 0.995252 | 1.057035 | 0.224837 | 0.999987 | 0.054878 | 14122.29 |
| 27 | 0.244155 | 0.567091 | 0.134833 | 0.438207 | 1.551090 | 0.995314 | 1.056814 | 0.225133 | 0.999989 | 0.060140 | 14292.94 |
| 28 | 0.261140 | 0.583005 | 0.148300 | 0.443302 | 1.522077 | 0.995382 | 1.056555 | 0.225315 | 0.999990 | 0.065750 | 14459.12 |
| 29 | 0.278974 | 0.598725 | 0.162681 | 0.448302 | 1.495321 | 0.995455 | 1.056252 | 0.225399 | 0.999991 | 0.071723 | 14622.21 |
| 30 | 0.297699 | 0.614308 | 0.178019 | 0.453252 | 1.470634 | 0.995535 | 1.055900 | 0.225396 | 0.999991 | 0.078074 | 14783.68 |
| 31 | 0.317361 | 0.629817 | 0.194364 | 0.458200 | 1.447832 | 0.995622 | 1.055491 | 0.225313 | 0.999992 | 0.084815 | 14945.07 |
| 32 | 0.338006 | 0.645322 | 0.211773 | 0.463197 | 1.426728 | 0.995717 | 1.055018 | 0.225153 | 0.999993 | 0.091978 | 15108.06 |
| 33 | 0.359683 | 0.660900 | 0.230313 | 0.468300 | 1.407123 | 0.995819 | 1.054472 | 0.224917 | 0.999993 | 0.099590 | 15274.47 |
| 34 | 0.382443 | 0.676626 | 0.250066 | 0.473570 | 1.388805 | 0.995930 | 1.053843 | 0.224602 | 0.999994 | 0.107680 | 15446.38 |
| 35 | 0.406342 | 0.692578 | 0.271129 | 0.479081 | 1.371540 | 0.996051 | 1.053118 | 0.224202 | 0.999994 | 0.116285 | 15626.14 |
| 36 | 0.431436 | 0.708826 | 0.293623 | 0.484917 | 1.355073 | 0.996182 | 1.052282 | 0.223708 | 0.999995 | 0.125450 | 15816.49 |
| 37 | 0.457785 | 0.725437 | 0.317693 | 0.491178 | 1.339125 | 0.996324 | 1.051317 | 0.223107 | 0.999995 | 0.135228 | 16020.69 |
| 38 | 0.485451 | 0.742468 | 0.343515 | 0.497984 | 1.323388 | 0.996478 | 1.050201 | 0.222381 | 0.999996 | 0.145686 | 16242.70 |
| 39 | 0.514500 | 0.759963 | 0.371303 | 0.505487 | 1.307529 | 0.996645 | 1.048909 | 0.221505 | 0.999996 | 0.156916 | 16487.41 |
| 40 | 0.545002 | 0.777958 | 0.401320 | 0.513877 | 1.291181 | 0.996827 | 1.047407 | 0.220446 | 0.999997 | 0.168987 | 16761.06 |
| 41 | 0.577029 | 0.796473 | 0.433886 | 0.523406 | 1.273934 | 0.997024 | 1.045654 | 0.219157 | 0.999997 | 0.182012 | 17071.87 |
| 42 | 0.610657 | 0.815513 | 0.469403 | 0.534416 | 1.255322 | 0.997238 | 1.043598 | 0.217573 | 0.999997 | 0.196132 | 17430.99 |
| 43 | 0.645966 | 0.835067 | 0.508383 | 0.547389 | 1.234802 | 0.997469 | 1.041175 | 0.215598 | 0.999998 | 0.211493 | 17854.11 |
| 44 | 0.683041 | 0.855103 | 0.551495 | 0.563020 | 1.211718 | 0.997718 | 1.038295 | 0.213082 | 0.999998 | 0.228411 | 18363.97 |
| 45 | 0.721970 | 0.875565 | 0.599633 | 0.582356 | 1.185283 | 0.997987 | 1.034843 | 0.209770 | 0.999998 | 0.247303 | 18994.65 |
| 46 | 0.762845 | 0.896363 | 0.654006 | 0.607020 | 1.154570 | 0.998275 | 1.030661 | 0.205175 | 0.999999 | 0.268823 | 19799.10 |
| 47 | 0.805764 | 0.917370 | 0.716194 | 0.639622 | 1.118643 | 0.998583 | 1.025543 | 0.198253 | 0.999999 | 0.293901 | 20862.47 |
| 48 | 0.850829 | 0.938408 | 0.787942 | 0.684511 | 1.077089 | 0.998909 | 1.019271 | 0.186521 | 0.999999 | 0.324374 | 22326.61 |
| 49 | 0.898148 | 0.959265 | 0.869587 | 0.749118 | 1.031931 | 0.999252 | 1.011863 | 0.163683 | 1.000000 | 0.363474 | 24433.90 |
| 50 | 0.947832 | 0.979756 | 0.953054 | 0.846281 | 0.993803 | 0.999612 | 1.004587 | 0.113569 | 1.000000 | 0.413661 | 27603.07 |
| 51 | 1.000000 | 1.000000 | 0.999398 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 0.0 | 1.000000 | 0.457174 | 32616.88 |

| N | Y/RN | O | O2 | NO | N | NO+ | N2 | E-/CC | Y IN | Y CM |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.23456D 00 | 0.0 | 0.0 | 0.0 | 0.76544D 00 | 0.0 | 0.0 | 0.0 |
| 2 | 0.00022 | 0.30433D-01 | 0.19743D 00 | 0.12735D-01 | 0.28942D-02 | 0.35064D-04 | 0.75648D 00 | 0.26482D 13 | 0.00615 | 0.01561 |
| 3 | 0.00044 | 0.55497D-01 | 0.16711D 00 | 0.22735D-01 | 0.57487D-02 | 0.65474D-04 | 0.74885D 00 | 0.37949D 13 | 0.01260 | 0.03200 |
| 4 | 0.00068 | 0.77268D-01 | 0.14115D 00 | 0.30713D-01 | 0.89935D-02 | 0.94327D-04 | 0.74178D 00 | 0.45155D 13 | 0.01938 | 0.04921 |
| 5 | 0.00094 | 0.96576D-01 | 0.11856D 00 | 0.36971D-01 | 0.12840D-01 | 0.12292D-03 | 0.73493D 00 | 0.50621D 13 | 0.02649 | 0.06729 |
| 6 | 0.00120 | 0.11384D 00 | 0.98833D-01 | 0.41692D-01 | 0.17417D-01 | 0.15199D-03 | 0.72806D 00 | 0.55283D 13 | 0.03396 | 0.08626 |
| 7 | 0.00148 | 0.12932D 00 | 0.81630D-01 | 0.45021D-01 | 0.22809D-01 | 0.18204D-03 | 0.72104D 00 | 0.59579D 13 | 0.04181 | 0.10619 |
| 8 | 0.00177 | 0.14317D 00 | 0.66718D-01 | 0.47091D-01 | 0.29072D-01 | 0.21347D-03 | 0.71373D 00 | 0.63750D 13 | 0.05004 | 0.12711 |
| 9 | 0.00207 | 0.15552D 00 | 0.53904D-01 | 0.48037D-01 | 0.36235D-01 | 0.24660D-03 | 0.70605D 00 | 0.67941D 13 | 0.05869 | 0.14908 |
| 10 | 0.00239 | 0.16647D 00 | 0.43014D-01 | 0.48000D-01 | 0.44304D-01 | 0.28173D-03 | 0.69793D 00 | 0.72246D 13 | 0.06777 | 0.17214 |
| 11 | 0.00273 | 0.17610D 00 | 0.33876D-01 | 0.47130D-01 | 0.53266D-01 | 0.31909D-03 | 0.68931D 00 | 0.76725D 13 | 0.07731 | 0.19636 |
| 12 | 0.00308 | 0.18451D 00 | 0.26318D-01 | 0.45580D-01 | 0.63086D-01 | 0.35890D-03 | 0.68015D 00 | 0.81418D 13 | 0.08732 | 0.22179 |
| 13 | 0.00345 | 0.19178D 00 | 0.20165D-01 | 0.43506D-01 | 0.73712D-01 | 0.40131D-03 | 0.67044D 00 | 0.86344D 13 | 0.09783 | 0.24849 |
| 14 | 0.00384 | 0.19802D 00 | 0.15240D-01 | 0.41062D-01 | 0.85080D-01 | 0.44642D-03 | 0.66016D 00 | 0.91512D 13 | 0.10887 | 0.27652 |
| 15 | 0.00425 | 0.20331D 00 | 0.11367D-01 | 0.38390D-01 | 0.97108D-01 | 0.49427D-03 | 0.64933D 00 | 0.96915D 13 | 0.12046 | 0.30596 |
| 16 | 0.00468 | 0.20777D 00 | 0.83772D-02 | 0.35620D-01 | 0.10971D 00 | 0.54485D-03 | 0.63798D 00 | 0.10254D 14 | 0.13263 | 0.33687 |
| 17 | 0.00513 | 0.21149D 00 | 0.61131D-02 | 0.32865D-01 | 0.12277D 00 | 0.59806D-03 | 0.62616D 00 | 0.10836D 14 | 0.14540 | 0.36933 |
| 18 | 0.00561 | 0.21455D 00 | 0.44313D-02 | 0.30214D-01 | 0.13621D 00 | 0.65378D-03 | 0.61394D 00 | 0.11434D 14 | 0.15882 | 0.40340 |
| 19 | 0.00610 | 0.21706D 00 | 0.32058D-02 | 0.27737D-01 | 0.14989D 00 | 0.71179D-03 | 0.60139D 00 | 0.12045D 14 | 0.17291 | 0.43919 |
| 20 | 0.00663 | 0.21910D 00 | 0.23294D-02 | 0.25481D-01 | 0.16371D 00 | 0.77183D-03 | 0.58861D 00 | 0.12665D 14 | 0.18770 | 0.47676 |
| 21 | 0.00717 | 0.22073D 00 | 0.17138D-02 | 0.23474D-01 | 0.17755D 00 | 0.83361D-03 | 0.57570D 00 | 0.13289D 14 | 0.20323 | 0.51621 |
| 22 | 0.00775 | 0.22202D 00 | 0.12883D-02 | 0.21728D-01 | 0.19127D 00 | 0.89678D-03 | 0.56279D 00 | 0.13913D 14 | 0.21954 | 0.55763 |
| 23 | 0.00835 | 0.22304D 00 | 0.99837D-03 | 0.20239D-01 | 0.20476D 00 | 0.96097D-03 | 0.55001D 00 | 0.14532D 14 | 0.23666 | 0.60112 |
| 24 | 0.00899 | 0.22382D 00 | 0.80312D-03 | 0.18997D-01 | 0.21788D 00 | 0.10258D-02 | 0.53748D 00 | 0.15143D 14 | 0.25464 | 0.64679 |
| 25 | 0.00965 | 0.22441D 00 | 0.67280D-03 | 0.17983D-01 | 0.23050D 00 | 0.10908D-02 | 0.52535D 00 | 0.15743D 14 | 0.27352 | 0.69474 |
| 26 | 0.01035 | 0.22484D 00 | 0.58650D-03 | 0.17179D-01 | 0.24250D 00 | 0.11557D-02 | 0.51374D 00 | 0.16327D 14 | 0.29334 | 0.74509 |
| 27 | 0.01109 | 0.22513D 00 | 0.52992D-03 | 0.16563D-01 | 0.25375D 00 | 0.12201D-02 | 0.50281D 00 | 0.16894D 14 | 0.31415 | 0.79795 |
| 28 | 0.01186 | 0.22531D 00 | 0.49360D-03 | 0.16118D-01 | 0.26412D 00 | 0.12836D-02 | 0.49267D 00 | 0.17440D 14 | 0.33601 | 0.85346 |
| 29 | 0.01267 | 0.22540D 00 | 0.47148D-03 | 0.15828D-01 | 0.27351D 00 | 0.13458D-02 | 0.48344D 00 | 0.17964D 14 | 0.35896 | 0.91175 |
| 30 | 0.01352 | 0.22540D 00 | 0.45985D-03 | 0.15683D-01 | 0.28182D 00 | 0.14065D-02 | 0.47524D 00 | 0.18465D 14 | 0.38305 | 0.97295 |
| 31 | 0.01441 | 0.22531D 00 | 0.45654D-03 | 0.15676D-01 | 0.28894D 00 | 0.14655D-02 | 0.46815D 00 | 0.18941D 14 | 0.40835 | 1.03720 |
| 32 | 0.01535 | 0.22515D 00 | 0.46047D-03 | 0.15804D-01 | 0.29481D 00 | 0.15224D-02 | 0.46225D 00 | 0.19390D 14 | 0.43491 | 1.10468 |
| 33 | 0.01634 | 0.22492D 00 | 0.47124D-03 | 0.16071D-01 | 0.29939D 00 | 0.15771D-02 | 0.45758D 00 | 0.19810D 14 | 0.46280 | 1.17552 |
| 34 | 0.01737 | 0.22460D 00 | 0.48904D-03 | 0.16482D-01 | 0.30263D 00 | 0.16292D-02 | 0.45416D 00 | 0.20199D 14 | 0.49209 | 1.24991 |
| 35 | 0.01846 | 0.22420D 00 | 0.51451D-03 | 0.17050D-01 | 0.30454D 00 | 0.16785D-02 | 0.45201D 00 | 0.20551D 14 | 0.52284 | 1.32801 |
| 36 | 0.01960 | 0.22371D 00 | 0.54876D-03 | 0.17790D-01 | 0.30513D 00 | 0.17245D-02 | 0.45110D 00 | 0.20860D 14 | 0.55513 | 1.41003 |
| 37 | 0.02079 | 0.22311D 00 | 0.59347D-03 | 0.18727D-01 | 0.30441D 00 | 0.17663D-02 | 0.45140D 00 | 0.21115D 14 | 0.58903 | 1.49614 |
| 38 | 0.02205 | 0.22238D 00 | 0.65115D-03 | 0.19889D-01 | 0.30242D 00 | 0.18028D-02 | 0.45286D 00 | 0.21298D 14 | 0.62463 | 1.58656 |
| 39 | 0.02337 | 0.22151D 00 | 0.72556D-03 | 0.21318D-01 | 0.29919D 00 | 0.18321D-02 | 0.45543D 00 | 0.21385D 14 | 0.66201 | 1.68150 |
| 40 | 0.02475 | 0.22045D 00 | 0.82264D-03 | 0.23068D-01 | 0.29471D 00 | 0.18516D-02 | 0.45910D 00 | 0.21341D 14 | 0.70125 | 1.78118 |
| 41 | 0.02621 | 0.21916D 00 | 0.95246D-03 | 0.25209D-01 | 0.28896D 00 | 0.18570D-02 | 0.46386D 00 | 0.21118D 14 | 0.74246 | 1.88585 |
| 42 | 0.02773 | 0.21757D 00 | 0.11337D-02 | 0.27835D-01 | 0.28183D 00 | 0.18429D-02 | 0.46978D 00 | 0.20652D 14 | 0.78573 | 1.99576 |
| 43 | 0.02934 | 0.21560D 00 | 0.14041D-02 | 0.31061D-01 | 0.27311D 00 | 0.18019D-02 | 0.47703D 00 | 0.19862D 14 | 0.83116 | 2.11116 |
| 44 | 0.03102 | 0.21308D 00 | 0.18481D-02 | 0.35017D-01 | 0.26242D 00 | 0.17246D-02 | 0.48591D 00 | 0.18654D 14 | 0.87887 | 2.23233 |
| 45 | 0.03279 | 0.20977D 00 | 0.26656D-02 | 0.39818D-01 | 0.24917D 00 | 0.16007D-02 | 0.49698D 00 | 0.16937D 14 | 0.92896 | 2.35955 |
| 46 | 0.03465 | 0.20518D 00 | 0.43556D-02 | 0.45448D-01 | 0.23237D 00 | 0.14205D-02 | 0.51123D 00 | 0.14640D 14 | 0.98155 | 2.49314 |
| 47 | 0.03660 | 0.19825D 00 | 0.81975D-02 | 0.51474D-01 | 0.21050D 00 | 0.11784D-02 | 0.53040D 00 | 0.11768D 14 | 1.03678 | 2.63341 |
| 48 | 0.03864 | 0.18652D 00 | 0.17506D-01 | 0.56329D-01 | 0.18118D 00 | 0.87902D-03 | 0.55759D 00 | 0.84517D 13 | 1.09476 | 2.78069 |
| 49 | 0.04079 | 0.16368D 00 | 0.40816D-01 | 0.55796D-01 | 0.14074D 00 | 0.54419D-03 | 0.59842D 00 | 0.50130D 13 | 1.15565 | 2.93534 |
| 50 | 0.04305 | 0.11357D 00 | 0.99144D-01 | 0.40730D-01 | 0.83563D-01 | 0.22320D-03 | 0.66277D 00 | 0.19801D 13 | 1.21957 | 3.09772 |
| 51 | 0.04542 | 0.0 | 0.23456D 00 | 0.0 | 0.0 | 0.0 | 0.76544D 00 | 0.0 | 1.28670 | 3.26822 |

```
K =1, I =  2, S =  0.200, NITER =  1, DIFI = 8.413D-01 3.676D-03 1.899D-03 4.341D-03 4.207D-03 5.070D-03 4.783D-03 3.390D-03
K =1, I =  2, S =  0.200, NITER =  2, DIFI = 2.754D-01 5.250D-02 2.213D-01 2.181D-01 1.372D-01 2.032D-01 3.141D-01 1.342D-01
K =1, I =  2, S =  0.200, NITER =  3, DIFI = 5.361D-02 3.732D-02 8.864D-02 9.614D-02 8.527D-02 5.426D-02 2.802D-01 5.619D-02
K =1, I =  2, S =  0.200, NITER =  4, DIFI = 7.675D-03 1.141D-02 8.564D-03 2.143D-02 1.707D-02 2.713D-02 6.531D-02 2.270D-02
K =1, I =  2, S =  0.200, NITER =  5, DIFI = 1.332D-03 2.779D-03 2.090D-02 7.060D-03 1.028D-02 1.538D-02 3.311D-02 2.236D-02
K =1, I =  2, S =  0.200, NITER =  6, DIFI = 2.585D-03 1.780D-03 8.810D-03 5.459D-03 6.091D-03 3.259D-03 2.025D-02 6.753D-03


   ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                    ****


     S           X            R            YSH          YSHP          XSH           RSH       NO ITER     NITTOT     NTOT    I     K
  0.200000    0.025602     0.197806     0.059564     0.141461    -0.032123     0.212497       6           36         36     2     1

     DS          CF           HEAT         STAN         CDF           CDP          CDTOT        PWALL        TWALL          PW/PO
  0.200000    0.009780     0.032161     0.067276     0.002439     1.718129     1.720568     0.876726 2460.000000      0.994607

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.000000    0.000000     0.141461     1.425378     1.425378     0.890295    0.652402

       USH          VSH           TSH           RSH           PSH          VPG
     0.135534    -0.099667     0.311504      9.940396      0.883787      0.0
      3401.91     -2501.64     32555.73
                               18086.52


K =1, I =  3, S =  0.400, NITER =  1, DIFI = 3.619D-01 8.428D-02 1.689D-01 3.836D-01 1.486D-01 2.759D-01 3.257D-01 1.051D-01
K =1, I =  3, S =  0.400, NITER =  2, DIFI = 7.375D-01 1.007D-01 1.445D-01 2.724D-01 1.461D-01 3.092D-01 1.580D-01 5.317D-02
K =1, I =  3, S =  0.400, NITER =  3, DIFI = 2.248D-02 7.029D-02 8.153D-02 1.053D-01 1.277D-01 2.536D-01 1.740D-01 5.013D-02
K =1, I =  3, S =  0.400, NITER =  4, DIFI = 1.424D-02 3.453D-02 3.041D-02 5.836D-02 8.122D-02 1.971D-02 2.894D-02 6.867D-03
K =1, I =  3, S =  0.400, NITER =  5, DIFI = 4.845D-03 2.341D-03 5.858D-03 7.174D-03 2.046D-02 1.160D-02 2.557D-02 4.596D-03
K =1, I =  3, S =  0.400, NITER =  6, DIFI = 5.783D-04 2.150D-03 3.936D-03 2.427D-03 3.563D-03 9.372D-03 1.515D-02 1.396D-03


   ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                    ****


     S           X            R            YSH          YSHP          XSH           RSH       NO ITER     NITTOT     NTOT    I     K
  0.400000    0.082326     0.389258     0.086069     0.123584     0.000385     0.415592       6           42         42     3     1

     DS          CF           HEAT         STAN         CDF           CDP          CDTOT        PWALL        TWALL          PW/PO
  0.200000    0.014734     0.025134     0.052577     0.003576     1.679753     1.683329     0.809976 2460.000000      0.918882

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.000000    0.000000     0.123584     1.210361     1.210361     0.534291    0.459847

       USH          VSH           TSH           RSH           PSH          VPG
     0.248794    -0.098573     0.298852      9.763471      0.833382      0.0
      6244.73     -2474.19     31233.49
                               17351.95
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K =1, I =  4, S =  0.600, NITER =  1, DIFI = 1.822D-01 7.875D-02 1.791D-01 3.419D-01 2.351D-01 2.815D-01 3.339D-01 2.570D-01
K =1, I =  4, S =  0.600, NITER =  2, DIFI = 2.398D-01 3.572D-02 1.333D-01 1.400D-01 1.819D-01 2.068D-01 3.621D-01 8.053D-02
K =1, I =  4, S =  0.600, NITER =  3, DIFI = 6.277D-02 6.209D-02 5.996D-02 1.013D-01 1.013D-01 1.409D-01 2.044D-01 2.958D-02
K =1, I =  4, S =  0.600, NITER =  4, DIFI = 1.211D-02 1.946D-02 1.513D-02 3.469D-02 3.975D-02 4.589D-02 2.711D-02 1.089D-02
K =1, I =  4, S =  0.600, NITER =  5, DIFI = 2.253D-03 3.824D-03 1.137D-02 7.902D-03 8.770D-03 1.471D-02 1.786D-02 7.902D-03
K =1, I =  4, S =  0.600, NITER =  6, DIFI = 1.597D-03 1.852D-03 2.530D-03 2.649D-03 4.133D-03 2.886D-03 8.421D-03 1.158D-03


    ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES              ****


      S           X           R          YSH         YSHP         XSH          RSH     NO ITER    NITTOT     NTOT    I     K
  0.600000    0.153125    0.576231    0.096495   -0.019326    0.064367    0.614090      6          48        48     4     1

     DS          CF          HEAT        STAN        CDF         CDP         CDTOT        PWALL        TWALL          PW/PO
  0.200000    0.020479    0.023084    0.048289    0.005478    1.584793    1.590271    0.715207 2460.000000     0.811371

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.000000    0.000000   -0.019326    1.114267    1.114267    0.398202    0.354594

        USH          VSH          TSH          RSH          PSH          VPG
      0.396758    -0.096763     0.278381     9.472317     0.752913     0.0
       9958.63     -2428.76     29094.02
                                16163.35


K =1, I =  5, S =  0.800, NITER =  1, DIFI = 5.671D-02 6.639D-02 4.649D-02 1.818D-01 1.763D-01 1.276D-01 2.177D-01 5.914D-02
K =1, I =  5, S =  0.800, NITER =  2, DIFI = 6.454D-02 4.236D-02 6.128D-02 1.263D-01 9.684D-02 7.138D-02 1.594D-01 3.263D-02
K =1, I =  5, S =  0.800, NITER =  3, DIFI = 6.153D-03 6.763D-03 1.009D-02 2.880D-02 2.058D-02 2.870D-02 3.909D-02 3.255D-03
K =1, I =  5, S =  0.800, NITER =  4, DIFI = 1.376D-03 2.073D-03 7.925D-03 9.689D-03 8.715D-03 5.450D-03 1.946D-02 4.435D-03


    ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES              ****


      S           X           R          YSH         YSHP         XSH          RSH     NO ITER    NITTOT     NTOT    I     K
  0.800000    0.241411    0.755630    0.101063    0.065006    0.152226    0.803166      4          52        52     5     1

     DS          CF          HEAT        STAN        CDF         CDP         CDTOT        PWALL        TWALL          PW/PO
  0.200000    0.021277    0.021063    0.044060    0.007456    1.488738    1.496195    0.645542 2460.000000     0.732339

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
 -0.000000    0.000000    0.065006    1.033441    1.033441    0.309931    0.278565

        USH          VSH          TSH          RSH          PSH          VPG
      0.476350    -0.095165     0.261554     9.228450     0.689214     0.0
      11956.40     -2388.64     27335.38
                                15186.33
```

```
K =1, I =  6, S =  1.000, NITER =  1, DIFI = 6.744D-02 6.072D-02 1.992D-01 3.195D-01 1.485D-01 3.353D-01 3.638D-01 1.429D-01
K =1, I =  6, S =  1.000, NITER =  2, DIFI = 1.941D-02 2.468D-02 4.402D-02 1.266D-01 1.740D-01 4.838D-02 1.702D-01 1.674D-02
K =1, I =  6, S =  1.000, NITER =  3, DIFI = 2.139D-02 1.038D-02 3.589D-02 4.951D-02 2.463D-02 2.613D-02 5.533D-02 1.404D-02
K =1, I =  6, S =  1.000, NITER =  4, DIFI = 3.735D-03 4.301D-03 3.206D-03 1.130D-02 8.656D-03 1.155D-02 1.503D-02 1.966D-03
K =1, I =  6, S =  1.000, NITER =  5, DIFI = 5.443D-04 1.175D-03 3.584D-03 3.897D-03 3.790D-03 2.550D-03 6.773D-03 1.493D-03


  ****  FREE FLIGHT 140B ORBITER  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                ****


    S             X           R            YSH          YSHP          XSH          RSH      NO ITER     NITTOT     NTOT    I     K
 1.000000     0.341452     0.928623     0.113880     0.063168     0.245184     0.989459      5           57        57     6     1

    DS            CF          HEAT         STAN          CDF          CDP         CDTOT       PWALL        TWALL        PW/PO
 0.200000     0.021234     0.018412     0.038515     0.009134     1.397617     1.406751    0.582807  2460.000000    0.661168

YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
 0.000000    0.000000     0.063168     0.971723     0.971723     0.245798     0.219850

       USH          VSH           TSH          RSH          PSH          VPG
     0.537871    -0.093541     0.245876    9.005450     0.632187      0.0
     13500.57     -2347.89     25696.87
                               14276.04
```

| N | Y/YSH | U/USH | V/VSH | T/TSH | R/RSH | P/PSH(APPR) | P/PSH | CA | CAEQ | XM | T DEG R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.095815 | 9.631821 | 0.921889 | 0.988605 | 0.0 | 0.000003 | 0.0 | 2462.14 |
| 2 | 0.004777 | 0.046909 | 0.000107 | 0.150547 | 5.907479 | 0.921893 | 0.988609 | 0.040516 | 0.009227 | 0.236835 | 3868.59 |
| 3 | 0.009792 | 0.085167 | 0.000492 | 0.192563 | 4.484113 | 0.921906 | 0.988622 | 0.073377 | 0.184018 | 0.378270 | 4948.27 |
| 4 | 0.015059 | 0.119027 | 0.001159 | 0.227991 | 3.691387 | 0.921932 | 0.988648 | 0.101812 | 0.666176 | 0.481614 | 5858.65 |
| 5 | 0.020588 | 0.150118 | 0.002117 | 0.258932 | 3.175753 | 0.921972 | 0.988688 | 0.126959 | 0.932329 | 0.564549 | 6653.75 |
| 6 | 0.026394 | 0.179278 | 0.003377 | 0.286353 | 2.810673 | 0.922026 | 0.988743 | 0.149329 | 0.984927 | 0.634993 | 7358.36 |
| 7 | 0.032491 | 0.207007 | 0.004951 | 0.310773 | 2.538118 | 0.922096 | 0.988812 | 0.169185 | 0.995381 | 0.697363 | 7985.89 |
| 8 | 0.038892 | 0.233623 | 0.006852 | 0.332522 | 2.327159 | 0.922184 | 0.988898 | 0.186690 | 0.998167 | 0.754226 | 8544.77 |
| 9 | 0.045614 | 0.259344 | 0.009093 | 0.351841 | 2.159540 | 0.922289 | 0.989002 | 0.201981 | 0.999119 | 0.807365 | 9041.21 |
| 10 | 0.052671 | 0.284316 | 0.011691 | 0.368937 | 2.023640 | 0.922415 | 0.989124 | 0.215199 | 0.999511 | 0.857905 | 9480.53 |
| 11 | 0.060081 | 0.308639 | 0.014661 | 0.384008 | 1.911628 | 0.922564 | 0.989265 | 0.226503 | 0.999698 | 0.906575 | 9867.81 |
| 12 | 0.067862 | 0.332374 | 0.018024 | 0.397249 | 1.817996 | 0.922736 | 0.989429 | 0.236076 | 0.999796 | 0.953856 | 10208.06 |
| 13 | 0.076032 | 0.355557 | 0.021800 | 0.408858 | 1.738735 | 0.922934 | 0.989615 | 0.244112 | 0.999853 | 1.000011 | 10506.36 |
| 14 | 0.084610 | 0.378200 | 0.026014 | 0.419029 | 1.670854 | 0.923162 | 0.989825 | 0.250806 | 0.999888 | 1.045155 | 10767.73 |
| 15 | 0.093617 | 0.400299 | 0.030694 | 0.427955 | 1.612084 | 0.923421 | 0.990062 | 0.256347 | 0.999912 | 1.089294 | 10997.11 |
| 16 | 0.103075 | 0.421834 | 0.035870 | 0.435820 | 1.560680 | 0.923714 | 0.990327 | 0.260903 | 0.999928 | 1.132409 | 11199.22 |
| 17 | 0.113006 | 0.442781 | 0.041574 | 0.442795 | 1.515299 | 0.924043 | 0.990620 | 0.264622 | 0.999939 | 1.174411 | 11378.44 |
| 18 | 0.123433 | 0.463107 | 0.047839 | 0.449033 | 1.474905 | 0.924413 | 0.990944 | 0.267625 | 0.999948 | 1.215201 | 11538.74 |
| 19 | 0.134381 | 0.482784 | 0.054700 | 0.454672 | 1.438703 | 0.924825 | 0.991299 | 0.270011 | 0.999954 | 1.254689 | 11683.65 |
| 20 | 0.145877 | 0.501787 | 0.062189 | 0.459830 | 1.406092 | 0.925282 | 0.991687 | 0.271854 | 0.999959 | 1.292814 | 11816.20 |
| 21 | 0.157947 | 0.520101 | 0.070341 | 0.464607 | 1.376619 | 0.925789 | 0.992107 | 0.273211 | 0.999964 | 1.329553 | 11938.95 |
| 22 | 0.170621 | 0.537724 | 0.079186 | 0.469085 | 1.349945 | 0.926346 | 0.992561 | 0.274122 | 0.999967 | 1.364932 | 12054.02 |
| 23 | 0.183929 | 0.554674 | 0.088754 | 0.473333 | 1.325823 | 0.926959 | 0.993050 | 0.274618 | 0.999970 | 1.399029 | 12163.17 |
| 24 | 0.197902 | 0.570988 | 0.099075 | 0.477406 | 1.304065 | 0.927631 | 0.993572 | 0.274721 | 0.999972 | 1.431984 | 12267.83 |
| 25 | 0.212574 | 0.586723 | 0.110176 | 0.481350 | 1.284531 | 0.928365 | 0.994130 | 0.274450 | 0.999975 | 1.463983 | 12369.19 |
| 26 | 0.227980 | 0.601956 | 0.122086 | 0.485206 | 1.267106 | 0.929165 | 0.994722 | 0.273818 | 0.999977 | 1.495256 | 12468.28 |
| 27 | 0.244155 | 0.616783 | 0.134833 | 0.489009 | 1.251688 | 0.930037 | 0.995351 | 0.272840 | 0.999978 | 1.526067 | 12565.99 |
| 28 | 0.261140 | 0.631313 | 0.148450 | 0.492790 | 1.238179 | 0.930986 | 0.996015 | 0.271532 | 0.999980 | 1.556705 | 12663.16 |
| 29 | 0.278974 | 0.645663 | 0.162976 | 0.496582 | 1.226472 | 0.932018 | 0.996717 | 0.269908 | 0.999981 | 1.587462 | 12760.61 |
| 30 | 0.297699 | 0.659954 | 0.178455 | 0.500419 | 1.216447 | 0.933140 | 0.997457 | 0.267987 | 0.999982 | 1.618617 | 12859.21 |
| 31 | 0.317361 | 0.674301 | 0.194942 | 0.504337 | 1.207966 | 0.934361 | 0.998236 | 0.265785 | 0.999984 | 1.650424 | 12959.87 |
| 32 | 0.338006 | 0.688809 | 0.212504 | 0.508375 | 1.200869 | 0.935690 | 0.999055 | 0.263319 | 0.999985 | 1.683090 | 13063.64 |
| 33 | 0.359683 | 0.703568 | 0.231218 | 0.512579 | 1.194976 | 0.937138 | 0.999914 | 0.260607 | 0.999986 | 1.716769 | 13171.67 |
| 34 | 0.382443 | 0.718652 | 0.251179 | 0.517000 | 1.190089 | 0.938715 | 1.000813 | 0.257662 | 0.999987 | 1.751552 | 13285.28 |
| 35 | 0.406342 | 0.734112 | 0.272494 | 0.521697 | 1.185994 | 0.940436 | 1.001751 | 0.254496 | 0.999988 | 1.787466 | 13405.97 |
| 36 | 0.431436 | 0.749979 | 0.295285 | 0.526736 | 1.182470 | 0.942315 | 1.002725 | 0.251116 | 0.999988 | 1.824436 | 13535.46 |
| 37 | 0.457785 | 0.766263 | 0.319689 | 0.532195 | 1.179293 | 0.944367 | 1.003730 | 0.247525 | 0.999989 | 1.862303 | 13675.74 |
| 38 | 0.485451 | 0.782955 | 0.345857 | 0.538165 | 1.176240 | 0.946609 | 1.004759 | 0.243720 | 0.999990 | 1.901038 | 13829.16 |
| 39 | 0.514500 | 0.800026 | 0.373960 | 0.544756 | 1.173087 | 0.949058 | 1.005800 | 0.239692 | 0.999991 | 1.940448 | 13998.53 |
| 40 | 0.545002 | 0.817431 | 0.404184 | 0.552104 | 1.169612 | 0.951733 | 1.006840 | 0.235424 | 0.999992 | 1.980300 | 14187.34 |
| 41 | 0.577029 | 0.835108 | 0.436747 | 0.560383 | 1.165575 | 0.954653 | 1.007855 | 0.230886 | 0.999993 | 2.020313 | 14400.08 |
| 42 | 0.610657 | 0.852977 | 0.471909 | 0.569826 | 1.160705 | 0.957837 | 1.008816 | 0.226035 | 0.999993 | 2.060163 | 14642.74 |
| 43 | 0.645966 | 0.870942 | 0.509994 | 0.580758 | 1.154667 | 0.961304 | 1.009680 | 0.220802 | 0.999994 | 2.099175 | 14923.67 |
| 44 | 0.683041 | 0.888891 | 0.551443 | 0.593659 | 1.147003 | 0.965070 | 1.010387 | 0.215084 | 0.999995 | 2.137136 | 15255.16 |
| 45 | 0.721970 | 0.906692 | 0.596881 | 0.609265 | 1.137058 | 0.969152 | 1.010844 | 0.208723 | 0.999996 | 2.174013 | 15656.20 |
| 46 | 0.762845 | 0.924196 | 0.647265 | 0.628788 | 1.123837 | 0.973556 | 1.010906 | 0.201468 | 0.999997 | 2.209711 | 16157.87 |
| 47 | 0.805764 | 0.941226 | 0.704142 | 0.654343 | 1.105797 | 0.978285 | 1.010337 | 0.192863 | 0.999997 | 2.245691 | 16814.57 |
| 48 | 0.850829 | 0.957576 | 0.770039 | 0.689872 | 1.080682 | 0.983323 | 1.008747 | 0.181783 | 0.999998 | 2.281208 | 17727.54 |
| 49 | 0.898148 | 0.972993 | 0.848632 | 0.743327 | 1.046004 | 0.988634 | 1.005639 | 0.164421 | 0.999999 | 2.324239 | 19101.17 |
| 50 | 0.947832 | 0.987189 | 0.940536 | 0.832190 | 1.004388 | 0.994169 | 1.001788 | 0.125308 | 0.999999 | 2.406573 | 21384.66 |
| 51 | 1.000000 | 1.000000 | 1.002465 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 0.0 | 1.000000 | 2.633335 | 25696.87 |

| N | Y/RN | O | O2 | NO | N | NO+ | N2 | E-/CC | Y IN | Y CM |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.23456D 00 | 0.0 | 0.0 | 0.0 | 0.76544D 00 | 0.0 | 0.0 | 0.0 |
| 2 | 0.00057 | 0.40516D-01 | 0.19136D 00 | 0.13313D-01 | 0.13368D-02 | 0.24702D-04 | 0.75345D 00 | 0.11792D 13 | 0.01627 | 0.04131 |
| 3 | 0.00118 | 0.73377D-01 | 0.15671D 00 | 0.23489D-01 | 0.29304D-02 | 0.46210D-04 | 0.74344D 00 | 0.16744D 13 | 0.03334 | 0.08470 |
| 4 | 0.00181 | 0.10181D 00 | 0.12733D 00 | 0.31359D-01 | 0.51663D-02 | 0.67112D-04 | 0.73427D 00 | 0.20019D 13 | 0.05128 | 0.13024 |
| 5 | 0.00247 | 0.12696D 00 | 0.10208D 00 | 0.37179D-01 | 0.82963D-02 | 0.88469D-04 | 0.72540D 00 | 0.22703D 13 | 0.07011 | 0.17807 |
| 6 | 0.00317 | 0.14933D 00 | 0.80462D-01 | 0.41080D-01 | 0.12518D-01 | 0.11092D-03 | 0.71650D 00 | 0.25193D 13 | 0.08988 | 0.22829 |
| 7 | 0.00391 | 0.16918D 00 | 0.62187D-01 | 0.43183D-01 | 0.17981D-01 | 0.13495D-03 | 0.70733D 00 | 0.27678D 13 | 0.11064 | 0.28102 |
| 8 | 0.00467 | 0.18669D 00 | 0.47030D-01 | 0.43655D-01 | 0.24780D-01 | 0.16096D-03 | 0.69768D 00 | 0.30268D 13 | 0.13243 | 0.33638 |
| 9 | 0.00548 | 0.20198D 00 | 0.34749D-01 | 0.42721D-01 | 0.32955D-01 | 0.18928D-03 | 0.68740D 00 | 0.33031D 13 | 0.15532 | 0.39452 |
| 10 | 0.00633 | 0.21520D 00 | 0.25061D-01 | 0.40662D-01 | 0.42487D-01 | 0.22019D-03 | 0.67637D 00 | 0.36007D 13 | 0.17935 | 0.45556 |
| 11 | 0.00722 | 0.22650D 00 | 0.17638D-01 | 0.37789D-01 | 0.53302D-01 | 0.25385D-03 | 0.66451D 00 | 0.39213D 13 | 0.20459 | 0.51965 |
| 12 | 0.00816 | 0.23608D 00 | 0.12123D-01 | 0.34420D-01 | 0.65285D-01 | 0.29032D-03 | 0.65180D 00 | 0.42650D 13 | 0.23108 | 0.58695 |
| 13 | 0.00914 | 0.24411D 00 | 0.81552D-02 | 0.30849D-01 | 0.78285D-01 | 0.32953D-03 | 0.63827D 00 | 0.46301D 13 | 0.25890 | 0.65761 |
| 14 | 0.01017 | 0.25081D 00 | 0.53909D-02 | 0.27321D-01 | 0.92130D-01 | 0.37132D-03 | 0.62398D 00 | 0.50135D 13 | 0.28811 | 0.73181 |
| 15 | 0.01125 | 0.25635D 00 | 0.35253D-02 | 0.24022D-01 | 0.10663D 00 | 0.41538D-03 | 0.60906D 00 | 0.54111D 13 | 0.31878 | 0.80971 |
| 16 | 0.01239 | 0.26090D 00 | 0.23037D-02 | 0.21071D-01 | 0.12160D 00 | 0.46133D-03 | 0.59366D 00 | 0.58180D 13 | 0.35099 | 0.89151 |
| 17 | 0.01358 | 0.26462D 00 | 0.15252D-02 | 0.18528D-01 | 0.13683D 00 | 0.50871D-03 | 0.57798D 00 | 0.62291D 13 | 0.38480 | 0.97740 |
| 18 | 0.01484 | 0.26763D 00 | 0.10399D-02 | 0.16401D-01 | 0.15214D 00 | 0.55703D-03 | 0.56223D 00 | 0.66389D 13 | 0.42031 | 1.06759 |
| 19 | 0.01615 | 0.27001D 00 | 0.74173D-03 | 0.14666D-01 | 0.16733D 00 | 0.60577D-03 | 0.54665D 00 | 0.70425D 13 | 0.45759 | 1.16228 |
| 20 | 0.01753 | 0.27185D 00 | 0.55921D-03 | 0.13278D-01 | 0.18221D 00 | 0.65439D-03 | 0.53145D 00 | 0.74354D 13 | 0.49674 | 1.26171 |
| 21 | 0.01898 | 0.27321D 00 | 0.44649D-03 | 0.12185D-01 | 0.19658D 00 | 0.70241D-03 | 0.51688D 00 | 0.78137D 13 | 0.53784 | 1.36611 |
| 22 | 0.02051 | 0.27412D 00 | 0.37534D-03 | 0.11334D-01 | 0.21027D 00 | 0.74934D-03 | 0.50315D 00 | 0.81742D 13 | 0.58100 | 1.47573 |
| 23 | 0.02211 | 0.27462D 00 | 0.32902D-03 | 0.10680D-01 | 0.22308D 00 | 0.79476D-03 | 0.49050D 00 | 0.85148D 13 | 0.62631 | 1.59083 |
| 24 | 0.02379 | 0.27472D 00 | 0.29793D-03 | 0.10185D-01 | 0.23485D 00 | 0.83827D-03 | 0.47911D 00 | 0.88336D 13 | 0.67389 | 1.71169 |
| 25 | 0.02555 | 0.27445D 00 | 0.27665D-03 | 0.98235D-02 | 0.24541D 00 | 0.87956D-03 | 0.46916D 00 | 0.91298D 13 | 0.72385 | 1.83859 |
| 26 | 0.02740 | 0.27382D 00 | 0.26220D-03 | 0.95748D-02 | 0.25462D 00 | 0.91835D-03 | 0.46081D 00 | 0.94031D 13 | 0.77631 | 1.97183 |
| 27 | 0.02935 | 0.27284D 00 | 0.25292D-03 | 0.94270D-02 | 0.26235D 00 | 0.95443D-03 | 0.45417D 00 | 0.96537D 13 | 0.83139 | 2.11174 |
| 28 | 0.03139 | 0.27153D 00 | 0.24792D-03 | 0.93728D-02 | 0.26852D 00 | 0.98768D-03 | 0.44934D 00 | 0.98821D 13 | 0.88923 | 2.25864 |
| 29 | 0.03353 | 0.26991D 00 | 0.24674D-03 | 0.94094D-02 | 0.27305D 00 | 0.10180D-02 | 0.44637D 00 | 0.10090D 14 | 0.94996 | 2.41289 |
| 30 | 0.03578 | 0.26799D 00 | 0.24918D-03 | 0.95367D-02 | 0.27594D 00 | 0.10456D-02 | 0.44524D 00 | 0.10278D 14 | 1.01372 | 2.57485 |
| 31 | 0.03815 | 0.26578D 00 | 0.25526D-03 | 0.97570D-02 | 0.27720D 00 | 0.10704D-02 | 0.44594D 00 | 0.10448D 14 | 1.08067 | 2.74490 |
| 32 | 0.04063 | 0.26332D 00 | 0.26512D-03 | 0.10075D-01 | 0.27688D 00 | 0.10926D-02 | 0.44836D 00 | 0.10603D 14 | 1.15097 | 2.92346 |
| 33 | 0.04323 | 0.26061D 00 | 0.27906D-03 | 0.10496D-01 | 0.27510D 00 | 0.11127D-02 | 0.45240D 00 | 0.10745D 14 | 1.22478 | 3.11095 |
| 34 | 0.04597 | 0.25766D 00 | 0.29755D-03 | 0.11029D-01 | 0.27197D 00 | 0.11310D-02 | 0.45791D 00 | 0.10876D 14 | 1.30229 | 3.30781 |
| 35 | 0.04884 | 0.25450D 00 | 0.32122D-03 | 0.11686D-01 | 0.26762D 00 | 0.11478D-02 | 0.46473D 00 | 0.11000D 14 | 1.38367 | 3.51452 |
| 36 | 0.05186 | 0.25112D 00 | 0.35099D-03 | 0.12482D-01 | 0.26220D 00 | 0.11635D-02 | 0.47269D 00 | 0.11118D 14 | 1.46912 | 3.73156 |
| 37 | 0.05502 | 0.24752D 00 | 0.38813D-03 | 0.13438D-01 | 0.25584D 00 | 0.11786D-02 | 0.48163D 00 | 0.11232D 14 | 1.55884 | 3.95945 |
| 38 | 0.05835 | 0.24372D 00 | 0.43445D-03 | 0.14585D-01 | 0.24866D 00 | 0.11933D-02 | 0.49141D 00 | 0.11342D 14 | 1.65305 | 4.19874 |
| 39 | 0.06184 | 0.23969D 00 | 0.49257D-03 | 0.15964D-01 | 0.24072D 00 | 0.12075D-02 | 0.50192D 00 | 0.11446D 14 | 1.75196 | 4.44999 |
| 40 | 0.06551 | 0.23542D 00 | 0.56637D-03 | 0.17636D-01 | 0.23208D 00 | 0.12209D-02 | 0.51308D 00 | 0.11539D 14 | 1.85583 | 4.71380 |
| 41 | 0.06936 | 0.23089D 00 | 0.66176D-03 | 0.19689D-01 | 0.22272D 00 | 0.12326D-02 | 0.52481D 00 | 0.11610D 14 | 1.96489 | 4.99081 |
| 42 | 0.07340 | 0.22604D 00 | 0.78807D-03 | 0.22248D-01 | 0.21260D 00 | 0.12407D-02 | 0.53708D 00 | 0.11637D 14 | 2.07940 | 5.28166 |
| 43 | 0.07764 | 0.22080D 00 | 0.96089D-03 | 0.25492D-01 | 0.20163D 00 | 0.12414D-02 | 0.54988D 00 | 0.11583D 14 | 2.19963 | 5.58706 |
| 44 | 0.08210 | 0.21508D 00 | 0.12089D-02 | 0.29671D-01 | 0.18961D 00 | 0.12286D-02 | 0.56319D 00 | 0.11388D 14 | 2.32588 | 5.90773 |
| 45 | 0.08678 | 0.20872D 00 | 0.15945D-02 | 0.35112D-01 | 0.17628D 00 | 0.11924D-02 | 0.57710D 00 | 0.10956D 14 | 2.45844 | 6.24443 |
| 46 | 0.09169 | 0.20147D 00 | 0.22835D-02 | 0.42181D-01 | 0.16113D 00 | 0.11178D-02 | 0.59182D 00 | 0.10151D 14 | 2.59762 | 6.59797 |
| 47 | 0.09685 | 0.19286D 00 | 0.38066D-02 | 0.51061D-01 | 0.14331D 00 | 0.98579D-03 | 0.60797D 00 | 0.88087D 13 | 2.74377 | 6.96918 |
| 48 | 0.10227 | 0.18178D 00 | 0.80512D-02 | 0.60954D-01 | 0.12132D 00 | 0.77904D-03 | 0.62711D 00 | 0.68032D 13 | 2.89723 | 7.35895 |
| 49 | 0.10795 | 0.16442D 00 | 0.21941D-01 | 0.67578D-01 | 0.92658D-01 | 0.49917D-03 | 0.65290D 00 | 0.42193D 13 | 3.05835 | 7.76822 |
| 50 | 0.11393 | 0.12531D 00 | 0.70344D-01 | 0.56865D-01 | 0.53727D-01 | 0.19683D-03 | 0.69356D 00 | 0.15975D 13 | 3.22754 | 8.19794 |
| 51 | 0.12020 | 0.0 | 0.23456D 00 | 0.0 | 0.0 | 0.0 | 0.76544D 00 | 0.0 | 3.40518 | 8.64915 |

## Listing of the Unit 6 Output Data for the 31° Hyperboloid Binary-Gas Sample Case

```
FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS


&INPUT
ALT=  245000.0000000000    ,BRAD=  2.360833000000000    ,CAINF= 0.0                      ,CAT=  1.000000000000000    ,CAW=
 0.0                    ,CCFAC= 0.0                    ,CONVRG= 0.9999997913837432D-02,DS= 0.2000000000000000    ,DSMAX=
  3.000000000000000     ,HANGLE=  31.00000000000000     ,PRNTCI= 0.0                ,RINF= 0.8672510279999999D-07,SEND=
  43.00000000000000     ,SIGM= 0.6999999880790710     ,SITEST= 0.9999999019782990D-04,SMALLT= 0.9999994290410541D-06,SSFAC=
 -1.000000000000000     ,SWFAC= -1.000000000000000     ,TB=  2460.000000000000     ,THINI= -1.000000000000000     ,TINF=
  361.4800000000000     ,UFAC= 0.5000000000000000     ,UINF=  25100.00000000000     ,WVFAC= 0.2500000000000000     ,XKETA=
  1.050000000000000     ,XLE=  1.399999618530273     ,XNSO= 0.1165999770164490     ,IE=           51,IEND=          6,IGEOM=          1,
IUN=          19,JFAC=           1,KEND=           1,KPLTTP=           0,KTWAL=           0,NAN=           1,NDATA=           1,NITMAX=
       9999,NITMIN=           3,NITMNI=           3,NS=           2,NSI=           2,NSPRF=           0,NTSH=          20,NTTWA=
          5
&END


LOG  RATES MATCH 6 SPECIE BLOTTNER-SANDIA

NR                REACTION               CRO        EXP(CRO)       CR1       CR2       DRO       EXP(DRO)       DR1      DR2
 1   O2    O2       =O     O    O2    44.9274640  0.3249D 20    59400.0    -1.0   37.8379411  0.2709D 17     0.0     -0.5
 2   O2    O        =O     O    O     45.9491153  0.9025D 20    59400.0    -1.0   38.8595923  0.7525D 17     0.0     -0.5

                 ALPHSB( 2, 2)
NR    ALSUB      NR      O      O2
 1     1.0        1      0.     2.
 2     1.0        2      1.     1.

                 BETASB( 2, 2)
NR  BETSUB       NR      O      O2
 1     2.0        1      2.     1.
 2     2.0        2      3.     0.

   GAMMPL( 2, 2)
 1     2.     0.
 2     2.     0.

   GAMMMI( 2, 2)
 1     0.     1.
 2     0.     1.

VSREF =   0.19332065D-04

  VSINF =   0.46451309D-06
```

```
K =1, I =   1, S =  0.0   , NITER =  1, DIFI = 4.253D 01 2.519D 00 0.0       1.000D 00
K =1, I =   1, S =  0.0   , NITER =  2, DIFI = 5.545D-01 2.008D 00 4.533D-01 1.442D 04
K =1, I =   1, S =  0.0   , NITER =  3, DIFI = 3.528D-01 2.539D-01 2.349D-01 2.542D 01
K =1, I =   1, S =  0.0   , NITER =  4, DIFI = 6.529D-02 3.417D-01 5.856D-02 9.870D 00
K =1, I =   1, S =  0.0   , NITER =  5, DIFI = 1.067D-01 3.887D-01 2.984D-01 4.251D 01
K =1, I =   1, S =  0.0   , NITER =  6, DIFI = 9.082D-02 2.376D-01 3.892D-01 7.778D 00
K =1, I =   1, S =  0.0   , NITER =  7, DIFI = 4.070D-02 3.471D-02 1.179D-01 1.504D 00
K =1, I =   1, S =  0.0   , NITER =  8, DIFI = 2.924D-02 3.617D-02 1.878D-02 9.356D-01
K =1, I =   1, S =  0.0   , NITER =  9, DIFI = 5.070D-02 3.601D-02 6.021D-02 1.115D 00
K =1, I =   1, S =  0.0   , NITER = 10, DIFI = 4.184D-02 2.709D-02 4.974D-02 9.068D-01
K =1, I =   1, S =  0.0   , NITER = 11, DIFI = 3.371D-02 2.058D-02 3.694D-02 6.673D-01
K =1, I =   1, S =  0.0   , NITER = 12, DIFI = 2.878D-02 1.745D-02 3.018D-02 5.339D-01
K =1, I =   1, S =  0.0   , NITER = 13, DIFI = 2.479D-02 1.512D-02 2.629D-02 4.379D-01
K =1, I =   1, S =  0.0   , NITER = 14, DIFI = 2.116D-02 1.279D-02 2.285D-02 3.569D-01
K =1, I =   1, S =  0.0   , NITER = 15, DIFI = 1.791D-02 1.067D-02 1.945D-02 2.908D-01
K =1, I =   1, S =  0.0   , NITER = 16, DIFI = 1.511D-02 8.908D-03 1.640D-02 2.368D-01
K =1, I =   1, S =  0.0   , NITER = 17, DIFI = 1.272D-02 7.455D-03 1.383D-02 1.934D-01
K =1, I =   1, S =  0.0   , NITER = 18, DIFI = 1.070D-02 6.237D-03 1.165D-02 1.583D-01
K =1, I =   1, S =  0.0   , NITER = 19, DIFI = 8.977D-03 5.207D-03 9.800D-03 1.297D-01
K =1, I =   1, S =  0.0   , NITER = 20, DIFI = 7.521D-03 4.340D-03 8.221D-03 1.065D-01
K =1, I =   1, S =  0.0   , NITER = 21, DIFI = 6.291D-03 3.615D-03 6.885D-03 8.750D-02
K =1, I =   1, S =  0.0   , NITER = 22, DIFI = 5.198D-03 3.008D-03 5.758D-03 7.204D-02
K =1, I =   1, S =  0.0   , NITER = 23, DIFI = 4.057D-03 2.198D-03 3.985D-03 5.048D-02
K =1, I =   1, S =  0.0   , NITER = 24, DIFI = 3.742D-03 2.133D-03 3.638D-03 4.678D-02
K =1, I =   1, S =  0.0   , NITER = 25, DIFI = 3.212D-03 1.893D-03 3.411D-03 4.214D-02
K =1, I =   1, S =  0.0   , NITER = 26, DIFI = 2.663D-03 1.582D-03 2.981D-03 3.611D-02
K =1, I =   1, S =  0.0   , NITER = 27, DIFI = 2.199D-03 1.304D-03 2.529D-03 3.030D-02
K =1, I =   1, S =  0.0   , NITER = 28, DIFI = 1.826D-03 1.074D-03 2.131D-03 2.526D-02
K =1, I =   1, S =  0.0   , NITER = 29, DIFI = 1.520D-03 8.824D-04 1.786D-03 2.095D-02
K =1, I =   1, S =  0.0   , NITER = 30, DIFI = 1.264D-03 7.213D-04 1.490D-03 1.729D-02
K =1, I =   1, S =  0.0   , NITER = 31, DIFI = 1.047D-03 5.871D-04 1.237D-03 1.418D-02
K =1, I =   1, S =  0.0   , NITER = 32, DIFI = 8.649D-04 4.763D-04 1.023D-03 1.159D-02
K =1, I =   1, S =  0.0   , NITER = 33, DIFI = 7.120D-04 3.852D-04 8.423D-04 9.435D-03

   UINF       PINF          TINF          CAINF       TB          BRAD          PR         LE          YSH           ALT
 0.251D 05  0.48676D-01  0.36148D 03   0.0         0.2460D 04  0.2361D 01   0.700 00   0.14D 01   0.5766D-01   0.245D 06

 THIN SHOCK LAYER  NO WALL SLIP  NO SHOCK SLIP    CAT WALL NO STEPS IN Y= 51 NO STEPS IN S=  6 S STEP SIZE=0.200

  TW/TS    EPS      REYINF       REYSH        TREF         UREF         RREF         PREF       ITER
0.0637   0.0613   0.1106D 05   0.6576D 03   0.1147D 06   0.2510D 05   0.8673D-07   0.5464D 02   1


  ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS              ****


    S          X           R           YSH          YSHP          XSH          RSH       NO ITER    NITTOT    NTOT    I     K
 0.0        0.0         0.0         0.057656     0.0         -0.057656     0.0          33          33       33     1     1

    DS         CF          HEAT        STAN         CDF          CDP         CDTOT        PWALL       TWALL         PW/PO
 0.200000   0.0         0.039524    0.082447     0.0         1.763935     1.763935     0.881967 2460.000000     1.000000

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.0        0.000000     0.0          1.471372    1.471372    1.000000    0.981643

     USH          VSH          TSH          RSH          PSH          VPG
    0.0        -0.105803     0.333258     9.404841     0.885758     0.0
        0.0    -2655.66      38214.38
```

| N | Y/YSH | U/USH | V/VSH | T/TSH | R/RSH | P/PSH(APPR) | P/PSH | CA | CAEQ | XM | T DEG R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.064374 | 15.467829 | 0.995721 | 1.065372 | 0.0 | 0.000002 | 0.0 | 2460.00 |
| 2 | 0.004777 | 0.041799 | 0.000107 | 0.082102 | 11.344995 | 0.995721 | 1.065373 | 0.069065 | 0.000278 | 0.000123 | 3137.48 |
| 3 | 0.009792 | 0.079597 | 0.000491 | 0.097529 | 9.021547 | 0.995722 | 1.065374 | 0.131751 | 0.004413 | 0.000506 | 3727.02 |
| 4 | 0.015059 | 0.114691 | 0.001185 | 0.111492 | 7.503604 | 0.995725 | 1.065375 | 0.190296 | 0.027867 | 0.001119 | 4260.59 |
| 5 | 0.020588 | 0.147769 | 0.002219 | 0.124411 | 6.424345 | 0.995729 | 1.065378 | 0.245887 | 0.103508 | 0.001945 | 4754.29 |
| 6 | 0.026394 | 0.179246 | 0.003623 | 0.136533 | 5.613617 | 0.995734 | 1.065380 | 0.299224 | 0.265575 | 0.002972 | 5217.53 |
| 7 | 0.032491 | 0.209382 | 0.005425 | 0.148012 | 4.980766 | 0.995741 | 1.065382 | 0.350738 | 0.502943 | 0.004194 | 5656.19 |
| 8 | 0.038892 | 0.238355 | 0.007656 | 0.158947 | 4.472651 | 0.995750 | 1.065383 | 0.400706 | 0.732528 | 0.005606 | 6074.06 |
| 9 | 0.045614 | 0.266281 | 0.010342 | 0.169406 | 4.055795 | 0.995761 | 1.065382 | 0.449305 | 0.878476 | 0.007205 | 6473.76 |
| 10 | 0.052671 | 0.293241 | 0.013513 | 0.179443 | 3.707887 | 0.995774 | 1.065377 | 0.496632 | 0.947201 | 0.008992 | 6857.30 |
| 11 | 0.060081 | 0.319288 | 0.017198 | 0.189105 | 3.413367 | 0.995788 | 1.065368 | 0.542715 | 0.976103 | 0.010967 | 7226.52 |
| 12 | 0.067862 | 0.344453 | 0.021426 | 0.198444 | 3.160953 | 0.995805 | 1.065353 | 0.587523 | 0.988411 | 0.013128 | 7583.43 |
| 13 | 0.076032 | 0.368754 | 0.026226 | 0.207522 | 2.942221 | 0.995823 | 1.065330 | 0.630962 | 0.993978 | 0.015479 | 7930.34 |
| 14 | 0.084610 | 0.392197 | 0.031633 | 0.216410 | 2.750747 | 0.995844 | 1.065298 | 0.672886 | 0.996676 | 0.018023 | 8269.96 |
| 15 | 0.093617 | 0.414780 | 0.037680 | 0.225187 | 2.581544 | 0.995867 | 1.065255 | 0.713101 | 0.998072 | 0.020765 | 8605.38 |
| 16 | 0.103075 | 0.436495 | 0.044406 | 0.233943 | 2.430701 | 0.995892 | 1.065198 | 0.751373 | 0.998836 | 0.023710 | 8939.99 |
| 17 | 0.113006 | 0.457335 | 0.051850 | 0.242770 | 2.295148 | 0.995920 | 1.065125 | 0.787438 | 0.999274 | 0.026867 | 9277.32 |
| 18 | 0.123433 | 0.477291 | 0.060056 | 0.251758 | 2.172493 | 0.995950 | 1.065033 | 0.821021 | 0.999536 | 0.030245 | 9620.79 |
| 19 | 0.134381 | 0.496361 | 0.069063 | 0.260984 | 2.060909 | 0.995982 | 1.064919 | 0.851854 | 0.999697 | 0.033853 | 9973.34 |
| 20 | 0.145877 | 0.514549 | 0.078910 | 0.270504 | 1.959036 | 0.996017 | 1.064780 | 0.879696 | 0.999799 | 0.037696 | 10337.14 |
| 21 | 0.157947 | 0.531868 | 0.089625 | 0.280344 | 1.865907 | 0.996054 | 1.064613 | 0.904358 | 0.999865 | 0.041780 | 10713.16 |
| 22 | 0.170621 | 0.548342 | 0.101224 | 0.290487 | 1.780882 | 0.996093 | 1.064413 | 0.925726 | 0.999907 | 0.046110 | 11100.77 |
| 23 | 0.183929 | 0.564008 | 0.113703 | 0.300867 | 1.703573 | 0.996135 | 1.064178 | 0.943784 | 0.999935 | 0.050685 | 11497.43 |
| 24 | 0.197902 | 0.578915 | 0.127035 | 0.311364 | 1.633765 | 0.996180 | 1.063905 | 0.958624 | 0.999954 | 0.055499 | 11898.58 |
| 25 | 0.212574 | 0.593126 | 0.141168 | 0.321810 | 1.571338 | 0.996227 | 1.063593 | 0.970448 | 0.999966 | 0.060541 | 12297.76 |
| 26 | 0.227980 | 0.606715 | 0.156023 | 0.331997 | 1.516193 | 0.996277 | 1.063239 | 0.979559 | 0.999975 | 0.065798 | 12687.07 |
| 27 | 0.244155 | 0.619764 | 0.171509 | 0.341702 | 1.468186 | 0.996330 | 1.062843 | 0.986330 | 0.999980 | 0.071254 | 13057.91 |
| 28 | 0.261140 | 0.632369 | 0.187523 | 0.350704 | 1.427087 | 0.996387 | 1.062406 | 0.991174 | 0.999984 | 0.076893 | 13401.93 |
| 29 | 0.278974 | 0.644629 | 0.203972 | 0.358817 | 1.392553 | 0.996446 | 1.061927 | 0.994506 | 0.999987 | 0.082702 | 13711.98 |
| 30 | 0.297699 | 0.656651 | 0.220781 | 0.365907 | 1.364131 | 0.996510 | 1.061407 | 0.996705 | 0.999989 | 0.088677 | 13982.92 |
| 31 | 0.317361 | 0.668546 | 0.237904 | 0.371904 | 1.341267 | 0.996578 | 1.060843 | 0.998095 | 0.999990 | 0.094822 | 14212.08 |
| 32 | 0.338006 | 0.680426 | 0.255336 | 0.376805 | 1.323338 | 0.996651 | 1.060235 | 0.998937 | 0.999991 | 0.101150 | 14399.35 |
| 33 | 0.359683 | 0.692403 | 0.273109 | 0.380667 | 1.309674 | 0.996729 | 1.059578 | 0.999421 | 0.999992 | 0.107683 | 14546.94 |
| 34 | 0.382443 | 0.704588 | 0.291295 | 0.383595 | 1.299592 | 0.996813 | 1.058865 | 0.999684 | 0.999992 | 0.114451 | 14658.86 |
| 35 | 0.406342 | 0.717086 | 0.310002 | 0.385728 | 1.292423 | 0.996903 | 1.058088 | 0.999814 | 0.999993 | 0.121495 | 14740.37 |
| 36 | 0.431436 | 0.729993 | 0.329367 | 0.387218 | 1.287531 | 0.997001 | 1.057235 | 0.999862 | 0.999993 | 0.128859 | 14797.31 |
| 37 | 0.457785 | 0.743397 | 0.349546 | 0.388218 | 1.284344 | 0.997108 | 1.056293 | 0.999857 | 0.999993 | 0.136596 | 14835.53 |
| 38 | 0.485451 | 0.757378 | 0.370710 | 0.388872 | 1.282359 | 0.997223 | 1.055244 | 0.999806 | 0.999993 | 0.144760 | 14860.50 |
| 39 | 0.514500 | 0.772004 | 0.393035 | 0.389305 | 1.281154 | 0.997348 | 1.054069 | 0.999701 | 0.999993 | 0.153407 | 14877.07 |
| 40 | 0.545002 | 0.787332 | 0.416704 | 0.389630 | 1.280379 | 0.997485 | 1.052745 | 0.999511 | 0.999993 | 0.162597 | 14889.47 |
| 41 | 0.577029 | 0.803414 | 0.441908 | 0.389948 | 1.279735 | 0.997634 | 1.051245 | 0.999180 | 0.999993 | 0.172391 | 14901.62 |
| 42 | 0.610657 | 0.820294 | 0.468861 | 0.390369 | 1.278932 | 0.997796 | 1.049539 | 0.998596 | 0.999993 | 0.182860 | 14917.71 |
| 43 | 0.645966 | 0.838011 | 0.497829 | 0.391043 | 1.277616 | 0.997974 | 1.047584 | 0.997552 | 0.999993 | 0.194089 | 14943.48 |
| 44 | 0.683041 | 0.856594 | 0.529190 | 0.392217 | 1.275240 | 0.998167 | 1.045327 | 0.995659 | 0.999994 | 0.206195 | 14988.35 |
| 45 | 0.721970 | 0.876057 | 0.563558 | 0.394347 | 1.270844 | 0.998379 | 1.042679 | 0.992158 | 0.999994 | 0.219363 | 15069.71 |
| 46 | 0.762845 | 0.896388 | 0.602050 | 0.398333 | 1.262606 | 0.998610 | 1.039492 | 0.985525 | 0.999994 | 0.233913 | 15222.03 |
| 47 | 0.805764 | 0.917514 | 0.646914 | 0.406094 | 1.246941 | 0.998861 | 1.035465 | 0.972505 | 0.999995 | 0.250484 | 15518.63 |
| 48 | 0.850829 | 0.939237 | 0.703167 | 0.422154 | 1.216488 | 0.999132 | 1.029906 | 0.945441 | 0.999996 | 0.270484 | 16132.36 |
| 49 | 0.898148 | 0.961086 | 0.783315 | 0.459144 | 1.155816 | 0.999418 | 1.021075 | 0.883076 | 0.999998 | 0.297423 | 17545.92 |
| 50 | 0.947832 | 0.981973 | 0.918610 | 0.563235 | 1.038886 | 0.999707 | 1.009357 | 0.708268 | 0.999999 | 0.341581 | 21523.68 |
| 51 | 1.000000 | 1.000000 | 1.002390 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 0.0 | 1.000000 | 0.359847 | 38214.38 |

```
K =1, I =  2, S =  0.200, NITER =  1, DIFI = 3.924D-02 7.939D-02 1.934D-02 8.090D-01
K =1, I =  2, S =  0.200, NITER =  2, DIFI = 4.566D-02 8.799D-03 5.121D-03 1.371D-01
K =1, I =  2, S =  0.200, NITER =  3, DIFI = 3.382D-03 5.031D-03 5.092D-03 9.156D-02
K =1, I =  2, S =  0.200, NITER =  4, DIFI = 7.382D-04 1.716D-03 2.521D-04 3.451D-03


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS                ****


     S            X            R           YSH          YSHP          XSH          RSH     NO ITER     NITTOT     NTOT    I     K
  0.200000     0.019709     0.198780     0.059531     0.018751    -0.038690     0.210333     4             37        37    2     1

     DS           CF          HEAT         STAN          CDF          CDP          CDTOT       PWALL        TWALL             PW/PO
  0.200000     0.013979     0.037700     0.078641     0.002730     1.655929     1.658658    0.838862 2460.000000        0.951126

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.000000    0.000000     0.018751     1.286004     1.286004    0.930449    0.856159

       USH          VSH           TSH          RSH          PSH         VPG
     0.190109    -0.103686     0.321006     9.426875     0.855116     0.0
      4771.75     -2602.52     36809.47
                               20449.72


K =1, I =  3, S =  0.400, NITER =  1, DIFI = 7.148D-02 1.372D-01 6.955D-02 6.379D 00
K =1, I =  3, S =  0.400, NITER =  2, DIFI = 8.167D-02 2.808D-02 2.000D-02 3.596D-01
K =1, I =  3, S =  0.400, NITER =  3, DIFI = 1.005D-02 1.116D-02 1.213D-02 2.055D-01
K =1, I =  3, S =  0.400, NITER =  4, DIFI = 2.866D-03 3.254D-03 1.402D-03 1.299D-02
K =1, I =  3, S =  0.400, NITER =  5, DIFI = 3.501D-04 1.093D-03 1.654D-03 2.665D-02
K =1, I =  3, S =  0.400, NITER =  6, DIFI = 4.410D-04 2.363D-04 1.825D-04 7.441D-03


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS                ****


     S            X            R           YSH          YSHP          XSH          RSH     NO ITER     NITTOT     NTOT    I     K
  0.400000     0.075579     0.390592     0.064482     0.030753     0.015372     0.413680     6             43        43    3     1

     DS           CF          HEAT         STAN          CDF          CDP          CDTOT       PWALL        TWALL             PW/PO
  0.200000     0.023314     0.033295     0.069452     0.005688     1.562459     1.568147    0.736973 2460.000000        0.835601

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.000000    0.000000     0.030753     1.132012     1.132012    0.770250    0.682420

       USH          VSH           TSH          RSH          PSH         VPG
     0.352899    -0.098578     0.291473     9.459808     0.779173     0.0
      8857.76     -2474.30     33422.95
                               18568.31
```

```
K =1, I =  4, S =  0.600, NITER =  1, DIFI = 6.459D-02 1.516D-01 1.321D-01 1.030D 01
K =1, I =  4, S =  0.600, NITER =  2, DIFI = 6.893D-02 2.434D-02 3.315D-02 3.028D-01
K =1, I =  4, S =  0.600, NITER =  3, DIFI = 1.645D-02 1.355D-02 1.847D-02 2.240D-01
K =1, I =  4, S =  0.600, NITER =  4, DIFI = 4.162D-03 3.551D-03 2.558D-03 1.829D-02
K =1, I =  4, S =  0.600, NITER =  5, DIFI = 1.614D-03 9.928D-04 2.681D-03 2.767D-02
K =1, I =  4, S =  0.600, NITER =  6, DIFI = 4.551D-04 2.645D-04 1.877D-04 5.134D-03


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS                ****


      S            X            R            YSH          YSHP          XSH           RSH       NO ITER     NITTOT      NTOT    I      K
  0.600000     0.160212     0.571609     0.071395     0.038378     0.097653     0.606013        6           49        49     4      1

     DS           CF          HEAT         STAN          CDF          CDP          CDTOT         PWALL        TWALL          PW/PO
  0.200000     0.027301     0.028282     0.058996     0.009255     1.441426     1.450681     0.624348 2460.000000     0.707904

 YSHP ( S   YSHP ( S+DS/2   NEW YSHP   ALPHA(S+DS/2 PHI(S+DS/2    KAPPA(S   KAPPA(S+DS/2
  -0.000000    0.000000     0.038378     1.011943     1.011943     0.599116     0.523715

        USH          VSH           TSH          RSH           PSH          VPG
      0.477527    -0.092728      0.257784     9.452562      0.688719      0.0
      11985.92     -2327.47      29559.90
                                 16422.17


K =1, I =  5, S =  0.800, NITER =  1, DIFI = 5.100D-02 1.379D-01 1.909D-01 5.540D 00
K =1, I =  5, S =  0.800, NITER =  2, DIFI = 3.851D-02 1.789D-02 4.861D-02 2.103D-01
K =1, I =  5, S =  0.800, NITER =  3, DIFI = 2.323D-02 1.496D-02 2.304D-02 1.618D-01
K =1, I =  5, S =  0.800, NITER =  4, DIFI = 2.381D-03 2.933D-03 4.452D-03 1.678D-02
K =1, I =  5, S =  0.800, NITER =  5, DIFI = 2.930D-03 1.340D-03 3.373D-03 1.762D-02
K =1, I =  5, S =  0.800, NITER =  6, DIFI = 1.679D-04 2.755D-04 1.208D-04 1.358D-03


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS                ****


      S            X            R            YSH          YSHP          XSH           RSH       NO ITER     NITTOT      NTOT    I      K
  0.800000     0.265984     0.741194     0.079502     0.042695     0.200721     0.786596        6           55        55     5      1

     DS           CF          HEAT         STAN          CDF          CDP          CDTOT         PWALL        TWALL          PW/PO
  0.200000     0.027935     0.023873     0.049799     0.012547     1.318926     1.331473     0.528085 2460.000000     0.598757

 YSHP ( S   YSHP ( S+DS/2   NEW YSHP   ALPHA(S+DS/2 PHI(S+DS/2    KAPPA(S   KAPPA(S+DS/2
   0.000000    0.000000     0.042695     0.920184     0.920184     0.457400     0.400051

        USH          VSH           TSH          RSH           PSH          VPG
      0.567944    -0.087477      0.227832     9.393196      0.604957      0.0
      14255.39     -2195.68      26125.29
                                 14514.06
```

```
K =1, I =  6, S =  1.000, NITER =  1, DIFI = 4.033D-02 1.195D-01 2.316D-01 2.382D 00
K =1, I =  6, S =  1.000, NITER =  2, DIFI = 1.000D-02 1.730D-02 6.420D-02 1.235D-01
K =1, I =  6, S =  1.000, NITER =  3, DIFI = 2.767D-02 1.560D-02 2.524D-02 9.768D-02
K =1, I =  6, S =  1.000, NITER =  4, DIFI = 2.814D-03 3.406D-03 6.291D-03 1.173D-02
K =1, I =  6, S =  1.000, NITER =  5, DIFI = 3.578D-03 1.307D-03 3.487D-03 8.456D-03


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, BINARY-GAS                ****


      S           X           R           YSH         YSHP        XSH         RSH      NO ITER     NITTOT     NTOT    I     K
   1.000000    0.386918    0.900366    0.088349    0.045774    0.318672    0.956473      5           60        60     6     1

      DS          CF          HEAT        STAN        CDF         CDP         CDTOT       PWALL       TWALL        PW/PO
   0.200000    0.027041    0.020347    0.042443    0.015234    1.208064    1.223298    0.453728 2460.000000    0.514450

  YSHP ( S   YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
    0.000000    0.000000    0.045774    0.849778    0.849778    0.350905    0.308952

        USH          VSH          TSH          RSH          PSH          VPG
      0.632912    -0.083156     0.203588     9.299610     0.535214     0.0
      15886.08     -2087.23     23345.19
                                12969.55
```

| N | Y/YSH | U/USH | V/VSH | T/TSH | R/RSH | P/PSH(APPR) | P/PSH | CA | CAEQ | XM | T DEG R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.105667 | 8.050302 | 0.847752 | 0.917449 | 0.0 | 0.000003 | 0.0 | 2466.81 |
| 2 | 0.004777 | 0.036003 | 0.000056 | 0.131821 | 6.120752 | 0.847756 | 0.917453 | 0.052327 | 0.000273 | 0.251505 | 3077.39 |
| 3 | 0.009792 | 0.069244 | 0.000257 | 0.153923 | 5.004202 | 0.847773 | 0.917469 | 0.100634 | 0.003502 | 0.440980 | 3593.37 |
| 4 | 0.015059 | 0.100716 | 0.000628 | 0.173325 | 4.261213 | 0.847811 | 0.917506 | 0.146427 | 0.019302 | 0.595177 | 4046.30 |
| 5 | 0.020588 | 0.130954 | 0.001191 | 0.190735 | 3.724962 | 0.847875 | 0.917568 | 0.190529 | 0.065651 | 0.726231 | 4452.74 |
| 6 | 0.026394 | 0.160276 | 0.001972 | 0.206585 | 3.316734 | 0.847968 | 0.917659 | 0.233433 | 0.162116 | 0.840647 | 4822.76 |
| 7 | 0.032491 | 0.188885 | 0.002997 | 0.221156 | 2.994102 | 0.848094 | 0.917782 | 0.275453 | 0.314721 | 0.942390 | 5162.93 |
| 8 | 0.038892 | 0.216911 | 0.004293 | 0.234642 | 2.731987 | 0.848256 | 0.917939 | 0.316790 | 0.501759 | 1.034031 | 5477.76 |
| 9 | 0.045614 | 0.244438 | 0.005889 | 0.247183 | 2.514512 | 0.848458 | 0.918135 | 0.357571 | 0.679370 | 1.117358 | 5770.52 |
| 10 | 0.052671 | 0.271514 | 0.007815 | 0.258883 | 2.331075 | 0.848703 | 0.918373 | 0.397872 | 0.811933 | 1.193819 | 6043.68 |
| 11 | 0.060081 | 0.298166 | 0.010103 | 0.269829 | 2.174284 | 0.848994 | 0.918656 | 0.437723 | 0.894061 | 1.264352 | 6299.20 |
| 12 | 0.067862 | 0.324395 | 0.012787 | 0.280092 | 2.038795 | 0.849335 | 0.918986 | 0.477120 | 0.939952 | 1.329654 | 6538.79 |
| 13 | 0.076032 | 0.350192 | 0.015903 | 0.289739 | 1.920632 | 0.849731 | 0.919368 | 0.516020 | 0.964842 | 1.390326 | 6764.02 |
| 14 | 0.084610 | 0.375529 | 0.019486 | 0.298837 | 1.816767 | 0.850184 | 0.919805 | 0.554350 | 0.978537 | 1.446762 | 6976.41 |
| 15 | 0.093617 | 0.400371 | 0.023577 | 0.307450 | 1.724840 | 0.850700 | 0.920301 | 0.592003 | 0.986337 | 1.499168 | 7177.49 |
| 16 | 0.103075 | 0.424672 | 0.028217 | 0.315646 | 1.642990 | 0.851283 | 0.920858 | 0.628842 | 0.990962 | 1.547780 | 7368.81 |
| 17 | 0.113006 | 0.448379 | 0.033447 | 0.323489 | 1.569734 | 0.851936 | 0.921480 | 0.664704 | 0.993818 | 1.592796 | 7551.91 |
| 18 | 0.123433 | 0.471438 | 0.039311 | 0.331044 | 1.503884 | 0.852664 | 0.922171 | 0.699398 | 0.995649 | 1.634398 | 7728.27 |
| 19 | 0.134381 | 0.493794 | 0.045855 | 0.338368 | 1.444494 | 0.853472 | 0.922932 | 0.732719 | 0.996862 | 1.672774 | 7899.25 |
| 20 | 0.145877 | 0.515395 | 0.053122 | 0.345509 | 1.390813 | 0.854363 | 0.923766 | 0.764444 | 0.997689 | 1.708136 | 8065.98 |
| 21 | 0.157947 | 0.536196 | 0.061155 | 0.352504 | 1.342261 | 0.855343 | 0.924676 | 0.794348 | 0.998267 | 1.740829 | 8229.28 |
| 22 | 0.170621 | 0.556164 | 0.069993 | 0.359369 | 1.298397 | 0.856415 | 0.925663 | 0.822210 | 0.998679 | 1.771088 | 8389.54 |
| 23 | 0.183929 | 0.575280 | 0.079666 | 0.366099 | 1.258906 | 0.857584 | 0.926731 | 0.847821 | 0.998977 | 1.799243 | 8546.65 |
| 24 | 0.197902 | 0.593541 | 0.090198 | 0.372663 | 1.223578 | 0.858855 | 0.927880 | 0.870998 | 0.999196 | 1.825722 | 8699.88 |
| 25 | 0.212574 | 0.610964 | 0.101599 | 0.379002 | 1.192289 | 0.860235 | 0.929114 | 0.891593 | 0.999357 | 1.851017 | 8847.87 |
| 26 | 0.227980 | 0.627588 | 0.113867 | 0.385032 | 1.164984 | 0.861729 | 0.930435 | 0.909502 | 0.999476 | 1.875684 | 8988.64 |
| 27 | 0.244155 | 0.643468 | 0.126981 | 0.390645 | 1.141656 | 0.863345 | 0.931848 | 0.924669 | 0.999564 | 1.900319 | 9119.67 |
| 28 | 0.261140 | 0.658682 | 0.140907 | 0.395717 | 1.122326 | 0.865092 | 0.933360 | 0.937095 | 0.999629 | 1.925547 | 9238.08 |
| 29 | 0.278974 | 0.673323 | 0.155601 | 0.400122 | 1.107015 | 0.866983 | 0.934977 | 0.946827 | 0.999676 | 1.951994 | 9340.92 |
| 30 | 0.297699 | 0.687500 | 0.171007 | 0.403745 | 1.095727 | 0.869028 | 0.936710 | 0.953957 | 0.999710 | 1.980262 | 9425.49 |
| 31 | 0.317361 | 0.701328 | 0.187078 | 0.406498 | 1.088422 | 0.871246 | 0.938573 | 0.958607 | 0.999732 | 2.010902 | 9489.77 |
| 32 | 0.338006 | 0.714932 | 0.203772 | 0.408338 | 1.085000 | 0.873655 | 0.940579 | 0.960915 | 0.999746 | 2.044390 | 9532.74 |
| 33 | 0.359683 | 0.728433 | 0.221077 | 0.409279 | 1.085280 | 0.876277 | 0.942747 | 0.961017 | 0.999752 | 2.081114 | 9554.70 |
| 34 | 0.382443 | 0.741951 | 0.239008 | 0.409396 | 1.088991 | 0.879137 | 0.945097 | 0.959030 | 0.999752 | 2.121315 | 9557.42 |
| 35 | 0.406342 | 0.755593 | 0.257626 | 0.408826 | 1.095774 | 0.882266 | 0.947649 | 0.955042 | 0.999747 | 2.165132 | 9544.12 |
| 36 | 0.431436 | 0.769451 | 0.277032 | 0.407758 | 1.105193 | 0.885697 | 0.950427 | 0.949096 | 0.999738 | 2.212602 | 9519.20 |
| 37 | 0.457785 | 0.783599 | 0.297365 | 0.406418 | 1.116758 | 0.889465 | 0.953451 | 0.941187 | 0.999725 | 2.263642 | 9487.89 |
| 38 | 0.485451 | 0.798089 | 0.318799 | 0.405045 | 1.129957 | 0.893612 | 0.956744 | 0.931259 | 0.999712 | 2.318084 | 9455.86 |
| 39 | 0.514500 | 0.812949 | 0.341530 | 0.403887 | 1.144286 | 0.898181 | 0.960326 | 0.919202 | 0.999699 | 2.375712 | 9428.81 |
| 40 | 0.545002 | 0.828188 | 0.365772 | 0.403181 | 1.159272 | 0.903219 | 0.964216 | 0.904857 | 0.999689 | 2.436276 | 9412.34 |
| 41 | 0.577029 | 0.843795 | 0.391752 | 0.403169 | 1.174463 | 0.908777 | 0.968428 | 0.888010 | 0.999685 | 2.499499 | 9412.05 |
| 42 | 0.610657 | 0.859739 | 0.419732 | 0.404107 | 1.189393 | 0.914908 | 0.972972 | 0.868396 | 0.999688 | 2.565047 | 9433.95 |
| 43 | 0.645966 | 0.875976 | 0.450029 | 0.406309 | 1.203510 | 0.921665 | 0.977846 | 0.845676 | 0.999703 | 2.632480 | 9485.35 |
| 44 | 0.683041 | 0.892441 | 0.483077 | 0.410201 | 1.216056 | 0.929104 | 0.983029 | 0.819410 | 0.999728 | 2.701197 | 9576.22 |
| 45 | 0.721970 | 0.909052 | 0.519528 | 0.416436 | 1.225870 | 0.937276 | 0.988464 | 0.788961 | 0.999767 | 2.770290 | 9721.78 |
| 46 | 0.762845 | 0.925695 | 0.560465 | 0.426111 | 1.231037 | 0.946218 | 0.994018 | 0.753294 | 0.999815 | 2.838079 | 9947.65 |
| 47 | 0.805764 | 0.942218 | 0.607873 | 0.441289 | 1.228214 | 0.955946 | 0.999404 | 0.710457 | 0.999870 | 2.901853 | 10301.97 |
| 48 | 0.850829 | 0.958399 | 0.665812 | 0.466405 | 1.211172 | 0.966421 | 1.003963 | 0.656121 | 0.999925 | 2.956807 | 10888.32 |
| 49 | 0.898148 | 0.973889 | 0.743720 | 0.512991 | 1.167655 | 0.977488 | 1.006091 | 0.578614 | 0.999969 | 2.994015 | 11975.87 |
| 50 | 0.947832 | 0.988084 | 0.864811 | 0.620638 | 1.075938 | 0.988768 | 1.004440 | 0.436357 | 0.999993 | 3.000035 | 14488.92 |
| 51 | 1.000000 | 1.000000 | 0.989477 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 0.0 | 1.000000 | 3.050047 | 23345.19 |

Listing of the Unit 6 Output Data for the 31° Hyperboloid 7-Species Sample Case

FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES

```
&INPUT
ALT=  245000.000000000    ,BRAD=  2.36083300000000    ,CAINF= 0.0                       ,CAT=  1.00000000000000    ,CAW=
 0.0                    ,CCFAC= 0.0                  ,CONVRG= 0.99999979138374320-02,DS= 0.200000000000000    ,DSMAX=
  3.00000000000000      ,HANGLE=  31.0000000000000    ,PRNTCI= 0.0                ,RINF= 0.86725102799999990-07,SEND=
  43.0000000000000      ,SIGM= 0.699999988079071     ,SITEST= 0.99999990197829900-04,SMALLT= 0.99999942904105410-06,SSFAC=
 -1.00000000000000      ,SWFAC= -1.00000000000000     ,TB=  2460.00000000000     ,THINI= -1.00000000000000    ,TINF=
  361.480000000000      ,UFAC= 0.500000000000000     ,UINF=  25100.0000000000     ,WVFAC= 0.250000000000000    ,XKETA=
  1.05000000000000      ,XLE=  1.39999961853027     ,XNSO= 0.116599977016449    ,IE=          51,IEND=          6,IGEOM=          1,
IUN=         19,JFAC=          1,KEND=          1,KPLTTP=          0,KTWAL=          0,NAN=          1,NDATA=          1,NITMAX=
      9999,NITMIN=          3,NITMNI=          3,NS=          6,NSI=          6,NSPRF=          0,NTSH=         20,NTTWA=
         5
&END
```

LOG  RATES MATCH 6 SPECIE BLOTTNER-SANDIA

| NR | | | REACTION | | | CRO | EXP(CRO) | CR1 | CR2 | DRO | EXP(DRO) | DR1 | DR2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | O2 | M1 | =O | O | M1 | 42.7302394 | 0.3610D 19 | 59400.0 | -1.0 | 35.6407165 | 0.3010D 16 | 0.0 | -0.5 |
| 2 | N2 | M2 | =N | N | M2 | 39.7962718 | 0.1920D 18 | 113100.0 | -0.5 | 36.9275392 | 0.1090D 17 | 0.0 | -0.5 |
| 3 | N2 | N | =N | N | N | 52.0799804 | 0.4150D 23 | 113100.0 | -1.5 | 49.1958541 | 0.2320D 22 | 0.0 | -1.5 |
| 4 | NO | M3 | =N | O | M3 | 47.4304680 | 0.3970D 21 | 75600.0 | -1.5 | 46.0616522 | 0.1010D 21 | 0.0 | -1.5 |
| 5 | NO | O | =O2 | N | | 21.8801470 | 0.3180D 10 | 19700.0 | 1.0 | 27.5933192 | 0.9630D 12 | 3600.0 | 0.5 |
| 6 | N2 | O | =NO | N | | 31.8431487 | 0.6750D 14 | 37500.0 | 0.0 | 30.3390713 | 0.1500D 14 | 0.0 | 0.0 |
| 7 | N | O | =NO+ | EL | | 22.9238182 | 0.9030D 10 | 32400.0 | 0.5 | 44.3369034 | 0.1800D 20 | 0.0 | -1.0 |

ALPHSB( 7,10)

| NR | ALSUB | NR | O | O2 | NO | N | NO+ | N2 | M1 | M2 | M3 | EL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 1 | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. |
| 2 | 1.0 | 2 | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 0. | 0. |
| 3 | 1.0 | 3 | 0. | 0. | 0. | 1. | 0. | 1. | 0. | 0. | 0. | 0. |
| 4 | 1.0 | 4 | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 1. | 0. |
| 5 | 1.0 | 5 | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 1.0 | 6 | 1. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 0. |
| 7 | 1.0 | 7 | 1. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. |

BETASB( 7,10)

| NR | BETSUB | NR | O | O2 | NO | N | NO+ | N2 | M1 | M2 | M3 | EL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.0 | 1 | 2. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. |
| 2 | 2.0 | 2 | 0. | 0. | 0. | 2. | 0. | 0. | 0. | 1. | 0. | 0. |
| 3 | 2.0 | 3 | 0. | 0. | 0. | 3. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4 | 2.0 | 4 | 1. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 0. |
| 5 | 1.0 | 5 | 0. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 1.0 | 6 | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. |
| 7 | 1.0 | 7 | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 0. | 1. |

ZSUB( 4, 6)

| | O | O2 | NO | N | NO+ | N2 |
|---|---|---|---|---|---|---|
| M1 | 25.0 | 9.0 | 1.0 | 1.0 | 0.0 | 2.0 |
| M2 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 2.5 |
| M3 | 20.0 | 1.0 | 20.0 | 20.0 | 0.0 | 1.0 |
| EL | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 |

GAMMPL( 7, 6)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2. | 0. | 0. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 2. | 0. | 0. |
| 3 | 0. | 0. | 0. | 2. | 0. | 0. |
| 4 | 1. | 0. | 0. | 1. | 0. | 0. |
| 5 | 0. | 1. | 0. | 1. | 0. | 0. |
| 6 | 0. | 0. | 1. | 1. | 0. | 0. |
| 7 | 0. | 0. | 0. | 0. | 1. | 0. |

GAMMMI( 7, 6)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0. | 1. | 0. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 0. | 0. | 1. |
| 3 | 0. | 0. | 0. | 0. | 0. | 1. |
| 4 | 0. | 0. | 1. | 0. | 0. | 0. |
| 5 | 1. | 0. | 1. | 0. | 0. | 0. |
| 6 | 1. | 0. | 0. | 0. | 0. | 1. |
| 7 | 1. | 0. | 0. | 1. | 0. | 0. |

VSREF = 0.23353999D-04

VSINF = 0.35867911D-06

```
K =1, I =   1, S =   0.0   , NITER =   1, DIFI = 3.883D 01 4.979D 00 0.0       1.000D 00 0.0       0.0       0.0       7.590D-01
K =1, I =   1, S =   0.0   , NITER =   2, DIFI = 6.558D-01 2.953D-01 8.918D-01 7.080D 02 8.909D 16 4.265D 17 9.433D 35 1.597D 00
K =1, I =   1, S =   0.0   , NITER =   3, DIFI = 4.204D-01 9.776D-01 3.333D 01 3.417D 03 1.864D 00 9.662D-01 9.946D-01 5.284D 01
K =1, I =   1, S =   0.0   , NITER =   4, DIFI = 2.643D 00 5.280D C0 9.097D-01 1.945D 02 2.218D 03 3.545D 00 1.496D 01 1.677D 01
K =1, I =   1, S =   0.0   , NITER =   5, DIFI = 1.445D-01 2.909D 01 8.622D-01 1.698D 02 3.141D 01 3.014D 02 5.858D 14 2.379D 01
K =1, I =   1, S =   0.0   , NITER =   6, DIFI = 2.724D-01 7.607D 00 3.954D 01 3.600D 36 5.444D-01 1.850D 08 2.243D 00 1.248D 00
K =1, I =   1, S =   0.0   , NITER =   7, DIFI = 1.294D 00 6.822D-01 9.907D-01 9.258D 00 9.310D 01 1.000D 00 7.918D 11 4.182D 00
K =1, I =   1, S =   0.0   , NITER =   8, DIFI = 4.327D-01 6.252D-01 1.000D 00 1.820D 36 9.857D-01 1.263D 06 1.000D 00 9.925D 00
K =1, I =   1, S =   0.0   , NITER =   9, DIFI = 5.729D-01 1.440D 00 1.399D 39 2.439D 38 1.000D 00 1.000D 00 1.439D C9 3.926D-01
K =1, I =   1, S =   0.0   , NITER =  10, DIFI = 6.240D-01 1.308D 00 7.172D 00 1.615D 01 1.135D 05 2.256D 05 1.721D 00 2.298D-01
K =1, I =   1, S =   0.0   , NITER =  11, DIFI = 4.947D-02 1.870D-01 7.712D 39 2.391D 39 9.818D 00 9.999D-01 1.239D 08 7.244D-01
K =1, I =   1, S =   0.0   , NITER =  12, DIFI = 4.306D-01 4.544D-01 1.672D 02 9.507D 39 1.389D 39 6.073D 03 1.000D 00 2.727D 00
K =1, I =   1, S =   0.0   , NITER =  13, DIFI = 3.172D-01 1.527D 00 1.000D 40 1.980D 00 5.110D 01 1.000D 00 4.075D 08 1.816D 00
K =1, I =   1, S =   0.0   , NITER =  14, DIFI = 7.654D-01 2.458D 0C 1.000D 00 1.032D 37 3.646D 38 5.370D 05 1.000D 00 9.323D 01
K =1, I =   1, S =   0.0   , NITER =  15, DIFI = 5.397D-01 6.285D 00 1.460D 39 2.399D 36 9.992D-01 9.753D-01 1.049D 07 3.312D-01
K =1, I =   1, S =   0.0   , NITER =  16, DIFI = 1.526D 00 8.234D-01 1.020D 03 4.255D 39 9.381D 02 6.824D 03 1.000D C0 2.302D 00
K =1, I =   1, S =   0.0   , NITER =  17, DIFI = 6.093D-01 4.193D 00 1.000D 00 7.018D 01 2.488D 02 1.000D 00 4.436D 06 1.157D 01
K =1, I =   1, S =   0.0   , NITER =  18, DIFI = 8.310D-01 7.888D-01 1.000D 00 1.003D 00 2.180D 00 8.862D 06 2.688D 00 6.866D 00
K =1, I =   1, S =   0.0   , NITER =  19, DIFI = 4.922D-01 4.760D 00 1.702D 39 4.158D 00 1.247D 39 1.000D 00 9.734D C3 4.831D 00
K =1, I =   1, S =   0.0   , NITER =  20, DIFI = 8.839D 00 4.908D 00 2.720D 05 4.470D 39 1.000D 00 1.437D 05 7.835D 00 6.134D-01
K =1, I =   1, S =   0.0   , NITER =  21, DIFI = 8.217D-01 2.689D-01 1.107D 00 1.660D 01 5.686D 39 9.989D-01 4.108D 05 2.474D 00
K =1, I =   1, S =   0.0   , NITER =  22, DIFI = 2.455D-01 5.078D-01 4.793D 03 1.000D 00 2.410D 00 7.208D 02 7.850D 00 1.023D 02
K =1, I =   1, S =   0.0   , NITER =  23, DIFI = 7.639D-01 4.932D-01 9.953D-01 1.000D 00 8.188D 00 1.619D 00 5.227D 04 7.979D 00
K =1, I =   1, S =   0.0   , NITER =  24, DIFI = 5.527D-01 3.594D-01 2.120D 02 1.186D 39 9.913D-01 2.453D 04 1.000D 00 3.069D 01
K =1, I =   1, S =   0.0   , NITER =  25, DIFI = 1.672D 00 4.639D-01 1.000D 00 1.000D 00 1.140D 02 1.000D 00 8.851D 03 9.107D 00
K =1, I =   1, S =   0.0   , NITER =  26, DIFI = 5.484D-01 2.513D-01 3.747D 04 6.383D 38 9.747D-01 3.692D 04 9.999D-01 1.345D 03
K =1, I =   1, S =   0.0   , NITER =  27, DIFI = 1.534D 00 2.780D-01 1.000D 00 1.000D 00 3.853D 01 1.000D 00 1.729D 04 1.609D 01
K =1, I =   1, S =   0.0   , NITER =  28, DIFI = 6.073D-01 3.732D-C1 1.000D 00 9.366D 38 1.000D 00 1.298D 05 1.000D 0C 1.763D 04
K =1, I =   1, S =   0.0   , NITER =  29, DIFI = 1.144D 00 1.016D 01 7.095D 38 4.025D 38 2.978D 38 7.374D 00 6.987D 00 1.463D-01
K =1, I =   1, S =   0.0   , NITER =  30, DIFI = 1.000D 00 1.000D 00 3.176D 00 1.000D 40 3.162D 01 1.093D 00 7.280D 01 1.006D 00
K =1, I =   1, S =   0.0   , NITER =  31, DIFI = 2.433D 02 1.585D C5 2.563D 37 2.238D 00 9.973D-01 2.497D 35 2.665D 34 2.906D 02
K =1, I =   1, S =   0.0   , NITER =  32, DIFI = 6.234D 03 2.379D C5 1.520D 01 1.000D 40 8.388D 02 8.538D 36 1.000D 00 1.026D 00
K =1, I =   1, S =   0.0   , NITER =  33, DIFI = 1.564D 05 3.123D 00 2.547D 05 3.323D 01 5.377D 01 1.000D 00 5.313D 12 9.966D 04
K =1, I =   1, S =   0.0   , NITER =  34, DIFI = 6.607D-01 7.042D-01 1.059D 01 6.186D-01 1.706D 00 3.362D 08 2.045D 00 1.268D-01
K =1, I =   1, S =   0.0   , NITER =  35, DIFI = 2.903D-01 1.340D-01 1.216D 00 8.006D-01 4.011D 00 4.969D 02 8.127D 02 3.519D-01
K =1, I =   1, S =   0.0   , NITER =  36, DIFI = 1.863D-01 1.720D-01 3.805D-01 4.359D-01 3.370D-01 3.736D 00 7.835D 00 2.209D-01
K =1, I =   1, S =   0.0   , NITER =  37, DIFI = 1.367D-01 6.267D-02 8.082D-01 6.229D-01 5.136D-01 1.415D 00 7.613D-01 4.257D-01
K =1, I =   1, S =   0.0   , NITER =  38, DIFI = 1.272D-01 7.205D-02 1.753D-01 2.493D-01 4.730D-01 1.102D 00 5.155D 00 2.451D-01
K =1, I =   1, S =   0.0   , NITER =  39, DIFI = 7.789D-02 2.380D-02 1.595D-01 6.033D-01 2.549D-01 6.172D-01 7.203D-01 1.791D-01
K =1, I =   1, S =   0.0   , NITER =  40, DIFI = 6.448D-02 5.423D-02 1.722D-01 2.680D-01 2.939D-01 4.272D-01 2.343D 00 1.658D-01
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K =1, I =   1, S =  0.0   , NITER = 41, DIFI = 4.193D-02 5.174D-02 8.346D-02 4.822D-01 1.322D-01 4.418D-01 5.163D-01 2.820D-02
K =1, I =   1, S =  0.0   , NITER = 42, DIFI = 3.507D-02 3.168D-02 8.943D-02 2.996D-01 2.228D-01 3.268D-01 1.224D 00 4.410D-02
K =1, I =   1, S =  0.0   , NITER = 43, DIFI = 2.398D-02 2.004D-02 8.370D-02 3.471D-01 1.484D-01 2.704D-01 4.023D-01 4.179D-02
K =1, I =   1, S =  0.0   , NITER = 44, DIFI = 1.725D-02 8.480D-03 6.963D-02 2.838D-01 1.601D-01 1.836D-01 6.361D-01 3.187D-02
K =1, I =   1, S =  0.0   , NITER = 45, DIFI = 1.250D-02 8.762D-03 6.094D-02 2.617D-01 1.296D-01 1.466D-01 3.062D-01 2.027D-02
K =1, I =   1, S =  0.0   , NITER = 46, DIFI = 8.784D-03 4.274D-03 4.524D-02 2.306D-01 1.188D-01 1.144D-01 3.729D-01 1.483D-02
K =1, I =   1, S =  0.0   , NITER = 47, DIFI = 6.308D-03 3.303D-03 3.840D-02 1.934D-01 9.775D-02 8.962D-02 2.184D-01 1.067D-02
K =1, I =   1, S =  0.0   , NITER = 48, DIFI = 4.566D-03 2.945D-03 2.750D-02 1.661D-01 8.533D-02 6.732D-02 2.179D-01 7.802D-03
K =1, I =   1, S =  0.0   , NITER = 49, DIFI = 3.261D-03 2.579D-03 2.315D-02 1.334D-01 6.818D-02 5.501D-02 1.492D-01 5.944D-03
K =1, I =   1, S =  0.0   , NITER = 50, DIFI = 2.311D-03 2.387D-03 1.576D-02 1.114D-01 5.749D-02 4.170D-02 1.305D-01 4.143D-03
K =1, I =   1, S =  0.0   , NITER = 51, DIFI = 1.670D-03 1.880D-03 1.324D-02 8.669D-02 4.496D-02 3.341D-02 9.795D-02 3.205D-03
K =1, I =   1, S =  0.0   , NITER = 52, DIFI = 1.195D-03 1.742D-03 8.859D-03 7.090D-02 3.714D-02 2.563D-02 7.802D-02 2.258D-03
K =1, I =   1, S =  0.0   , NITER = 53, DIFI = 9.920D-04 1.303D-03 7.563D-03 5.421D-02 2.847D-02 2.060D-02 6.197D-02 1.782D-03
K =1, I =   1, S =  0.0   , NITER = 54, DIFI = 6.961D-04 1.205D-03 4.977D-03 4.375D-02 2.333D-02 1.557D-02 4.620D-02 1.250D-03
K =1, I =   1, S =  0.0   , NITER = 55, DIFI = 6.296D-04 8.555D-04 4.398D-03 3.306D-02 1.774D-02 1.251D-02 3.816D-02 1.028D-03
K =1, I =   1, S =  0.0   , NITER = 56, DIFI = 4.270D-04 7.891D-04 2.875D-03 2.665D-02 1.435D-02 9.502D-03 2.712D-02 7.238D-04
K =1, I =   1, S =  0.0   , NITER = 57, DIFI = 3.808D-04 5.428D-04 2.572D-03 1.998D-02 1.085D-02 7.557D-03 2.295D-02 5.993D-04
K =1, I =   1, S =  0.0   , NITER = 58, DIFI = 2.558D-04 4.969D-04 1.673D-03 1.606D-02 8.729D-03 5.743D-03 1.575D-02 4.232D-04
K =1, I =   1, S =  0.0   , NITER = 59, DIFI = 2.238D-04 3.396D-04 1.516D-03 1.199D-02 6.565D-03 4.561D-03 1.354D-02 3.541D-04
K =1, I =   1, S =  0.0   , NITER = 60, DIFI = 1.496D-04 3.118D-04 9.803D-04 9.610D-03 5.264D-03 3.449D-03 9.040D-03 2.495D-04


   UINF        PINF          TINF         CAINF        TB           BRAD         PR          LE          YSH          ALT
 0.251D 05   0.53938D-01   0.36148D 03   0.0         0.2460D 04   0.2361D 01   0.70D 00   0.14D 01   0.5730D-01   0.245D 06

 THIN SHOCK LAYER  NO WALL SLIP  NC SHOCK SLIP    CAT WALL NC STEPS IN Y= 51 NO STEPS IN S=  6 S STEP SIZE=0.200

 TW/TS    EPS       REYINF       REYSH       TREF        UREF        RREF        PREF       ITER
0.0744   0.0674   0.1433D 05   0.6568D 03   0.1045D 06   0.2510D 05   0.8673D-07   0.5464D 02   1


  ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES              ****


   S          X          R          YSH         YSHP        XSH         RSH       NO ITER    NITTOT    NTOT   I    K
  0.0        0.0        0.0        0.057298    0.0       -0.057298    0.0          60         60       60    1    1

   DS         CF        HEAT        STAN        CDF        CDP         CDTOT       PWALL       TWALL       PW/PO
  0.200000   0.0        0.035446    0.074147    0.0        1.776036    1.776036    0.888018 2460.000000   1.000000

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2  KAPPA(S  KAPPA(S+DS/2
  0.0        0.000000     0.0          1.471372     1.471372    1.000000   0.981643

     USH          VSH          TSH          RSH          PSH          VPG
     0.0        -0.099835     0.313485     9.967057     0.891793     0.0
          0.0   -2505.86     32762.80
                             18201.56
```

| N | Y/YSH | U/USH | V/VSH | T/TSH | R/RSH | P/PSH(APPR) | P/PSH | CA | CAEQ | XM | T DEG R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.075085 | 13.261843 | 0.995768 | 1.059935 | 0.0 | 0.000002 | 0.0 | 2460.00 |
| 2 | 0.004777 | 0.044398 | 0.000120 | 0.117487 | 8.191109 | 0.995768 | 1.059935 | 0.035481 | 0.007009 | 0.000113 | 3849.20 |
| 3 | 0.009792 | 0.080532 | 0.000553 | 0.150773 | 6.210330 | 0.995769 | 1.059936 | 0.064107 | 0.150073 | 0.000458 | 4939.76 |
| 4 | 0.015059 | 0.112365 | 0.001300 | 0.179252 | 5.100603 | 0.995770 | 1.059938 | 0.088580 | 0.603878 | 0.000979 | 5872.80 |
| 5 | 0.020588 | 0.141459 | 0.002366 | 0.204449 | 4.376505 | 0.995773 | 1.059939 | 0.109923 | 0.912136 | 0.001655 | 6698.31 |
| 6 | 0.026394 | 0.168627 | 0.003758 | 0.227086 | 3.862194 | 0.995777 | 1.059941 | 0.128647 | 0.980755 | 0.002474 | 7439.96 |
| 7 | 0.032491 | 0.194355 | 0.005487 | 0.247565 | 3.476608 | 0.995781 | 1.059942 | 0.145055 | 0.994337 | 0.003432 | 8110.93 |
| 8 | 0.038892 | 0.218960 | 0.007562 | 0.266144 | 3.176490 | 0.995787 | 1.059943 | 0.159357 | 0.997847 | 0.004528 | 8719.61 |
| 9 | 0.045614 | 0.242659 | 0.009994 | 0.283006 | 2.936348 | 0.995794 | 1.059942 | 0.171725 | 0.999009 | 0.005764 | 9272.06 |
| 10 | 0.052671 | 0.265605 | 0.012796 | 0.298302 | 2.740011 | 0.995801 | 1.059940 | 0.182315 | 0.999474 | 0.007143 | 9773.22 |
| 11 | 0.060081 | 0.287906 | 0.015980 | 0.312170 | 2.576642 | 0.995811 | 1.059936 | 0.191284 | 0.999689 | 0.008671 | 10227.55 |
| 12 | 0.067862 | 0.309639 | 0.019563 | 0.324736 | 2.438672 | 0.995822 | 1.059929 | 0.198793 | 0.999799 | 0.010356 | 10639.25 |
| 13 | 0.076032 | 0.330856 | 0.023560 | 0.336124 | 2.320634 | 0.995834 | 1.059918 | 0.205005 | 0.999862 | 0.012204 | 11012.36 |
| 14 | 0.084610 | 0.351589 | 0.027993 | 0.346453 | 2.218485 | 0.995848 | 1.059903 | 0.210085 | 0.999900 | 0.014225 | 11350.76 |
| 15 | 0.093617 | 0.371858 | 0.032881 | 0.355837 | 2.129165 | 0.995864 | 1.059883 | 0.214190 | 0.999924 | 0.016429 | 11658.20 |
| 16 | 0.103075 | 0.391672 | 0.038248 | 0.364384 | 2.050326 | 0.995881 | 1.059857 | 0.217472 | 0.999940 | 0.018825 | 11938.25 |
| 17 | 0.113006 | 0.411031 | 0.044120 | 0.372199 | 1.980150 | 0.995901 | 1.059822 | 0.220066 | 0.999952 | 0.021424 | 12194.28 |
| 18 | 0.123433 | 0.429929 | 0.050522 | 0.379375 | 1.917217 | 0.995923 | 1.059779 | 0.222097 | 0.999960 | 0.024236 | 12429.38 |
| 19 | 0.134381 | 0.448361 | 0.057481 | 0.385998 | 1.860415 | 0.995948 | 1.059724 | 0.223669 | 0.999966 | 0.027274 | 12646.36 |
| 20 | 0.145877 | 0.466320 | 0.065026 | 0.392144 | 1.808875 | 0.995975 | 1.059657 | 0.224874 | 0.999971 | 0.030548 | 12847.74 |
| 21 | 0.157947 | 0.483802 | 0.073185 | 0.397883 | 1.761912 | 0.996005 | 1.059575 | 0.225786 | 0.999975 | 0.034068 | 13035.76 |
| 22 | 0.170621 | 0.500808 | 0.081985 | 0.403273 | 1.718987 | 0.996038 | 1.059475 | 0.226467 | 0.999978 | 0.037847 | 13212.37 |
| 23 | 0.183929 | 0.517349 | 0.091452 | 0.408368 | 1.679677 | 0.996074 | 1.059356 | 0.226967 | 0.999980 | 0.041894 | 13379.27 |
| 24 | 0.197902 | 0.533443 | 0.101614 | 0.413213 | 1.643640 | 0.996113 | 1.059214 | 0.227324 | 0.999982 | 0.046219 | 13538.00 |
| 25 | 0.212574 | 0.549121 | 0.112497 | 0.417849 | 1.610600 | 0.996156 | 1.059046 | 0.227567 | 0.999984 | 0.050830 | 13689.91 |
| 26 | 0.227980 | 0.564425 | 0.124125 | 0.422316 | 1.580325 | 0.996202 | 1.058848 | 0.227720 | 0.999985 | 0.055743 | 13836.26 |
| 27 | 0.244155 | 0.579408 | 0.136527 | 0.426649 | 1.552610 | 0.996253 | 1.058617 | 0.227798 | 0.999987 | 0.060968 | 13978.23 |
| 28 | 0.261140 | 0.594137 | 0.149730 | 0.430885 | 1.527267 | 0.996308 | 1.058348 | 0.227814 | 0.999988 | 0.066517 | 14116.99 |
| 29 | 0.278974 | 0.608686 | 0.163767 | 0.435059 | 1.504111 | 0.996368 | 1.058036 | 0.227775 | 0.999989 | 0.072404 | 14253.74 |
| 30 | 0.297699 | 0.623140 | 0.178676 | 0.439209 | 1.482955 | 0.996432 | 1.057676 | 0.227685 | 0.999990 | 0.078645 | 14389.73 |
| 31 | 0.317361 | 0.637586 | 0.194504 | 0.443379 | 1.463600 | 0.996502 | 1.057262 | 0.227548 | 0.999990 | 0.085257 | 14526.32 |
| 32 | 0.338006 | 0.652116 | 0.211305 | 0.447611 | 1.445831 | 0.996578 | 1.056785 | 0.227362 | 0.999991 | 0.092264 | 14665.00 |
| 33 | 0.359683 | 0.666817 | 0.229151 | 0.451958 | 1.429416 | 0.996661 | 1.056238 | 0.227126 | 0.999992 | 0.099687 | 14807.41 |
| 34 | 0.382443 | 0.681773 | 0.248127 | 0.456476 | 1.414100 | 0.996750 | 1.055610 | 0.226836 | 0.999992 | 0.107554 | 14955.43 |
| 35 | 0.406342 | 0.697061 | 0.268337 | 0.461229 | 1.399609 | 0.996847 | 1.054888 | 0.226487 | 0.999993 | 0.115913 | 15111.16 |
| 36 | 0.431436 | 0.712748 | 0.289908 | 0.466293 | 1.385650 | 0.996952 | 1.054059 | 0.226072 | 0.999994 | 0.124807 | 15277.07 |
| 37 | 0.457785 | 0.728890 | 0.312991 | 0.471755 | 1.371918 | 0.997066 | 1.053103 | 0.225580 | 0.999994 | 0.134291 | 15456.01 |
| 38 | 0.485451 | 0.745533 | 0.337766 | 0.477721 | 1.358091 | 0.997190 | 1.052000 | 0.224995 | 0.999995 | 0.144426 | 15651.46 |
| 39 | 0.514500 | 0.762709 | 0.364444 | 0.484320 | 1.343837 | 0.997324 | 1.050724 | 0.224298 | 0.999995 | 0.155286 | 15867.68 |
| 40 | 0.545002 | 0.780442 | 0.393279 | 0.491720 | 1.328805 | 0.997470 | 1.049242 | 0.223461 | 0.999996 | 0.166958 | 16110.11 |
| 41 | 0.577029 | 0.798740 | 0.424574 | 0.500138 | 1.312614 | 0.997628 | 1.047514 | 0.222442 | 0.999996 | 0.179567 | 16385.92 |
| 42 | 0.610657 | 0.817602 | 0.458705 | 0.509873 | 1.294836 | 0.997800 | 1.045493 | 0.221184 | 0.999997 | 0.193227 | 16704.88 |
| 43 | 0.645966 | 0.837010 | 0.496148 | 0.521351 | 1.274951 | 0.997986 | 1.043114 | 0.219600 | 0.999997 | 0.208087 | 17080.93 |
| 44 | 0.683041 | 0.856930 | 0.537543 | 0.535204 | 1.252293 | 0.998186 | 1.040293 | 0.217559 | 0.999997 | 0.224356 | 17534.78 |
| 45 | 0.721970 | 0.877301 | 0.583786 | 0.552415 | 1.225958 | 0.998403 | 1.036914 | 0.214848 | 0.999998 | 0.242336 | 18098.65 |
| 46 | 0.762845 | 0.898030 | 0.636188 | 0.574585 | 1.194711 | 0.998634 | 1.032809 | 0.211088 | 0.999998 | 0.262657 | 18825.03 |
| 47 | 0.805764 | 0.918976 | 0.696704 | 0.604456 | 1.156925 | 0.998881 | 1.027733 | 0.205480 | 0.999999 | 0.286385 | 19803.68 |
| 48 | 0.850829 | 0.939927 | 0.768120 | 0.646967 | 1.110841 | 0.999142 | 1.021351 | 0.196027 | 0.999999 | 0.315260 | 21196.44 |
| 49 | 0.898148 | 0.960592 | 0.853243 | 0.711490 | 1.056246 | 0.999416 | 1.013441 | 0.176912 | 0.999999 | 0.353212 | 23310.40 |
| 50 | 0.947832 | 0.980636 | 0.947414 | 0.816436 | 1.002283 | 0.999699 | 1.005289 | 0.129755 | 1.000000 | 0.406458 | 26748.73 |
| 51 | 1.000000 | 1.000000 | 0.999512 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 0.0 | 1.000000 | 0.456962 | 32762.80 |

| N | Y/RN | O | O2 | NO | N | NO+ | N2 | E-/CC | Y IN | Y CM |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.23456D 00 | 0.0 | 0.0 | 0.0 | 0.76544D 00 | 0.0 | 0.0 | 0.0 |
| 2 | 0.00027 | 0.35481D-01 | 0.19169D 00 | 0.14123D-01 | 0.27265D-02 | 0.33959D-04 | 0.75594D 00 | 0.24877D 13 | 0.00775 | 0.01969 |
| 3 | 0.00056 | 0.64107D-01 | 0.15748D 00 | 0.24815D-01 | 0.55919D-02 | 0.63296D-04 | 0.74794D 00 | 0.35156D 13 | 0.01590 | 0.04037 |
| 4 | 0.00086 | 0.88580D-01 | 0.12877D 00 | 0.32958D-01 | 0.91067D-02 | 0.91367D-04 | 0.74049D 00 | 0.41680D 13 | 0.02444 | 0.06209 |
| 5 | 0.00118 | 0.10992D 00 | 0.10434D 00 | 0.38925D-01 | 0.13523D-01 | 0.11953D-03 | 0.73317D 00 | 0.46785D 13 | 0.03342 | 0.08489 |
| 6 | 0.00151 | 0.12865D 00 | 0.83544D-01 | 0.42958D-01 | 0.18994D-01 | 0.14855D-03 | 0.72571D 00 | 0.51312D 13 | 0.04285 | 0.10883 |
| 7 | 0.00186 | 0.14505D 00 | 0.65977D-01 | 0.45268D-01 | 0.25614D-01 | 0.17898D-03 | 0.71791D 00 | 0.55651D 13 | 0.05274 | 0.13396 |
| 8 | 0.00223 | 0.15936D 00 | 0.51309D-01 | 0.46074D-01 | 0.33432D-01 | 0.21125D-03 | 0.70962D 00 | 0.60015D 13 | 0.06313 | 0.16036 |
| 9 | 0.00261 | 0.17172D 00 | 0.39246D-01 | 0.45604D-01 | 0.42451D-01 | 0.24572D-03 | 0.70073D 00 | 0.64529D 13 | 0.07404 | 0.18807 |
| 10 | 0.00302 | 0.18231D 00 | 0.29499D-01 | 0.44104D-01 | 0.52641D-01 | 0.28267D-03 | 0.69116D 00 | 0.69270D 13 | 0.08550 | 0.21717 |
| 11 | 0.00344 | 0.19128D 00 | 0.21777D-01 | 0.41823D-01 | 0.63937D-01 | 0.32233D-03 | 0.68086D 00 | 0.74278D 13 | 0.09753 | 0.24772 |
| 12 | 0.00389 | 0.19879D 00 | 0.15790D-01 | 0.39007D-01 | 0.76249D-01 | 0.36483D-03 | 0.66980D 00 | 0.79571D 13 | 0.11016 | 0.27980 |
| 13 | 0.00436 | 0.20501D 00 | 0.11250D-01 | 0.35882D-01 | 0.89466D-01 | 0.41022D-03 | 0.65799D 00 | 0.85141D 13 | 0.12342 | 0.31349 |
| 14 | 0.00485 | 0.21008D 00 | 0.78886D-02 | 0.32650D-01 | 0.10346D 00 | 0.45848D-03 | 0.64546D 00 | 0.90969D 13 | 0.13734 | 0.34885 |
| 15 | 0.00536 | 0.21419D 00 | 0.54582D-02 | 0.29475D-01 | 0.11809D 00 | 0.50949D-03 | 0.63228D 00 | 0.97019D 13 | 0.15197 | 0.38599 |
| 16 | 0.00591 | 0.21747D 00 | 0.37424D-02 | 0.26482D-01 | 0.13322D 00 | 0.56303D-03 | 0.61852D 00 | 0.10324D 14 | 0.16732 | 0.42499 |
| 17 | 0.00648 | 0.22007D 00 | 0.25594D-02 | 0.23757D-01 | 0.14869D 00 | 0.61884D-03 | 0.60431D 00 | 0.10960D 14 | 0.18344 | 0.46593 |
| 18 | 0.00707 | 0.22210D 00 | 0.17616D-02 | 0.21349D-01 | 0.16436D 00 | 0.67659D-03 | 0.58975D 00 | 0.11601D 14 | 0.20036 | 0.50892 |
| 19 | 0.00770 | 0.22367D 00 | 0.12344D-02 | 0.19273D-01 | 0.18008D 00 | 0.73590D-03 | 0.57501D 00 | 0.12245D 14 | 0.21813 | 0.55406 |
| 20 | 0.00836 | 0.22487D 00 | 0.89166D-03 | 0.17525D-01 | 0.19570D 00 | 0.79635D-03 | 0.56022D 00 | 0.12883D 14 | 0.23680 | 0.60146 |
| 21 | 0.00905 | 0.22579D 00 | 0.67162D-03 | 0.16080D-01 | 0.21106D 00 | 0.85752D-03 | 0.54554D 00 | 0.13513D 14 | 0.25639 | 0.65123 |
| 22 | 0.00978 | 0.22647D 00 | 0.53116D-03 | 0.14908D-01 | 0.22602D 00 | 0.91899D-03 | 0.53115D 00 | 0.14129D 14 | 0.27696 | 0.70348 |
| 23 | 0.01054 | 0.22697D 00 | 0.44140D-03 | 0.13971D-01 | 0.24044D 00 | 0.98033D-03 | 0.51720D 00 | 0.14727D 14 | 0.29856 | 0.75835 |
| 24 | 0.01134 | 0.22732D 00 | 0.38362D-03 | 0.13236D-01 | 0.25417D 00 | 0.10411D-02 | 0.50384D 00 | 0.15305D 14 | 0.32125 | 0.81597 |
| 25 | 0.01218 | 0.22757D 00 | 0.34602D-03 | 0.12671D-01 | 0.26707D 00 | 0.11011D-02 | 0.49124D 00 | 0.15860D 14 | 0.34506 | 0.87646 |
| 26 | 0.01306 | 0.22772D 00 | 0.32141D-03 | 0.12249D-01 | 0.27902D 00 | 0.11598D-02 | 0.47954D 00 | 0.16392D 14 | 0.37007 | 0.93998 |
| 27 | 0.01399 | 0.22780D 00 | 0.30552D-03 | 0.11951D-01 | 0.28988D 00 | 0.12170D-02 | 0.46885D 00 | 0.16900D 14 | 0.39633 | 1.00667 |
| 28 | 0.01496 | 0.22781D 00 | 0.29586D-03 | 0.11761D-01 | 0.29956D 00 | 0.12727D-02 | 0.45930D 00 | 0.17384D 14 | 0.42390 | 1.07670 |
| 29 | 0.01598 | 0.22777D 00 | 0.29107D-03 | 0.11672D-01 | 0.30796D 00 | 0.13265D-02 | 0.45097D 00 | 0.17845D 14 | 0.45285 | 1.15023 |
| 30 | 0.01706 | 0.22769D 00 | 0.29041D-03 | 0.11677D-01 | 0.31504D 00 | 0.13786D-02 | 0.44393D 00 | 0.18284D 14 | 0.48324 | 1.22744 |
| 31 | 0.01818 | 0.22755D 00 | 0.29358D-03 | 0.11775D-01 | 0.32073D 00 | 0.14289D-02 | 0.43822D 00 | 0.18704D 14 | 0.51516 | 1.30850 |
| 32 | 0.01937 | 0.22736D 00 | 0.30054D-03 | 0.11967D-01 | 0.32504D 00 | 0.14777D-02 | 0.43385D 00 | 0.19108D 14 | 0.54867 | 1.39362 |
| 33 | 0.02061 | 0.22713D 00 | 0.31145D-03 | 0.12257D-01 | 0.32799D 00 | 0.15251D-02 | 0.43079D 00 | 0.19497D 14 | 0.58386 | 1.48300 |
| 34 | 0.02191 | 0.22684D 00 | 0.32667D-03 | 0.12652D-01 | 0.32960D 00 | 0.15714D-02 | 0.42901D 00 | 0.19874D 14 | 0.62080 | 1.57684 |
| 35 | 0.02328 | 0.22649D 00 | 0.34671D-03 | 0.13161D-01 | 0.32996D 00 | 0.16170D-02 | 0.42843D 00 | 0.20240D 14 | 0.65960 | 1.67538 |
| 36 | 0.02472 | 0.22607D 00 | 0.37236D-03 | 0.13796D-01 | 0.32913D 00 | 0.16620D-02 | 0.42897D 00 | 0.20597D 14 | 0.70033 | 1.77884 |
| 37 | 0.02623 | 0.22558D 00 | 0.40468D-03 | 0.14574D-01 | 0.32720D 00 | 0.17068D-02 | 0.43053D 00 | 0.20942D 14 | 0.74310 | 1.88748 |
| 38 | 0.02782 | 0.22499D 00 | 0.44521D-03 | 0.15518D-01 | 0.32426D 00 | 0.17510D-02 | 0.43303D 00 | 0.21268D 14 | 0.78801 | 2.00155 |
| 39 | 0.02948 | 0.22430D 00 | 0.49618D-03 | 0.16663D-01 | 0.32034D 00 | 0.17941D-02 | 0.43640D 00 | 0.21563D 14 | 0.83517 | 2.12132 |
| 40 | 0.03123 | 0.22346D 00 | 0.56092D-03 | 0.18054D-01 | 0.31548D 00 | 0.18346D-02 | 0.44061D 00 | 0.21803D 14 | 0.88468 | 2.24708 |
| 41 | 0.03306 | 0.22244D 00 | 0.64467D-03 | 0.19759D-01 | 0.30964D 00 | 0.18697D-02 | 0.44565D 00 | 0.21949D 14 | 0.93667 | 2.37913 |
| 42 | 0.03499 | 0.22118D 00 | 0.75622D-03 | 0.21875D-01 | 0.30269D 00 | 0.18947D-02 | 0.45160D 00 | 0.21941D 14 | 0.99125 | 2.51778 |
| 43 | 0.03701 | 0.21960D 00 | 0.91190D-03 | 0.24539D-01 | 0.29442D 00 | 0.19019D-02 | 0.45862D 00 | 0.21687D 14 | 1.04857 | 2.66337 |
| 44 | 0.03914 | 0.21756D 00 | 0.11465D-02 | 0.27942D-01 | 0.28446D 00 | 0.18800D-02 | 0.46701D 00 | 0.21056D 14 | 1.10875 | 2.81623 |
| 45 | 0.04137 | 0.21485D 00 | 0.15460D-02 | 0.32337D-01 | 0.27219D 00 | 0.18129D-02 | 0.47726D 00 | 0.19878D 14 | 1.17194 | 2.97674 |
| 46 | 0.04371 | 0.21109D 00 | 0.23530D-02 | 0.38002D-01 | 0.25658D 00 | 0.16803D-02 | 0.49030D 00 | 0.17954D 14 | 1.23829 | 3.14527 |
| 47 | 0.04617 | 0.20548D 00 | 0.43128D-02 | 0.45057D-01 | 0.23588D 00 | 0.14611D-02 | 0.50781D 00 | 0.15119D 14 | 1.30796 | 3.32223 |
| 48 | 0.04875 | 0.19603D 00 | 0.98198D-02 | 0.52766D-01 | 0.20715D 00 | 0.11428D-02 | 0.53310D 00 | 0.11354D 14 | 1.38112 | 3.50803 |
| 49 | 0.05146 | 0.17691D 00 | 0.26645D-01 | 0.57455D-01 | 0.16528D 00 | 0.73809D-03 | 0.57297D 00 | 0.69725D 13 | 1.45793 | 3.70313 |
| 50 | 0.05431 | 0.12976D 00 | 0.79327D-01 | 0.47501D-01 | 0.10154D 00 | 0.30985D-03 | 0.64157D 00 | 0.27775D 13 | 1.53858 | 3.90798 |
| 51 | 0.05730 | 0.0 | 0.23456D 00 | 0.0 | 0.0 | 0.0 | 0.76544D 00 | 0.0 | 1.62326 | 4.12307 |

```
K =1, I =  2, S =  0.200, NITER =  1, DIFI = 3.912D-02 5.392D-02 2.990D-02 4.413D-02 4.555D-02 6.885D-02 7.509D-02 4.763D-02
K =1, I =  2, S =  0.200, NITER =  2, DIFI = 2.762D-02 1.550D-02 2.912D-02 2.836D-02 5.926D-02 2.639D-02 5.829D-02 1.163D-02
K =1, I =  2, S =  0.200, NITER =  3, DIFI = 6.851D-03 5.341D-03 1.915D-02 2.903D-02 2.304D-02 1.811D-02 2.626D-02 1.144D-02
K =1, I =  2, S =  0.200, NITER =  4, DIFI = 1.992D-03 3.587D-03 3.102D-03 7.073D-03 7.086D-03 3.781D-03 1.596D-02 9.245D-04


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                ****


      S           X           R           YSH         YSHP        XSH         RSH     NO ITER    NITTOT     NTOT   I     K
   0.200000    0.019709    0.198780    0.059483    0.021851   -0.038643    0.210324     4           64        64    2     1

      DS          CF          HEAT        STAN        CDF         CDP         CDTOT       PWALL       TWALL          PW/PO
   0.200000    0.013616    0.033625    0.070339    0.002658    1.665276    1.667934    0.843597 2460.000000     0.949977

  YSHP ( S   YSHP ( S+DS/2   NEW YSHP   ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
   0.000000    0.000000    0.021851    1.286004    1.286004    0.930449    0.856159

        USH          VSH          TSH          RSH          PSH          VPG
      0.190109    -0.099149     0.305478     9.857033     0.859673     0.0
       4771.75     -2488.64     31925.95
                                17736.65

K =1, I =  3, S =  0.400, NITER =  1, DIFI = 7.504D-02 8.836D-02 8.205D-02 1.429D-01 1.228D-01 2.003D-01 1.899D-01 1.158D-01
K =1, I =  3, S =  0.400, NITER =  2, DIFI = 5.094D-02 4.144D-02 5.423D-02 8.857D-02 1.634D-01 5.909D-02 1.765D-01 2.668D-02
K =1, I =  3, S =  0.400, NITER =  3, DIFI = 2.282D-02 1.548D-02 3.568D-02 5.958D-02 4.728D-02 2.923D-02 6.188D-02 1.858D-02
K =1, I =  3, S =  0.400, NITER =  4, DIFI = 2.834D-03 5.003D-03 4.085D-03 1.332D-02 1.347D-02 8.661D-03 2.194D-02 1.600D-03
K =1, I =  3, S =  0.400, NITER =  5, DIFI = 6.926D-04 6.443D-04 4.402D-03 3.919D-03 6.491D-03 2.995D-03 1.236D-02 2.920D-03


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                ****


      S           X           R           YSH         YSHP        XSH         RSH     NO ITER    NITTOT     NTOT   I     K
   0.400000    0.075579    0.390592    0.066038    0.043701    0.013918    0.414237     5           69        69    3     1

      DS          CF          HEAT        STAN        CDF         CDP         CDTOT       PWALL       TWALL          PW/PO
   0.200000    0.022658    0.029178    0.061036    0.005531    1.569058    1.574589    0.738811 2460.000000     0.831977

  YSHP ( S   YSHP ( S+DS/2   NEW YSHP   ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
   0.000000    0.000000    0.043701    1.132012    1.132012    0.770250    0.682420

        USH          VSH          TSH          RSH          PSH          VPG
      0.352899    -0.097389     0.285411     9.573061     0.780431     0.0
       8857.76     -2444.46     29828.70
                                16571.50
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K =1, I =   4, S =  0.600, NITER =  1, DIFI = 7.429D-02 1.009D-01 1.224D-01 2.437D-01 1.631D-01 3.040D-01 2.412D-01 1.325D-01
K =1, I =   4, S =  0.600, NITER =  2, DIFI = 2.563D-02 5.542D-02 5.400D-02 1.450D-01 2.233D-01 6.594D-02 2.460D-01 2.628D-02
K =1, I =   4, S =  0.600, NITER =  3, DIFI = 2.881D-02 1.646D-02 3.541D-02 6.730D-02 4.525D-02 2.504D-02 7.077D-02 1.620D-02
K =1, I =   4, S =  0.600, NITER =  4, DIFI = 2.102D-03 4.213D-03 2.888D-03 1.328D-02 1.319D-02 1.339D-02 1.986D-02 1.530D-03
K =1, I =   4, S =  0.600, NITER =  5, DIFI = 6.421D-04 1.083D-03 4.144D-03 4.930D-03 5.858D-03 2.827D-03 1.055D-02 2.183D-03


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                  ****


      S           X           R           YSH         YSHP        XSH         RSH      NO ITER    NITTOT    NTOT   I    K
  0.600000    0.160212    0.571609    0.076696    0.062874    0.093008    0.608567      5          74        74    4    1

     DS          CF         HEAT        STAN         CDF         CDP        CDTOT       PWALL       TWALL        PW/PO
  0.200000    0.026259    0.024101    0.050415    0.008950    1.444526    1.453476    0.623041 2460.000000    0.701608

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
 -0.000000    0.000000    0.062874    1.011943    1.011943    0.599116    0.523715

      USH         VSH          TSH          RSH          PSH          VPG
    0.477527   -0.095066    0.260795     9.218269     0.686812     0.0
    11985.92    -2386.15    27256.05
                            15142.25


K =1, I =   5, S =  0.800, NITER =  1, DIFI = 6.597D-02 1.012D-01 1.453D-01 3.320D-01 1.581D-01 3.568D-01 3.250D-01 1.091D-01
K =1, I =   5, S =  0.800, NITER =  2, DIFI = 1.719D-02 5.364D-02 6.529D-02 1.686D-01 2.264D-01 5.874D-02 2.295D-01 2.278D-02
K =1, I =   5, S =  0.800, NITER =  3, DIFI = 2.675D-02 1.382D-02 3.016D-02 6.218D-02 3.320D-02 2.447D-02 5.773D-02 1.220D-02
K =1, I =   5, S =  0.800, NITER =  4, DIFI = 3.740D-03 3.851D-03 3.922D-03 1.022D-02 1.029D-02 1.336D-02 1.319D-02 1.375D-03
K =1, I =   5, S =  0.800, NITER =  5, DIFI = 4.769D-04 1.252D-03 3.327D-03 4.676D-03 4.297D-03 2.324D-03 6.529D-03 1.403D-03


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                  ****


      S           X           R           YSH         YSHP        XSH         RSH      NO ITER    NITTOT    NTOT   I    K
  0.800000    0.265984    0.741194    0.090693    0.077092    0.191535    0.792987      5          79        79    5    1

     DS          CF         HEAT        STAN         CDF         CDP        CDTOT       PWALL       TWALL        PW/PO
  0.200000    0.026611    0.019757    0.041328    0.012057    1.318461    1.330517    0.523949 2460.000000    0.590020

 YSHP ( S  YSHP ( S+DS/2  NEW YSHP  ALPHA(S+DS/2 PHI(S+DS/2   KAPPA(S  KAPPA(S+DS/2
  0.000000    0.000000    0.077092    0.920184    0.920184    0.457400    0.400051

      USH         VSH          TSH          RSH          PSH          VPG
    0.567944   -0.092485    0.236825     8.883399     0.600965     0.0
    14255.39    -2321.38    24750.93
                            13750.52
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K =1, I =   6, S =   1.000, NITER =   1, DIFI = 5.623D-02 9.548D-02 1.540D-01 3.766D-01 1.462D-01 3.770D-01 3.918D-01 8.135D-02
K =1, I =   6, S =   1.000, NITER =   2, DIFI = 1.201D-02 4.527D-02 6.800D-02 1.714D-01 2.071D-01 4.929D-02 2.002D-01 1.839D-02
K =1, I =   6, S =   1.000, NITER =   3, DIFI = 2.234D-02 1.087D-02 2.576D-02 6.088D-02 2.275D-02 2.206D-02 4.625D-02 8.598D-03
K =1, I =   6, S =   1.000, NITER =   4, DIFI = 4.093D-03 3.003D-03 4.041D-03 7.656D-03 8.161D-03 1.156D-02 8.531D-03 1.119D-03
K =1, I =   6, S =   1.000, NITER =   5, DIFI = 3.592D-04 1.029D-03 2.342D-03 3.672D-03 2.963D-03 2.090D-03 4.094D-03 8.368D-04


    ****  FREE FLIGHT HYPERBOLOID  ALT=245K FT. M=26.9  ALPHA=30, 7-SPECIES                ****


       S            X            R            YSH          YSHP         XSH          RSH       NO ITER     NITTOT     NTOT    I     K
    1.000000     0.386918     0.900366     0.106946     0.085438     0.304307     0.968283      5           84        84     6     1

       DS           CF           HEAT         STAN         CDF          CDP          CDTOT        PWALL        TWALL          PW/PO
    0.200000     0.025591     0.016469     0.034450     0.014560     1.204355     1.218915     0.447458 2460.000000      0.503884

  YSHP ( S   YSHP ( S+DS/2   NEW YSHP   ALPHA(S+DS/2 PHI(S+DS/2    KAPPA(S   KAPPA(S+DS/2
    0.000000     0.000000     0.085438     0.849778     0.849778     0.350905     0.308952

        USH          VSH           TSH           RSH           PSH           VPG
      0.632912     -0.089807     0.215602      8.610272      0.530179      0.0
      15886.08     -2254.16      22532.88
                                 12518.27
```

| N | Y/YSH | U/USH | V/VSH | T/TSH | R/RSH | P/PSH(APPR) | P/PSH | CA | CAEQ | XM | T DEG R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 | 0.109400 | 7.735541 | 0.843976 | 0.900964 | 0.0 | 0.000004 | 0.0 | 2465.10 |
| 2 | 0.004777 | 0.045377 | 0.000117 | 0.166077 | 4.950164 | 0.843982 | 0.900970 | 0.030088 | 0.006533 | 0.274894 | 3742.18 |
| 3 | 0.009792 | 0.083085 | 0.000536 | 0.210122 | 3.820344 | 0.844004 | 0.900993 | 0.054964 | 0.130814 | 0.446973 | 4734.65 |
| 4 | 0.015059 | 0.116797 | 0.001265 | 0.247439 | 3.176770 | 0.844049 | 0.901040 | 0.076726 | 0.545970 | 0.575939 | 5575.52 |
| 5 | 0.020588 | 0.147983 | 0.002313 | 0.280210 | 2.752112 | 0.844118 | 0.901112 | 0.096163 | 0.883606 | 0.681070 | 6313.94 |
| 6 | 0.026394 | 0.177413 | 0.003698 | 0.309485 | 2.447904 | 0.844215 | 0.901212 | 0.113649 | 0.973406 | 0.771418 | 6973.58 |
| 7 | 0.032491 | 0.205549 | 0.005433 | 0.335849 | 2.218337 | 0.844342 | 0.901342 | 0.129381 | 0.992178 | 0.851868 | 7567.64 |
| 8 | 0.038892 | 0.232691 | 0.007537 | 0.359665 | 2.038805 | 0.844501 | 0.901506 | 0.143474 | 0.997055 | 0.925466 | 8104.29 |
| 9 | 0.045614 | 0.259043 | 0.010027 | 0.381184 | 1.894734 | 0.844695 | 0.901704 | 0.156008 | 0.998659 | 0.994124 | 8589.18 |
| 10 | 0.052671 | 0.284746 | 0.012921 | 0.400596 | 1.776854 | 0.844928 | 0.901942 | 0.167051 | 0.999294 | 1.059334 | 9026.58 |
| 11 | 0.060081 | 0.309898 | 0.016239 | 0.418061 | 1.678925 | 0.845203 | 0.902221 | 0.176672 | 0.999585 | 1.122034 | 9420.12 |
| 12 | 0.067862 | 0.334567 | 0.020003 | 0.433729 | 1.596557 | 0.845525 | 0.902547 | 0.184954 | 0.999733 | 1.182870 | 9773.16 |
| 13 | 0.076032 | 0.358792 | 0.024237 | 0.447746 | 1.526549 | 0.845897 | 0.902922 | 0.191988 | 0.999816 | 1.242309 | 10089.00 |
| 14 | 0.084610 | 0.382594 | 0.028965 | 0.460258 | 1.466500 | 0.846326 | 0.903352 | 0.197880 | 0.999866 | 1.300628 | 10370.94 |
| 15 | 0.093617 | 0.405977 | 0.034216 | 0.471415 | 1.414567 | 0.846816 | 0.903842 | 0.202745 | 0.999897 | 1.357968 | 10622.34 |
| 16 | 0.103075 | 0.428930 | 0.040023 | 0.481368 | 1.369308 | 0.847373 | 0.904396 | 0.206698 | 0.999918 | 1.414364 | 10846.61 |
| 17 | 0.113006 | 0.451435 | 0.046419 | 0.490268 | 1.329579 | 0.848003 | 0.905020 | 0.209857 | 0.999933 | 1.469775 | 11047.16 |
| 18 | 0.123433 | 0.473461 | 0.053440 | 0.498265 | 1.294469 | 0.848714 | 0.905719 | 0.212333 | 0.999944 | 1.524149 | 11227.34 |
| 19 | 0.134381 | 0.494976 | 0.061127 | 0.505503 | 1.263243 | 0.849510 | 0.906498 | 0.214229 | 0.999952 | 1.577364 | 11390.43 |
| 20 | 0.145877 | 0.515946 | 0.069519 | 0.512118 | 1.235317 | 0.850401 | 0.907364 | 0.215635 | 0.999958 | 1.629290 | 11539.50 |
| 21 | 0.157947 | 0.536337 | 0.078657 | 0.518239 | 1.210226 | 0.851392 | 0.908321 | 0.216631 | 0.999963 | 1.679809 | 11677.41 |
| 22 | 0.170621 | 0.556125 | 0.088582 | 0.523977 | 1.187605 | 0.852491 | 0.909375 | 0.217282 | 0.999967 | 1.728827 | 11806.71 |
| 23 | 0.183929 | 0.575292 | 0.099334 | 0.529434 | 1.167173 | 0.853707 | 0.910531 | 0.217643 | 0.999970 | 1.776297 | 11929.67 |
| 24 | 0.197902 | 0.593833 | 0.110950 | 0.534696 | 1.148718 | 0.855046 | 0.911794 | 0.217757 | 0.999973 | 1.822216 | 12048.23 |
| 25 | 0.212574 | 0.611759 | 0.123464 | 0.539835 | 1.132081 | 0.856519 | 0.913169 | 0.217656 | 0.999975 | 1.866623 | 12164.05 |
| 26 | 0.227980 | 0.629098 | 0.136911 | 0.544913 | 1.117145 | 0.858133 | 0.914663 | 0.217368 | 0.999978 | 1.909652 | 12278.46 |
| 27 | 0.244155 | 0.645893 | 0.151319 | 0.549979 | 1.103824 | 0.859900 | 0.916282 | 0.216910 | 0.999979 | 1.951466 | 12392.61 |
| 28 | 0.261140 | 0.662201 | 0.166719 | 0.555074 | 1.092049 | 0.861829 | 0.918030 | 0.216298 | 0.999981 | 1.992268 | 12507.41 |
| 29 | 0.278974 | 0.678095 | 0.183141 | 0.560232 | 1.081759 | 0.863933 | 0.919917 | 0.215543 | 0.999983 | 2.032290 | 12623.65 |
| 30 | 0.297699 | 0.693653 | 0.200618 | 0.565487 | 1.072894 | 0.866225 | 0.921949 | 0.214655 | 0.999984 | 2.071772 | 12742.04 |
| 31 | 0.317361 | 0.708956 | 0.219187 | 0.570867 | 1.065386 | 0.868721 | 0.924135 | 0.213641 | 0.999985 | 2.110949 | 12863.27 |
| 32 | 0.338006 | 0.724085 | 0.238895 | 0.576403 | 1.059153 | 0.871437 | 0.926485 | 0.212508 | 0.999986 | 2.150028 | 12988.02 |
| 33 | 0.359683 | 0.739112 | 0.259798 | 0.582130 | 1.054098 | 0.874393 | 0.929009 | 0.211263 | 0.999987 | 2.189174 | 13117.08 |
| 34 | 0.382443 | 0.754100 | 0.281965 | 0.588087 | 1.050110 | 0.877608 | 0.931718 | 0.209910 | 0.999988 | 2.228497 | 13251.29 |
| 35 | 0.406342 | 0.769095 | 0.305480 | 0.594317 | 1.047058 | 0.881107 | 0.934622 | 0.208451 | 0.999989 | 2.268048 | 13391.67 |
| 36 | 0.431436 | 0.784131 | 0.330443 | 0.600872 | 1.044805 | 0.884914 | 0.937731 | 0.206886 | 0.999990 | 2.307749 | 13539.38 |
| 37 | 0.457785 | 0.799226 | 0.356970 | 0.607815 | 1.043205 | 0.889056 | 0.941056 | 0.205208 | 0.999991 | 2.347435 | 13695.81 |
| 38 | 0.485451 | 0.814381 | 0.385194 | 0.615217 | 1.042112 | 0.893564 | 0.944604 | 0.203405 | 0.999992 | 2.387220 | 13862.60 |
| 39 | 0.514500 | 0.829588 | 0.415266 | 0.623167 | 1.041382 | 0.898467 | 0.948379 | 0.201458 | 0.999993 | 2.426978 | 14041.74 |
| 40 | 0.545002 | 0.844827 | 0.447357 | 0.631776 | 1.040875 | 0.903800 | 0.952384 | 0.199334 | 0.999993 | 2.466565 | 14235.73 |
| 41 | 0.577029 | 0.860067 | 0.481666 | 0.641190 | 1.040448 | 0.909595 | 0.956613 | 0.196987 | 0.999994 | 2.505820 | 14447.85 |
| 42 | 0.610657 | 0.875272 | 0.518428 | 0.651606 | 1.039936 | 0.915890 | 0.961055 | 0.194355 | 0.999995 | 2.544568 | 14682.57 |
| 43 | 0.645966 | 0.890394 | 0.557941 | 0.663312 | 1.039133 | 0.922720 | 0.965685 | 0.191353 | 0.999995 | 2.582159 | 14946.33 |
| 44 | 0.683041 | 0.905381 | 0.600599 | 0.676731 | 1.037746 | 0.930121 | 0.970457 | 0.187866 | 0.999996 | 2.618825 | 15248.69 |
| 45 | 0.721970 | 0.920171 | 0.646947 | 0.692514 | 1.035349 | 0.938127 | 0.975298 | 0.183728 | 0.999996 | 2.654758 | 15604.33 |
| 46 | 0.762845 | 0.934691 | 0.697768 | 0.711691 | 1.031321 | 0.946767 | 0.980082 | 0.178648 | 0.999997 | 2.690201 | 16036.45 |
| 47 | 0.805764 | 0.948854 | 0.754165 | 0.735939 | 1.024828 | 0.956061 | 0.984616 | 0.171982 | 0.999998 | 2.727327 | 16582.82 |
| 48 | 0.850829 | 0.962561 | 0.817559 | 0.768108 | 1.014973 | 0.966017 | 0.988629 | 0.162011 | 0.999998 | 2.767447 | 17307.68 |
| 49 | 0.898148 | 0.975697 | 0.889089 | 0.813435 | 1.001603 | 0.976628 | 0.991894 | 0.143769 | 0.999999 | 2.817515 | 18329.04 |
| 50 | 0.947832 | 0.988163 | 0.966070 | 0.882724 | 0.988699 | 0.987900 | 0.995098 | 0.102744 | 0.999999 | 2.908442 | 19890.30 |
| 51 | 1.000000 | 1.000000 | 1.023879 | 1.000000 | 1.000000 | 1.000000 | 1.000000 | 0.0 | 0.999999 | 3.113401 | 22532.88 |

| N | Y/RN | O | O2 | NO | N | NO+ | N2 | E-/CC | Y IN | Y CM |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.23456D 00 | 0.0 | 0.0 | 0.0 | 0.76544D 00 | 0.0 | 0.0 | 0.0 |
| 2 | 0.00055 | 0.30088D-01 | 0.19723D 00 | 0.11583D-01 | 0.16672D-02 | 0.22498D-04 | 0.75941D 00 | 0.86045D 12 | 0.01563 | 0.03970 |
| 3 | 0.00113 | 0.54964D-01 | 0.16659D 00 | 0.20703D-01 | 0.34126D-02 | 0.42001D-04 | 0.75429D 00 | 0.12397D 13 | 0.03204 | 0.08138 |
| 4 | 0.00174 | 0.76726D-01 | 0.14013D 00 | 0.27995D-01 | 0.55512D-02 | 0.60526D-04 | 0.74954D 00 | 0.14856D 13 | 0.04927 | 0.12514 |
| 5 | 0.00238 | 0.96163D-01 | 0.11691D 00 | 0.33688D-01 | 0.82628D-02 | 0.78920D-04 | 0.74489D 00 | 0.16781D 13 | 0.06736 | 0.17110 |
| 6 | 0.00305 | 0.11365D 00 | 0.96491D-01 | 0.37898D-01 | 0.11677D-01 | 0.97671D-04 | 0.74019D 00 | 0.18472D 13 | 0.08636 | 0.21935 |
| 7 | 0.00375 | 0.12938D 00 | 0.78614D-01 | 0.40716D-01 | 0.15893D-01 | 0.11712D-03 | 0.73528D 00 | 0.20074D 13 | 0.10630 | 0.27001 |
| 8 | 0.00449 | 0.14347D 00 | 0.63115D-01 | 0.42235D-01 | 0.20985D-01 | 0.13755D-03 | 0.73005D 00 | 0.21667D 13 | 0.12725 | 0.32321 |
| 9 | 0.00527 | 0.15601D 00 | 0.49858D-01 | 0.42574D-01 | 0.26997D-01 | 0.15918D-03 | 0.72440D 00 | 0.23302D 13 | 0.14924 | 0.37907 |
| 10 | 0.00608 | 0.16705D 00 | 0.38699D-01 | 0.41875D-01 | 0.33949D-01 | 0.18220D-03 | 0.71824D 00 | 0.25013D 13 | 0.17233 | 0.43772 |
| 11 | 0.00694 | 0.17667D 00 | 0.29481D-01 | 0.40308D-01 | 0.41829D-01 | 0.20677D-03 | 0.71150D 00 | 0.26822D 13 | 0.19657 | 0.49930 |
| 12 | 0.00784 | 0.18495D 00 | 0.22022D-01 | 0.38062D-01 | 0.50596D-01 | 0.23299D-03 | 0.70413D 00 | 0.28740D 13 | 0.22203 | 0.56396 |
| 13 | 0.00878 | 0.19199D 00 | 0.16121D-01 | 0.35336D-01 | 0.60184D-01 | 0.26092D-03 | 0.69611D 00 | 0.30774D 13 | 0.24876 | 0.63186 |
| 14 | 0.00977 | 0.19788D 00 | 0.11563D-01 | 0.32325D-01 | 0.70502D-01 | 0.29055D-03 | 0.68744D 00 | 0.32921D 13 | 0.27683 | 0.70315 |
| 15 | 0.01081 | 0.20274D 00 | 0.81312D-02 | 0.29214D-01 | 0.81435D-01 | 0.32183D-03 | 0.67815D 00 | 0.35173D 13 | 0.30630 | 0.77800 |
| 16 | 0.01190 | 0.20670D 00 | 0.56146D-02 | 0.26159D-01 | 0.92855D-01 | 0.35463D-03 | 0.66832D 00 | 0.37518D 13 | 0.33724 | 0.85660 |
| 17 | 0.01305 | 0.20986D 00 | 0.38184D-02 | 0.23288D-01 | 0.10462D 00 | 0.38877D-03 | 0.65803D 00 | 0.39936D 13 | 0.36973 | 0.93912 |
| 18 | 0.01426 | 0.21233D 00 | 0.25713D-02 | 0.20689D-01 | 0.11656D 00 | 0.42402D-03 | 0.64742D 00 | 0.42408D 13 | 0.40385 | 1.02578 |
| 19 | 0.01552 | 0.21423D 00 | 0.17287D-02 | 0.18420D-01 | 0.12853D 00 | 0.46013D-03 | 0.63663D 00 | 0.44909D 13 | 0.43967 | 1.11676 |
| 20 | 0.01685 | 0.21564D 00 | 0.11745D-02 | 0.16502D-01 | 0.14035D 00 | 0.49680D-03 | 0.62584D 00 | 0.47416D 13 | 0.47728 | 1.21230 |
| 21 | 0.01824 | 0.21663D 00 | 0.81905D-03 | 0.14934D-01 | 0.15186D 00 | 0.53372D-03 | 0.61522D 00 | 0.49905D 13 | 0.51677 | 1.31261 |
| 22 | 0.01970 | 0.21728D 00 | 0.59635D-03 | 0.13696D-01 | 0.16288D 00 | 0.57057D-03 | 0.60497D 00 | 0.52353D 13 | 0.55824 | 1.41793 |
| 23 | 0.02124 | 0.21764D 00 | 0.45977D-03 | 0.12754D-01 | 0.17325D 00 | 0.60704D-03 | 0.59529D 00 | 0.54741D 13 | 0.60178 | 1.52853 |
| 24 | 0.02286 | 0.21776D 00 | 0.37775D-03 | 0.12073D-01 | 0.18279D 00 | 0.64283D-03 | 0.58636D 00 | 0.57052D 13 | 0.64750 | 1.64465 |
| 25 | 0.02455 | 0.21766D 00 | 0.32979D-03 | 0.11618D-01 | 0.19137D 00 | 0.67765D-03 | 0.57835D 00 | 0.59271D 13 | 0.69550 | 1.76658 |
| 26 | 0.02633 | 0.21737D 00 | 0.30311D-03 | 0.11356D-01 | 0.19883D 00 | 0.71124D-03 | 0.57143D 00 | 0.61389D 13 | 0.74591 | 1.89461 |
| 27 | 0.02820 | 0.21691D 00 | 0.29010D-03 | 0.11262D-01 | 0.20505D 00 | 0.74337D-03 | 0.56574D 00 | 0.63397D 13 | 0.79883 | 2.02903 |
| 28 | 0.03016 | 0.21630D 00 | 0.28642D-03 | 0.11320D-01 | 0.20994D 00 | 0.77384D-03 | 0.56138D 00 | 0.65291D 13 | 0.85440 | 2.17018 |
| 29 | 0.03222 | 0.21554D 00 | 0.28983D-03 | 0.11517D-01 | 0.21343D 00 | 0.80247D-03 | 0.55842D 00 | 0.67069D 13 | 0.91275 | 2.31839 |
| 30 | 0.03438 | 0.21465D 00 | 0.29932D-03 | 0.11852D-01 | 0.21546D 00 | 0.82914D-03 | 0.55691D 00 | 0.68731D 13 | 0.97402 | 2.47400 |
| 31 | 0.03665 | 0.21364D 00 | 0.31469D-03 | 0.12325D-01 | 0.21604D 00 | 0.85376D-03 | 0.55683D 00 | 0.70276D 13 | 1.03835 | 2.63740 |
| 32 | 0.03904 | 0.21251D 00 | 0.33633D-03 | 0.12946D-01 | 0.21519D 00 | 0.87625D-03 | 0.55814D 00 | 0.71705D 13 | 1.10589 | 2.80897 |
| 33 | 0.04154 | 0.21126D 00 | 0.36506D-03 | 0.13729D-01 | 0.21298D 00 | 0.89657D-03 | 0.56076D 00 | 0.73018D 13 | 1.17682 | 2.98911 |
| 34 | 0.04417 | 0.20991D 00 | 0.40217D-03 | 0.14693D-01 | 0.20951D 00 | 0.91467D-03 | 0.56457D 00 | 0.74210D 13 | 1.25129 | 3.17826 |
| 35 | 0.04693 | 0.20845D 00 | 0.44945D-03 | 0.15864D-01 | 0.20489D 00 | 0.93048D-03 | 0.56942D 00 | 0.75274D 13 | 1.32948 | 3.37687 |
| 36 | 0.04983 | 0.20689D 00 | 0.50938D-03 | 0.17277D-01 | 0.19924D 00 | 0.94383D-03 | 0.57514D 00 | 0.76189D 13 | 1.41158 | 3.58541 |
| 37 | 0.05287 | 0.20521D 00 | 0.58534D-03 | 0.18974D-01 | 0.19271D 00 | 0.95439D-03 | 0.58157D 00 | 0.76923D 13 | 1.49779 | 3.80438 |
| 38 | 0.05606 | 0.20341D 00 | 0.68205D-03 | 0.21011D-01 | 0.18542D 00 | 0.96158D-03 | 0.58852D 00 | 0.77422D 13 | 1.58831 | 4.03430 |
| 39 | 0.05942 | 0.20146D 00 | 0.80618D-03 | 0.23459D-01 | 0.17746D 00 | 0.96446D-03 | 0.59585D 00 | 0.77599D 13 | 1.68335 | 4.27571 |
| 40 | 0.06294 | 0.19933D 00 | 0.96755D-03 | 0.26407D-01 | 0.16892D 00 | 0.96158D-03 | 0.60341D 00 | 0.77330D 13 | 1.78315 | 4.52919 |
| 41 | 0.06664 | 0.19699D 00 | 0.11814D-02 | 0.29965D-01 | 0.15982D 00 | 0.95080D-03 | 0.61109D 00 | 0.76432D 13 | 1.88793 | 4.79535 |
| 42 | 0.07052 | 0.19436D 00 | 0.14730D-02 | 0.34260D-01 | 0.15017D 00 | 0.92916D-03 | 0.61881D 00 | 0.74655D 13 | 1.99796 | 5.07481 |
| 43 | 0.07460 | 0.19135D 00 | 0.18895D-02 | 0.39428D-01 | 0.13990D 00 | 0.89279D-03 | 0.62654D 00 | 0.71678D 13 | 2.11348 | 5.36825 |
| 44 | 0.07888 | 0.18787D 00 | 0.25278D-02 | 0.45572D-01 | 0.12887D 00 | 0.83702D-03 | 0.63433D 00 | 0.67111D 13 | 2.23479 | 5.67636 |
| 45 | 0.08338 | 0.18373D 00 | 0.36090D-02 | 0.52680D-01 | 0.11687D 00 | 0.75698D-03 | 0.64236D 00 | 0.60553D 13 | 2.36215 | 5.99987 |
| 46 | 0.08810 | 0.17865D 00 | 0.56716D-02 | 0.60419D-01 | 0.10352D 00 | 0.64894D-03 | 0.65109D 00 | 0.51709D 13 | 2.49589 | 6.33956 |
| 47 | 0.09306 | 0.17198D 00 | 0.10068D-01 | 0.67706D-01 | 0.88308D-01 | 0.51295D-03 | 0.66142D 00 | 0.40615D 13 | 2.63631 | 6.69624 |
| 48 | 0.09826 | 0.16201D 00 | 0.20200D-01 | 0.71857D-01 | 0.70599D-01 | 0.35636D-03 | 0.67498D 00 | 0.27946D 13 | 2.78376 | 7.07075 |
| 49 | 0.10373 | 0.14377D 00 | 0.44432D-01 | 0.67279D-01 | 0.49857D-01 | 0.19741D-03 | 0.69447D 00 | 0.15276D 13 | 2.93857 | 7.46398 |
| 50 | 0.10946 | 0.10274D 00 | 0.10247D 00 | 0.44887D-01 | 0.26147D-01 | 0.66120D-04 | 0.72368D 00 | 0.50508D 12 | 3.10113 | 7.87688 |
| 51 | 0.11549 | 0.0 | 0.23456D 00 | 0.0 | 0.0 | 0.0 | 0.76544D 00 | 0.0 | 3.27182 | 8.31042 |

## APPENDIX C: FORTRAN IV PROGRAM

This appendix gives a list of the program common statements, a listing of the common statements as they occur by subroutines and a complete listing of the FORTRAN IV source statements for PROGRAM VISLNABB.

### List of Common Statements

```
 COMMON /BODY/ HANGLE,XJFAC,IGEOM,JFAC
 COMMON /COMABZ/ ALPHSB(15,11),BETASB(15,11),ZSUB(5,6),ALSUB(15),BE
1TSUB(15),GAMMMI(15,6),GAMMPL(15,6)
 COMMON /COMARL/ XNSP(202),XSOL(200)
 COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
6),VON(51),V1(51),V2(51),V2N(51)
 COMMON /COMBC/ CAINF,CAW,CINF6(6),CIWW6(6)
 COMMON /COMDBL/ AJB(51,6),AJM(51,6),CC(51,6),CCL(51,6),CCN(51,6),C
1PI(51,6),C1(51,6),C2(51,6),C20(51,6),DW(51,6),HI(51,6),WO(51,6),W1
2(51,6)
 COMMON /COMEDG/ CIE(6),TCIE
 COMMON /COMEL/ ELN(6),ELO(6)
 COMMON /COMFAC/ CCFAC,UFAC
 COMMON /COMFS/ PINF,REYIN,RINF,TINF,UINF
 COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
 COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
 COMMON /COMG1/ CP,CPB,SP,SPB
 COMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
 COMMON /COMG3/ CSF,RS,SIF,XB,XNS1
 COMMON /COMNS/ NS
 COMMON /COMNS2/ NJ,NR,NSM1,NZ
 COMMON /COMPRF/ SPRF(10),NSPRF
 COMMON /COMREF/ CONREF,CPREF,HREF,PREF,RREF,TREF,UREF,VSREF,WREF
 COMMON /COMRX/ RSH,XSH
 COMMON /COMSET/ RATE2(15,6),RATE6(15,6),ZSUB2(5,6),ZSUB6(5,6),KRTI
1TL(18),KREQ2(15,6),NAME2(11),NJ2,NR2,NZ2,KREQ6(15,6),NAME6(11),NJ6
2,NR6,NZ6
 COMMON /COMSML/ SMALLT
 COMMON /COMSUM/ CPJSUM(51),HDWSUM(51),HWSUM(51),HJSUMW
 COMMON /COMSO/ PPSO,TTSO,VVSO,UUSO,NSOLD
 COMMON /COMTAB/ CPTAB(50,6),HTAB(50,6),TMPTAB(50),NTAB
 COMMON /COMTST/ DIFI(8),DIF,XU25
 COMMON /COMUV/ URSH,VRSH
 COMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
 COMMON /COMVSP/ VSPP1,VSPP2
 COMMON /COMW/ CIW(6),CIWW(6),CPIW(6),HIW(6),HTFLB,TB,TCNW,TW
 COMMON /COMXR/ ALP,ALT,BRAD,BO,CDF,CDFO,CDF1,CDF2,CDP,CDPO,CDP1,CD
1P2,OLDSLP,PHI,SEND,WVFAC,XNSO,IEND,IUN,KPLTTP,NITMIN,NITTOT,NTOT,N
2TPL,NTW
 COMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
 COMMON /INV2/ XNSA,XNSIVO,XNSIV1,XNSTMP,NAN
 COMMON /KJI/ IJK
 COMMON /KNTR/ KNTR1,KNTW1,KNTW2
 COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
 COMMON /PRLE/ SIGM,XLE
 COMMON /RTECON/ CRO(15),CR1(15),CR2(15),DRO(15),DR1(15),DR2(15)
 COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
 COMMON /TITLE/ KTITLE(20)
```

## Occurrence of Common Statements by Subroutines

A listing of the subroutines in which each common block occurs is given below. The listing used with the section "Description of Variables in Common" is an aid in determining where FORTRAN variables appear in the program.

| COMMON | OCCURS IN |
|---|---|
| BODY | ENERGY, GEOM, MAIN, MASS, SMOMNT, SPECIE |
| COMABZ | SET2, WISUB |
| COMARL | ENERGY, MAIN, MASS, NMOMNT, RESET, SMOMNT, SPECIE |
| COMAR1 | ENERGY, MAIN, MASS, NMOMNT, RESET, SET, SMOMNT, SPECIE, THERM |
| COMBC | MAIN, RESET, SET2 |
| COMDBL | MAIN, RESET, SET, SPECIE, THERM, WISUB |
| COMEDG | ENERGY, MAIN, SET, SHVALS, SPECIE |
| COMEL | BLDATA, MAIN |
| COMFAC | ENERGY, MAIN, SMOMNT, SPECIE |
| COMFS | MAIN, RESET, SHVALS, THERM |
| COMFSA | BLDATA, ENERGY, HCP, HCPA, MAIN, RESET, SET, SET2, SHVALS, SPECIE, THERM |
| COMG | ENERGY, MAIN, MASS, NMOMNT, RESET, SET, SMOMNT, SPECIE |
| COMG1 | ENERGY, MAIN, SMOMNT, SPECIE |
| COMG2 | ENERGY, MAIN, MASS, NMOMNT, RESET, SET, SMOMNT, SPECIE |
| COMG3 | MAIN, MASS, RESET |
| COMNS | ENERGY, HCP, HCPA, MAIN, RESET, SET, SET2, SHVALS, SPECIE, THERM, VISCNA, VISCON, WISUB |
| COMNS2 | MAIN, SET2, SPECIE, WISUB |
| COMPRF | MAIN, RESET |
| COMREF | ENERGY, MAIN, RESET, SHVALS, THERM, WISUB |
| COMRX | MASS, RESET |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| COMSET | RTEDTA, | SET2 | | | | | | |
| COMSML | HCP, | HCPA, | INTRPS, | INTRP3, | MAIN, | RESET, | SMTHAR, | SPECIE |
| CONSUM | ENERGY, | RESET, | SPECIE | | | | | |
| COMSO | MAIN, | NMOMNT, | SET | | | | | |
| COMTAB | BLDATA, | HCP, | HCPA | | | | | |
| COMTST | ENERGY, | MAIN, | SMOMNT, | SPECIE | | | | |
| COMUV | ENERGY, | MAIN, | SMOMNT | | | | | |
| COMVS | BLDATA, | MAIN, | RESET, | SHVALS, | THERM, | VISCNA, | VISCON, | WISUB |
| COMVSP | MAIN, | MASS | | | | | | |
| COMW | ENERGY, | MAIN, | RESET, | SET, | SET2, | SPECIE, | THERM | |
| COMXR | MAIN, | RESET, | RTEDTA | | | | | |
| INSH | ENERGY, | MAIN, | MASS, | NMOMNT, | RESET, | SHVALS, | SMOMNT, | SPECIE |
| INV2 | MAIN, | MASS, | RESET | | | | | |
| KJI | GEOM, | MAIN | | | | | | |
| KNTR | MAIN, | RESET | | | | | | |
| OUTSH | ENERGY, THERM | MAIN, | MASS, | NMOMNT, | RESET, | SHVALS, | SMOMNT, | SPECIE |
| PRLE | MAIN, | RESET, | SPECIE, | THERM | | | | |
| RTECON | SET2, | WISUB | | | | | | |
| SOLV | ENERGY, SOLVE, | MAIN, SPECIE, | MASS, THERM | NMOMNT, | RESET, | SET, | SHVALS, | SMOMNT, |
| TITLE | MAIN, | RESET | | | | | | |

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Note: BLDATA stands for BLOCK DATA.

Listing of PROGRAM VISLNABB

The FORTRAN source statements of Program VISLNABB are listed on the following pages.

```
C     PROGRAM VISLNABB
C
C     MAIN CONTROLS LOGIC FLOW OF THE PROGRAM, PERFORMS SOME
C     CALCULATIONS, AND UP DATES THE SHOCK SHAPES.
C
C     MAIN CALLS SUBROUTINES DERIV3, ENERGY, GEOM, INTRP3, MASS, NMOMNT,
C                            RESET, RTEDTA, SET, SET2, SHVALS, SMOMNT,
C                             SMTHPR, SPECIE, THERM, AND VPRFLE
C
C     * * JCL FOR IBM 370/158 * *
C
C     //JOBCARD
C     // EXEC FORTGCLG,REGION=200K
C     //FORT.SYSIN DD *
C
C          FORTRAN SOURCE PROGRAM
C
C     /*
C     //GO.FT01F001 DD SYSOUT=A
C     //GO.FT03F001 DD SYSOUT=A
C     //GO.FT04F001 DD *
C
C          BODY GEOMETRY DATA
C
C     /*
C     //GO.FT08F001 DD SYSOUT=A
C     //GO.FT09F001 DD SYSOUT=A
C     //GO.FT15F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),SPACE=(440,(200)),
C     //     DCB=(RECFM=VS,BLKSIZE=440,LRECL=436)
C     //GO.FT16F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),SPACE=(440,(200)),
C     //     DCB=(RECFM=VS,BLKSIZE=440,LRECL=436)
C     //GO.FT19F001 DD *
C
C          REACTION RATE DATA
C
C     /*
C     //GO.FT20F001 DD *
C
C          SHOCK SHAPE DATA
C
C     /*
C     //GO.SYSIN DD *
C
C          UNIT 5 - INPUT DATA
C
C     /*
C     //
C
C
      COMMON /BODY/ HANGLE,XJFAC,IGECM,JFAC
      COMMON /COMARL/ XNSP(202),XSCL(200)
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
      COMMON /COMBC/ CAINF,CAW,CINF6(6),CIWW6(6)
      COMMON /COMDBL/ AJB(51,6),AJM(51,6),CC(51,6),CCL(51,6),CCN(51,6),C
     1PI(51,6),C1(51,6),C2(51,6),C20(51,6),DW(51,6),HI(51,6),WO(51,6),W1
     2(51,6)
      COMMON /COMECG/ CIE(6),TCIE
      COMMON /COMEL/ ELN(6),ELO(6)
      COMMON /COMFAC/ CCFAC,UFAC
      COMMON /COMFS/ PINF,REYIN,RINF,TINF,UINF
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
      COMMON /COMG1/ CP,CPB,SP,SPB
      COMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
      COMMON /COMG3/ CSF,RS,SIF,XB,XNS1
```

```
      COMMON /COMNS/ NS
      COMMON /COMNS2/ NJ,NR,NSM1,NZ
      COMMCN /COMPRF/ SPRF(10),NSPRF
      COMMON /COMREF/ CONREF,CPREF,HREF,PREF,RREF,TREF,UREF,VSREF,WREF
      COMMON /COMSML/ SMALLT
      CCMMON /COMSO/ PPSO,TTSO,VVSO,UUSO,NSOLD
      COMMON /COMTST/ DIFI(8),DIF,XU25
      COMMON /COMUV/ URSH,VRSH
      CCMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
      CCMMON /COMVSP/ VSPP1,VSPP2
      COMMON /COMW/ CIW(6),CIWW(6),CPIW(6),HIW(6),HTFLB,TB,TCNW,TW
      COMMON /COMXR/ ALP,ALT,BRAD,BO,CDF,CDFD,CDF1,CDF2,CDP,CDPD,CDP1,CD
     1P2,OLDSLP,PHI,SEND,WVFAC,XNSO,IEND,IUN,KPLTTP,NITMIN,NITTOT,NTOT,N
     2TPL,NTW
      CCMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
      COMMON /INV2/ XNSA,XNSIVO,XNSIV1,XNSTMP,NAN
      COMMON /KJI/ IJK
      CCMMON /KNTR/ KNTR1,KNTW1,KNTW2
      COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      COMMON /PRLE/ SIGM,XLE
      CCMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
      COMMON /TITLE/ KTITLE(20)
C
      DIMENSION ENSHN(301), SHSLPN(301), SN(301), XXNP(301)
      DIMENSION STWA(100), TWA(100)
      DIMENSION CNVRGI(8), TERMN(6), TERMO(6)
C
      NAMELIST /INPUT/ ALT,BRAD,CAINF,CAT,CAW,CCFAC,CONVRG,DS,DSMAX,HANG
     1LE,PRNTCI,RINF,SEND,SIGM,SITEST,SMALLT,SSFAC,SWFAC,TB,THINI,TINF,U
     2FAC,UINF,WVFAC,XKETA,XLE,XNSO,IE,IEND,IGEOM,IUN,JFAC,KEND,KPLTTP,K
     3TWAL,NAN,NDATA,NITMAX,NITMIN,NITMNI,NS,NSI,NSPRF,NTSH,NTTWA
C
      DATA BLNK/1H /
C
      DATA XXNP/301*0.0/
C
C
      IJK=0
      VPG=0.0
      READ (5,620) KTITLE
      WRITE (6,630) KTITLE
      KNTR1=0
      KNTW1=0
      KNTW2=0
      NTPL=13
      NTR=15
      NTW=16
      NTOT=0
      NSOLD=0
C
C     INITIALIZE NAMELIST INTEGER VARIABLES
C
      IE=51
      IEND=200
      IUN=19
      JFAC=1
      KEND=2
      KPLTTP=0
      KTWAL=0
      NAN=1
      NCATA=0
      NITMAX=9999
      NITMIN=3
      NITMNI=3
      NS=2
      NSI=2
      NSPRF=0
      NTSH=5
      NTTWA=5
C
```

```
C     INITIALIZE NAMELIST REAL VARIABLES
C
      CAINF=0.0
      CAT=1.0
      CAW=0.0
      CCFAC=0.0
      CCNVRG=0.01
      DS=0.1
      DSMAX=5.0
      HANGLE=10.0
      PRNTCI=0.0
      SEND=0.0
      SIGM=0.7
      SITEST=0.0001
      SMALLT=1.0E-6
      SSFAC=-1.0
      SWFAC=-1.0
      THINI=+1.00
      UFAC=0.5
      WVFAC=0.250
      XKETA=1.0
      XLE=1.4
      XNSO=0.1166
      DO 10 J=1,6
      CINF(J)=0.00
      CIWW(J)=0.00
10    CONTINUE
      THIN=1.00
C
C     NAMELIST INPUT
C
      READ (5,INPUT)
      IF (NDATA.EQ.0) SEND=DS*(IEND+1)
      XJFAC=JFAC
      WRITE (6,INPUT)
      NSM1=NS-1
      NSPL2=NS+2
      DO 20 N=1,IE
      VG(N)=0.0
20    VGS(N)=0.0
      READ (5,750) (CINF6(J),J=1,6)
      READ (5,750) (CIWW6(J),J=1,6)
      IF (NDATA.EQ.0) GO TO 80
      N=0
30    N=N+1
C
C     SHOCK SHAPE DATA
C
      READ (NTSH,700) SN(N),SHSLPN(N),ENSHN(N),ENO
      IF (ENO.EQ.BLNK) GO TO 30
      NSDATA=N
      IF (SEND.LT.0.0001) SEND=SN(NSDATA)
      IF (SEND.GT.SN(NSDATA)) SEND=SN(NSDATA)
      CALL DERIV3 (ENSHN,SN,NSDATA,2,SHSLPN)
      SHSLPN(1)=0.0
      SHSLPN(NSDATA+1)=SHSLPN(NSDATA)
      SN(NSDATA+1)=SN(NSDATA)+(SN(NSDATA)-SN(NSDATA-1))
      DO 60 KLSQ=1,4
      DO 40 N=2,NSDATA
40    XXNP(N)=2.0*(SHSLPN(N+1)-SHSLPN(N-1))*(SN(N)-SN(N-1))/(3.0*(SN(N+1
     1)-SN(N-1)))+(2.0*SHSLPN(N-1)+SHSLPN(N))/3.0
      DO 50 N=2,NSDATA
50    SHSLPN(N)=XXNP(N)
60    CONTINUE
      DO 70 N=1,300
70    XXNP(N)=0.0
      GO TO 100
80    CONTINUE
      IEND2=IEND+2
      DO 90 N=1,IEND2
90    XXNP(N)=0.00
```

```
100   CONTINUE
      IF (KTWAL.EQ.0) GO TO 120
      N=0
110   N=N+1
C
C     WALL TEMPERATURE DATA
C
      READ (NTTWA,540) STWA(N),TWA(N),ENO
      IF (ENO.EQ.BLNK) GO TO 110
      NPTT=N
120   CONTINUE
      IF (NSPRF.NE.0) READ (5,550) SPRF
      IF (NSPRF.NE.0) SPRF(NSPRF)=SEND
      CALL RTEDTA
      IM=IE-1
      DY=1.0/IM
C
C     SET GRID SPACING
C
      IF (XKETA.NE.1.0) DN(1)=(XKETA-1.0)/(XKETA**IM-1.0)
      IF (XKETA.EQ.1.0) DN(1)=DY
      XN(1)=0.0
      DO 130 N=1,IE
      DN(N+1)=XKETA*DN(N)
130   XN(N+1)=XN(N)+DN(N)
      XN(IE)=1.00
      DSCLD=DS
      IF (KPLTTP.NE.0) WRITE (NTPL,690) KTITLE
C
C     BEGIN MAIN LOOP
C
      DO 530 K=1,KEND
      WRITE (1,730)
      WRITE (3,740)
      IF (NDATA.EQ.0) GO TO 150
C
C     PRINT SHOCK SHAPE DATA
C
      WRITE (8,640) K
      WRITE (8,710)
      DO 140 N=1,NSDATA
      WRITE (8,720) SN(N),SHSLPN(N),N
140   CONTINUE
150   CONTINUE
      WRITE (8,640) K
      WRITE (8,650)
      DO 160 J=1,NSPL2
160   CNVRGI(J)=CONVRG
      IF (NS.EQ.6) CNVRGI(7)=CONVRG*100.0
      IF (NS.EQ.2.AND.CAT.LE.0.0) CNVRGI(4)=CONVRG*100.0
      NITER=0
      UPSH=0.00
      TPSH=0.00
      VISCO=0.00
      CONO=0.00
      XNS=XNSO
      XNS1=XNS
      DS1=DS
      DS2=DS/2.00
      CK=1.00
      CSF=0.00
      SIF=1.00
      RS=0.00
      RS2=0.00
      XB=0.0
      CDF=0.0
      CDP=0.0
      CDP1=0.
      CDP2=0.
      CDF1=0.
      CDF2=0.
```

```
      CDPD=0.
      CDFD=0.
      CNS=(XNS1+XNS)/2.
      CRNI=1.0
      NITTOT=0
      S=-DS2
      S1=S+DS2
      IF (THIN.LE.0.0) CALL VPRFLE (S1,VSPP1,VO,IE,NTR,1)
      UUS0=0.0
      PPS0=0.833
      VVS0=-0.167
      TTS0=0.486
      RRS0=6.0
      URSH=0.0
      VRSH=VVS0
      TTSH=TTS0
      TTS2=TTS0
      PPS=PPS0
      RRS=RRS0
      TTS=TTS0
      CALL SET2
      CALL THERM (1,BRAD,CONC,VISCO,EPS,VIS2)
      CALL SET
      AA(1)=0.0
      BB(1)=0.0
      XNSP(1)=0.0
C
C     BEGIN SOLUTION ALONG BODY
C
      DO 390 I=1,IEND
170   S=S+DS2
      IF (KTWAL.EQ.0) GO TO 180
      NUTW=2
      CALL SMTHPR (S,TW,STWA,TWA,NPTT,NUTW)
      TW=TW/TREF
180   CONTINUE
      IF (THIN.GE.0.0) GO TO 190
C
C     RETRIEVE V PROFILES FOR FVSL
C
      S1=S
      S2=S+DS
      CALL VPRFLE (S1,VSPP1,VCI1,IE,NTR,2)
      CALL VPRFLE (S2,VSPP2,VCI2,IE,NTR,2)
C
190   CONTINUE
      CALL GEOM (S,DS2,RS2,CK2,CSF2,SIF2,XB2)
      PHI=ARCOS(CSF2)
C
C     NDATA = 1 / USE TABULATED SHOCK SLOPE DATA
C
      IF (NDATA.EQ.0) GO TO 200
      SPDS=S+DS
      CALL INTRP3 (SPDS,SN,SHSLPN,NSDATA,XNSP(I+1))
200   CONTINUE
      XNSPM=(XNSP(I)+XNSP(I+1))/2.00
      ALP=PHI+ATAN(XNSPM/(1.0+CK2*XNS))
      OLDSLP=XNSP(I)
      WRITE (8,680) I,S,OLDSLP,XNSPM,ALP
      SP=SIN(ALP)
      CP=COS(ALP)
      SPB=SP*SIF2+CP*CSF2
      CPB=CP*SIF2-SP*CSF2
210   CONTINUE
      DIF=0.0
      DO 220 J=1,NSPL2
220   DIFI(J)=0.00
      TGUE=0.0
230   CONTINUE
      TCIE=TC(IE)*TTS*TREF
      CALL SHVALS (SP,CP,SPB,CPB,TTSH,VRSH,URSH,PPSH,2)
```

```
      IF (S.GE.0.0001) GO TO 240
      CALL SHVALS (1.00,0.00,1.00,0.00,TTSO,VVSO,UUSO,PPSO,1)
      BO=TW/TTSO
240   CONTINUE
      SIT=ABS(TGUE-TTS)
      TGUE=TTS
C
C     ITERATE FOR SHOCK TEMPERATURE
C
      IF (SIT.GE.SITEST) GO TO 230
      CALL THERM (2,BRAD,CONO,VISCO,EPS,VIS2)
      REFAC=RRS*VVS*CNS/(EPS*EPS*VISCO)
      XKSL=VIS2*RRS*VVS*SQRT(PPS2*P2(1)/(RRS2*R2(1)))/(PPS2*P2(1)*REFAC)
      DO 260 N=1,IE
      IF (S.GE.0.0001) GO TO 250
      PFAC(N)=4.00*(P2(N)+(PPS2/PPSO-2.00)*PO(N))/(UUS2*DS)-XNSP(2)*XN(N
     1)*PON(N)/(2.00*UUS2*CNS)
      GO TO 260
250   VC(N)=VCD(N)/VVS
260   CONTINUE
C
C     SOLVE GOVERNING EQUATIONS
C
      CALL SPECIE
      CALL ENERGY
      CALL SMOMNT
      CALL MASS
      CALL NMOMNT
      NITER=NITER+1
      NITTOT=NITTOT+1
      NTCT=NTOT+1
      TFACT=XU25-U2(15)
      DIFI(1)=DIF
      IF (PRNTCI.LT.0.5) GO TO 300
C
C     PRINT SPECIES PROFILES AND ATOM SUMS
C
      WRITE (6,560) K,I,S,NITER,DIF
      IF (NS.EQ.6) WRITE (6,570) (NSPI(J),J=1,NS)
      IF (NS.EQ.2) WRITE (6,580) (NSPI(J),J=1,NS)
      WRITE (6,590) (DIFI(J),J=1,NSPL2)
      DO 270 J=1,NS
      TERMN(J)=ELN(J)*EMI(4)/EMI(J)
      TERMO(J)=ELO(J)*EMI(1)/EMI(J)
270   CONTINUE
      DO 290 N=1,IE
      SUM=0.0
      SUMN=0.00
      SUMO=0.00
      DO 280 J=1,NS
      SUMN=SUMN+CC(N,J)*TERMN(J)
      SUMO=SUMO+CC(N,J)*TERMO(J)
280   SUM=SUM+CC(N,J)
      SUM=SUM-1.00
      WRITE (6,600) N,XN(N),UC(N),TC(N),(CC(N,J),J=1,NS),SUM,SUMO,SUMN
290   CONTINUE
300   CONTINUE
C
C     PRINT PROFILE DIFFERENCES
C
      IF (PRNTCI.LT.0.5) WRITE (6,610) K,I,S,NITER,(DIFI(J),J=1,NSPL2)
      WRITE (9,660) K,I,S,NITER,NITTOT,TFACT,DIF,XNS,CNS
      IF (NITER.LT.NITMAX) GO TO 330
      DO 310 J=1,NSPL2
C
C     TEST FOR CONVERGENCE
C
      IF (DIFI(J).GT.CNVRGI(J)) GO TO 320
310   CONTINUE
      GO TO 350
320   CONTINUE
```

```
      IF (I.EQ.1) GO TO 330
      WRITE (6,670) S,TFACT,NITER,NITTOT,DIF,CONVRG
C
C     CUT STEP SIZE IN HALF AND TRY FCR SOLUTION AGAIN
C     IF NITER .EQ. NITMAX
C
      DS=DS/2.0
      DS2=CS2/2.0
      S=S-DS-DS2
      CALL GEOM (S,DS2,RS,CK,CSF,SIF,XB)
      NITER=0
      GO TO 170
330   CCNTINUE
      DO 340 J=1,NSPL2
      IF (DIFI(J).GT.CNVRGI(J)) GO TC 210
340   CCNTINUE
350   CCNTINUE
C
C     PRINT SOLUTION DATA ANC RESET VARIABLE FOR NEXT GLOBAL ITERATION
C
      CALL RESET
      DS=DS1
      IF (NITER.GT.NITMIN) GO TC 360
      IF (CS.GE.DSMAX) GO TO 360
C
C     DOUBLE STEP SIZE
C
      DS=DS*2.0
360   CONTINUE
      RS=RS2
      DS1=DS
      IEI=I
      IF (NSPRF.EQ.0) GO TO 380
      DC 370 NK=1,NSPRF
      IF (S.GE.SPRF(NK)) GO TO 370
      IF (ABS(1.00-S/SPRF(NK)).LE.SMALLT) GO TO 370
      IF ((S+1.25*DS).LE.SPRF(NK)) GO TO 370
      DS=SPRF(NK)-S
      GO TO 380
370   CCNTINUE
380   CCNTINUE
      IF (ABS(1.00-S/SEND).LE.SMALLT) GO TC 400
      IF (S.GE.SEND) GO TO 400
      DS2=DS/2.00
      S=S+DS2
      CALL GEOM (S,DS2,RS,CK,CSF,SIF,XB)
      RS2=RS
      NITER=0
390   CONTINUE
C
C     END SOLUTION ALONG BODY
C
400   CCNTINUE
      S1=S+DS1
      S2=S1+DS1
      WRITE (NTW) S1,VVS,VSP,VCI2
      WRITE (NTW) S2,VVS,VSP,VCI2
      S1=S2+DS1
      S2=S1+DS1
      WRITE (NTW) S1,VVS,VSP,VCI2
      WRITE (NTW) S2,VVS,VSP,VCI2
      KNTW1=KNTW1+4
      IF (NDATA.EQ.0) GO TO 480
C
C     UPDATE SHOCK SHAPE DATA
C
      IEI1=IEI+1
      XSOL(IEI1)=XSCL(IEI)+DS
      XNSP(IEI1)=XNSP(IEI)
      DC 430 KLSQ=1,4
      DO 410 N=2,IEI
```

```
410   XXNP(N)=2.0*(XNSP(N+1)-XNSP(N-1))*(XSOL(N)-XSOL(N-1))/(3.0*(XSOL(N
     1+1)-XSOL(N-1)))+(2.0*XNSP(N-1)+XNSP(N))/3.0
      DO 420 N=2,IEI
420   XNSP(N)=XXNP(N)
430   CONTINUE
      DO 440 N=2,NSDATA
      NN=N
      IF (SN(NN).GE.XSOL(IEI)) GO TO 450
440   CONTINUE
      GO TO 460
450   NSDATA=NN
460   CONTINUE
      DO 470 N=2,NSDATA
470   CALL INTRP3 (SN(N),XSOL,XNSP,IEI,SHSLPN(N))
      GO TO 520
480   CONTINUE
C
C     AVERAGE SHOCK SHAPE FOR ANALYTIC BODIES
C
      XNSP(IEND+1)=XNSP(IEND)
      DO 510 KLSQ=1,4
      DO 490 N=2,IEND
490   XXNP(N)=(XNSP(N-1)+XNSP(N)+XNSP(N+1))/3.
      DO 500 N=2,IEND
500   XNSP(N)=XXNP(N)
510   CONTINUE
520   CONTINUE
C
C     SET COUNTERS FOR NEXT GLOBAL ITERATION
C
      REWIND NTR
      REWIND NTW
      NTO=NTR
      NTR=NTW
      NTW=NTO
      KNTW2=KNTW1
      KNTR1=0
      KNTW1=0
      DS=DSOLD
      THIN=THINI
      NITMIN=NITMNI
      NSOLD=NS
      NS=NSI
      NSM1=NS-1
      NSPL2=NS+2
530   CONTINUE
C
C     END MAIN LOOP
C
      RETURN
C
C
C
540   FORMAT (2E15.6,A1)
550   FORMAT (10F8.0)
560   FORMAT (1H1,2X,3HK =,I1,4H,I =,I3,4H,S =,F10.6,9H, NITER =,I3,7H,
     1DIF =,E15.7)
570   FORMAT (1H0,4X,1HN,3X,2HXN,7X,2HUC,7X,2HTC,2X,6(7X,A4),2X,9HSUMCI-
     11.0,7X,4HSUMO,7X,4HSUMN)
580   FORMAT (1H0,4X,1HN,3X,2HXN,7X,2HUC,7X,2HTC,2X,2(7X,A4),2X,9HSUMCI-
     11.0,7X,4HSUMO,7X,4HSUMN)
590   FORMAT (1H ,7X,6H(DIFI),1X,2F9.6,1PE11.4,5E11.4)
600   FORMAT (1H ,2X,I3,3F9.6,1PE11.4,8E11.4)
610   FORMAT (1H ,3HK =,I1,5H, I =,I3,5H, S =,F7.3,9H, NITER =,I3,8H, DI
     1FI =,1PE10.3,7E10.3)
620   FORMAT (20A4)
630   FORMAT (1H0,//25X,20A4,///)
640   FORMAT (1H1,20X,3HK =,I2)
650   FORMAT (1H0,8HSTA. NO.,10X,1HS,7X,8HOLD XNSP,10X,5HXNSPM,2X,13HALP
     1HA(S+DS/2),7X,8HNEW XNSP,6X,2X,7HNEW YSH,12X,3HXSH,12X,3HRSH)
660   FORMAT (1H ,2HK=,I2,4H, I=,I3,3H,S=,F10.6,9H, NITER =,I5,10H, NITT
```

```
     1OT =,I5,9H, TFACT =,E15.7,7H, DIF =,E15.7,1P2E14.6)
670   FORMAT (1HO,2X,3HS =,F10.6,9H, TFACT =,1PE15.7,9H, NITER =,I5,11H,
     1  NITTOT =,I5,7H, DIF =,E16.7,10H, CONVRG =,E15.7)
680   FORMAT (1H ,1X,I3,4F15.10)
690   FORMAT (20A4)
700   FORMAT (3E15.6,A1)
710   FORMAT (1HO,8X,1HS,13X,4HYSHP,8X,1HN)
720   FORMAT (1H ,2E15.6,I5)
730   FORMAT (2H- ,1HK,4X,1HI,6X,4HS/RN,3X,4HITER,6X,3HYSH,9X,4HYSHP,8X,
     12HCF,10X,4HHEAT,8X,4HSTAN,8X,5HPW/PO,7X,4HQ/QO,8X,1HS,11X,4HQDOT//
     2)
740   FORMAT (1HO,//2X,1HK,4X,1HI,1X,4HITER,6X,4HS/RN,8X,3HYSH,9X,5HYSH-
     1D,7X,6HYSH-ST,6X,6HYSH-AV,3X,9HE-/CC,MAX,4X,8HXN,E-MAX,4X,8HY,IN,E
     2-M,6X,4HS/RN,8X,4HS FT//)
750   FORMAT (6F10.5)
      END
```

```
      SUBROUTINE DERIV3 (F,X,IMAX,IMIN,FP)
C
C     SUBROUTINE DERIV3 CALCULATES THE FIRST DERIVATIVES OF F WITH
C     RESPECT TO X AND RETURNS THE ARRAY FP
C
C     SUBROUTINE DERIV3 IS CALLED BY MAIN AND SUBROUTINES ENERGY, MASS,
C                              SET, SMOMNT, SOLVE, SPECIE, AND THERM.
C
      DIMENSION F(IMAX), X(IMAX), FP(IMAX)
C
C
      DO 10 J=IMIN,IMAX
      K=J
      IF (K.LT.(IMIN+1)) K=IMIN+1
      IF (K.GT.(IMAX-1)) K=IMAX-1
      AN1=2.0*X(J)-X(K)-X(K+1)
      AN2=2.0*X(J)-X(K-1)-X(K+1)
      AN3=2.0*X(J)-X(K-1)-X(K)
      DN1=(X(K-1)-X(K))*(X(K-1)-X(K+1))
      DN2=(X(K)-X(K-1))*(X(K)-X(K+1))
      DN3=(X(K+1)-X(K-1))*(X(K+1)-X(K))
      CN1=AN1/DN1
      CN2=AN2/DN2
      CN3=AN3/DN3
      FP(J)=CN1*F(K-1)+CN2*F(K)+CN3*F(K+1)
10    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ENERGY
C
C     SUBROUTINE ENERGY SOLVES THE ENERGY EQUATION
C
C     SUBROUTINE ENERGY CALLS SUBROUTINES DERIV3, HCP, AND SOLVE.
C
C     SUBROUTINE ENERGY IS CALLED BY MAIN.
C
      COMMON /BODY/ HANGLE,XJFAC,IGEOM,JFAC
      COMMON /COMARL/ XNSP(202),XSCL(200)
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
```

```
      COMMON /COMEDG/ CIE(6),TCIE
      COMMON /COMFAC/ CCFAC,UFAC
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
      COMMON /COMG1/ CP,CPB,SP,SPB
      COMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
      COMMON /COMNS/ NS
      COMMON /COMREF/ CONREF,CPREF,HREF,PREF,RREF,TREF,UREF,VSREF,WREF
      COMMON /COMSUM/ CPJSUM(51),HDWSUM(51),HWSUM(51),HJSUMW
      COMMON /COMTST/ DIFI(8),DIF,XU25
      COMMON /COMUV/ URSH,VRSH
      COMMON /COMW/ CIW(6),CIWW(6),CPIW(6),HIW(6),HTFLB,TB,TCNW,TW
      COMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
      COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
C
      DIMENSION HII(6), HFAC(6), CPII(6)
C
      DO 10 N=1,IE
      CHM1=CPJSUM(N)*CNS/(CON(N)*CCNO)
      CHMFAC=CNS*CNS*RRS*RC(N)/(EPS*EPS*CONO*CON(N))
      CHM2=CHMFAC*HWSUM(N)/TTS
      CHM3=CHMFAC*HDWSUM(N)
      CHM4=CHM3*TC(N)
C
C     CALCULATE COEFFICIENTS FOR PARTIAL DIFFERENTIAL EQUATION
C
      A1(N)=REFAC*VISCO*CPST(N)*(UUS*XNSP(I)*RNSH(N)*RC(N)*UC(N)*XN(N)/(
     1VVS*CNS)-RC(N)*VC(N))/(CONO*CON(N))+RCON(N)+CK*RNSH(N)+RCSF(N)*XJF
     2AC-CHM1
      A4(N)=-REFAC*VISCO*CPST(N)*UUS*RNSH(N)*RC(N)*UC(N)/(VVS*CONO*CON(N
     1))
      A2(N)=A4(N)*TSP/TTS-CHM3
10    A3(N)=REFAC*PPS*VISCO*(RNSH(N)*UUS*UUS*UC(N)*PFAC(N)+VVS*VC(N)*PCN
     1(N))/(TTS*RRS*VVS*CONO*CON(N))+UUS*UUS*VISC(N)*VISCO*(UCN(N)-CK*RN
     2SH(N)*UC(N))**2/(TTS*CONO*CON(N))-CHM2+CHM4
      TTS2TR=TTS2*TREF
      CALL HCP (TTS2TR,CPII,HII,HFAC)
      SUMCDH=0.0
      SUMCHF=0.0
      DO 20 J=1,NS
      SUMCDH=SUMCDH+CINF(J)*(HINF(J)-DELHIF(J))/HREF
      SUMCHF=SUMCHF+CINF(J)*HFAC(J)/CPREF
20    CONTINUE
C
C     CALCULATE SLIP VARIABLES
C
      CS1=SP*XNS*(SUMCHF)/(EPS*EPS*CONO)
      CS2=-SP*XNS*(0.50*(URSH-CP)**2+0.50*(SP**2-VRSH**2)+SUMCDH)/(EPS*E
     1PS*CONO*TTS2)
      E1=0.0
      F1=TW/TTS2
C
      CALL SOLVE (T1,T2,E1,F1,CRNI,1.00,CS1,CS2,SSFAC)
C
      TTS2G=TTS2
      SMALL=1.0E-6
      DO 30 N=2,IE
      IF (T2(N).LE.0.0) T2(N)=SMALL
30    CONTINUE
      CALL DERIV3 (T2,XN,IE,1,Q1)
      T2NIE=Q1(IE)
      IF (SSFAC) 70,70,40
40    TPSH=T2NIE
      TTS2=T2(IE)*TTS2G
      IF (S.GE.0.0001) GO TO 50
      TTS1=TTS2
50    TTS=(TTS2+TTS1)/2.0
      DO 60 N=1,IE
60    T2(N)=T2(N)*TTS2G/TTS2
```

```
      GO TO 80
70    TPSH=0.0
80    CONTINUE
      XU25=U2(15)
      DO 120 N=1,IE
      R2(N)=P2(N)*EMBAR(N)/(T2(N)*EMBAR(IE))
      IF (S.GE.0.0001) GO TO 100
      IF (NITER.GT.20) GO TO 90
      R1(N)=R2(N)
      T1(N)=T2(N)
      GO TO 100
90    CONTINUE
      R1(N)=UFAC*R1(N)+(1.0-UFAC)*R2(N)
      T1(N)=UFAC*T1(N)+(1.0-UFAC)*T2(N)
100   TC(N)=(T1(N)+T2(N))/2.
C
C     CALCULATE PROFILE DIFFERENCE
C
      IF (T21(N).EQ.0.00) GO TO 110
      DIFF=ABS(1.00-T2(N)/T21(N))
      IF (DIFF.GT.DIFI(2)) DIFI(2)=DIFF
110   CONTINUE
      T21(N)=T2(N)
      VC(N)=VCD(N)/VVS
120   RC(N)=(R2(N)+R1(N))/2.0
      CALL DERIV3 (TC,XN,IE,1,Q1)
      TCNW=Q1(1)
      RETURN
      END
```

```
      SUBROUTINE GEOM (S,DS,RS,CK,CSF,SIF,XB)
C
C     SUBROUTINE GEOM CALCULATES THE BODY GEOMETRY
C
C     SUBROUTINE  GEOM  CALLS SUBROUTINE SMOOTH.
C
C     SUBROUTINE  GEOM  IS CALLED BY MAIN.
C
      COMMON /BODY/ HANGLE,XJFAC,IGEOM,JFAC
      COMMON /KJI/ IJK
      DIMENSION ZAX(301), RWA(301), SUR(301), CKA(301), THA(301)
      DATA KBL/1H /
      IRN4=4
      GO TO (40,10,70), IGEOM
C
C     IGEOM = 1 HYPERBOLOID
C           = 2 PARABOLOID
C           = 3 CURVE FIT
C
C
C     PARABOLOID
C
10    CONTINUE
      XS=S+DS
      DR=DS/SQRT(1.00+RS*RS)
      REXP=RS+DR
      DELTA=1.00
20    CONTINUE
      IF (ABS(DELTA).LE.0.00000010) GO TO 30
      RFAC=SQRT(1.00+REXP*REXP)
      DELTA=(XS-0.50*REXP*RFAC-0.50*ALOG(REXP+RFAC))/RFAC
      REXP=REXP+DELTA
      GO TO 20
30    CONTINUE
      XB=REXP*REXP/2.00
      RS=REXP
```

```
      DRX=1.00/SQRT(1.00+RS*RS)
      CSF=RS/SQRT(1.00+RS*RS)
      SIF=DRX
      CK=SIF**3
      RETURN
40    CONTINUE
C
C     FOR A HYPERBOLOID ASYMPTOTIC TO A CONE OF TOTAL INTERIOR ANGLE
C     OF ( 2. * HANGLE) DEGREES
C
      ANG=HANGLE/57.2957795
      CT1=ATAN(ANG)**2
      CT2=1.00+CT1
      DERR=DS*SQRT(CT1*RS*RS+1.0)/SQRT(CT2*RS*RS+1.0)
      REXP=RS+DERR/2.00
50    CONTINUE
      DERR=DS*SQRT(CT1*REXP*REXP+1.0)/SQRT(CT2*REXP*REXP+1.0)
      DELT=RS+DERR/2.00-REXP
      IF (DELT.LE.0.00001) GO TO 60
      REXP=RS+DERR/2.00
      GO TO 50
60    RS=RS+DERR
      SQPT=SQRT(1.00+CT2*RS*RS)
      XB=(-1.00+SQRT(1.00+CT1*RS*RS))/CT1
      CK=1.00/(SQPT*SQPT*SQPT)
      CSF=RS/SQPT
      SIF=SQRT(1.00-CSF*CSF)
      RETURN
C
C     CURVE FIT OF PIECEWISE CONTINUOUS FUNCTION
C
70    CONTINUE
      IF (IJK.EQ.123) GO TO 110
      I=0
80    CONTINUE
      I=I+1
      IF (I.EQ.302) GO TO 90
      READ (IRN4,120) ZAX(I),RWA(I),SUR(I),CKA(I),THA(I),KND
      IF (KND-KBL) 100,80,100
90    CONTINUE
      I=I-1
      WRITE (6,130) SUR(I)
100   CONTINUE
      IJK=123
      NX=I
110   CONTINUE
      S=S+DS
      CALL INTRP3 (S,SUR,ZAX,NX,XB)
      CALL INTRP3 (S,SUR,RWA,NX,RS)
      CALL INTRP3 (S,SUR,CKA,NX,CK)
      CALL INTRP3 (S,SUR,THA,NX,THC)
      CSF=COS(THC)
      SIF=SIN(THC)
      S=S-DS
      RETURN
C
C
C
120   FORMAT (5E15.6,A1)
130   FORMAT (1H0,79HWARNING - CURVE FIT GEOMETRY DATA EXCEDES ARRAY STO
     1RAGE; DATA TRUNCATED AT S = ,1PE13.6//)
      END
```

```
      SUBROUTINE HCP (TR,CPII,HII,HIFAC)
C
C     SUBROUTINE HCP INTERPOLATES FOR ENTHALPY AND SPECIFIC HEAT
C     FOR ONE TEMPERATURE
C
C     SUBROUTINE  HCP   CALLS SUBROUTINE INTER3.
C
C     SUBROUTINE HCP IS CALLED BY SUBROUTINES ENERGY, SHVALS, AND THERM.
C
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMNS/ NS
      COMMON /COMSML/ SMALLT
      COMMON /COMTAB/ CPTAB(50,6),HTAB(50,6),TMPTAB(50),NTAB
      DIMENSION HIFAC(6)
      DIMENSION CPII(6), HII(6)
C
C     TR - DEGREES R
C
      FAC=1.0+SMALLT
      JC=0
10    JC=JC+1
      IF (JC.GT.NTAB) GO TO 20
      IF (TR.GT.TMPTAB(JC)*FAC) GO TO 10
20    CONTINUE
      IF (JC.LT.2) JC=2
      IF (JC.GT.(NTAB-1)) JC=NTAB-1
      DO 30 J=1,NS
      CALL INTER3 (TR,TMPTAB(JC-1),TMPTAB(JC),TMPTAB(JC+1),HTAB(JC-1,J),
     1HTAB(JC,J),HTAB(JC+1,J),HIFAC(J))
      CALL INTER3 (TR,TMPTAB(JC-1),TMPTAB(JC),TMPTAB(JC+1),CPTAB(JC-1,J)
     1,CPTAB(JC,J),CPTAB(JC+1,J),CPII(J))
      HII(J)=HIFAC(J)*TR+DELHIF(J)
30    CONTINUE
C
C     CPII - FT**2/SEC**2-DEGR
C     HII  - FT**2/SEC**2
C
      RETURN
      END
```

```
      SUBROUTINE HCPA (TA,IE,HREF,CPREF,TTS,TREF,HI,CPI)
C
C     SUBROUTINE HCPA INTERPOLATES FOR ENTHALPY AND SPECIFIC HEAT
C     FOR AN ARRAY OF TEMPERATURES
C
C     SUBROUTINE  HCPA  CALLS SUBROUTINE INTER3.
C
C     SUBROUTINE  HCPA  IS CALLED BY SUBROUTINE THERM.
C
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMNS/ NS
      COMMON /COMSML/ SMALLT
      COMMON /COMTAB/ CPTAB(50,6),HTAB(50,6),TMPTAB(50),NTAB
      DIMENSION TA(51)
      DIMENSION HI(51,6)
      DIMENSION CPI(51,6)
C
C     TR - DEGREES R
C
      FAC=1.0+SMALLT
      DO 40 N=1,IE
      TR=TA(N)*TTS*TREF
      JC=0
10    JC=JC+1
      IF (JC.GT.NTAB) GO TO 20
      IF (TR.GT.TMPTAB(JC)*FAC) GO TO 10
20    CONTINUE
```

```
      IF (JC.LT.2) JC=2
      IF (JC.GT.(NTAB-1)) JC=NTAB-1
      DO 30 J=1,NS
      CALL INTER3 (TR,TMPTAB(JC-1),TMPTAB(JC),TMPTAB(JC+1),HTAB(JC-1,J),
     1HTAB(JC,J),HTAB(JC+1,J),HIFAC)
      CALL INTER3 (TR,TMPTAB(JC-1),TMPTAB(JC),TMPTAB(JC+1),CPTAB(JC-1,J)
     1,CPTAB(JC,J),CPTAB(JC+1,J),CPIFAC)
      HI(N,J)=(HIFAC*TR+DELHIF(J))/HREF
      CPI(N,J)=CPIFAC/CPREF
30    CONTINUE
40    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INTERP (XX,XN,F2,IE,FF)
C
C
C     SUBROUTINE INTERP USES FUNCTION TLU TO INTERPOLATE IN ARRAY F2
C     FOR THE VALUE FF CORRESPONDING TO THE VALUE XX IN ARRAY XN.
C     IF XX .LT. XN(1) .OR. XX .GT. XN(IE), FF IS SET EQUAL TO F2(IE)
C     AND A MESSAGE IS PRINTED.
C
C     SUBROUTINE INTERP IS CALLED BY SUBROUTINE VPRFLE.
C
C     SUBROUTINE INTERP CALLS FUNCTION TLU.
C
      DIMENSION XN(IE), F2(IE)
C
C
      FF=TLU(IE,F2,XN,XX,NFLAG)
      IF (NFLAG.NE.1) RETURN
      WRITE (6,10)
      FF=F2(IE)
      RETURN
C
C
C
10    FORMAT (1H0,10X,38HINADAQUATE TABLE FOR SUBROUTINE INTEPP,//11X,43
     1HSTANDARD FIXUP TAKEN - EXECUTION CONTINUING)
      END
```

```
      SUBROUTINE INTER3 (X,X1,X2,X3,F1,F2,F3,F)
C
C     SUBROUTINE INTER3 INTERPOLATES FOR THE VALUE F CORRESPONDING TO
C     POINT X USING 3 POINT LAGRANGIAN INTERPOLATION.
C
C     SUBROUTINE INTER3 IS CALLED BY SUBROUTINES INTRP3, HCP, AND HCPA.
C
C     ASSUMES X1 .LE. X .LE. X3.
C
      AN1=(X-X2)*(X-X3)
      AN2=(X-X1)*(X-X3)
      AN3=(X-X1)*(X-X2)
      DN1=(X1-X2)*(X1-X3)
      DN2=(X2-X1)*(X2-X3)
      DN3=(X3-X1)*(X3-X2)
      CN1=AN1/DN1
      CN2=AN2/DN2
      CN3=AN3/DN3
      F=CN1*F1+CN2*F2+CN3*F3
      RETURN
      END
```

```
      SUBROUTINE INTRPS (XX,YY,X,Y,NP,NNU,DYY)
C
C     SUBRCUTINE INTRPS CALLS SUBROUTINE SMOOTH.
C
C     SUBRCUTINE INTRPS IS CALLED BY SUBROUTINE SMTHPR.
C
      COMMCN /COMSML/ SMALLT
C
C     USES SUBROUTINE SMOOTH TO INTERPOLATE FOR YY IN ARRAY Y
C     CORRESPONDING TO XX IN ARRAY X
C
C     NP = NUMBER OF POINTS IN ARRAYS
C     NU = 1/2 OF THE NUMBER OF POINTS TO BE USED IN SMOOTH
C     NNU = PREFERRED VALUE OF NU
C
      DIMENSION X(NP), Y(NP)
      FAC=1.0+SMALLT
      JC=0
10    JC=JC+1
      IF (XX.GT.X(JC)*FAC) GO TO 10
      NU=NNU
      NFAC=NP-JC+1
      IF (NFAC.LE.NU) NU=NFAC
      IF (JC.LE.NU) NU=JC
      IF (NU.LE.0) NU=1
      CALL SMOOTH (XX,X,Y,NP,YY,DYY,NU,DDYY)
      RETURN
      END


      SUBRCUTINE INTRP3 (XX,X,Y,NPNTS,YY)
C
C     SUBROUTINE INTRP3 SETS UP THE CALLING ARGUMENT FOR
C     SUBROUTINE INTER3
C
C     SUBROUTINE INTRP3 CALLS SUBROUTINE INTER3.
C
C     SUBRCUTINE INTRP3 IS CALLED BY MAIN.
C
C     YY IS THE VALUE RETURNED FROM ARRAY Y
C     WHICH CORRESPONDS TO THE VALUE XX IN ARRAY X
C
      COMMCN /COMSML/ SMALLT
      DIMENSION X(NPNTS), Y(NPNTS)
C
      FAC=1.0+SMALLT
      JC=0
10    JC=JC+1
      IF (XX.GT.X(JC)*FAC) GO TO 10
      IF (JC.LT.2) JC=2
      IF (JC.GT.(NPNTS-1)) JC=NPNTS-1
      CALL INTER3 (XX,X(JC-1),X(JC),X(JC+1),Y(JC-1),Y(JC),Y(JC+1),YY)
      RETURN
      END


      SUBROUTINE MASS
C
C     SUBROUTINE MASS SOLVES THE MASS CONSERVATION EQUATION
C
C     SUBROUTINE  MASS  CALLS SUBROUTINE DERIV3.
C
C     SUBROUTINE  MASS  IS CALLED BY MAIN.
C
      COMMON /BODY/ HANGLE,XJFAC,IGECM,JFAC
      COMMON /COMAR1/ XNSP(202),XSOL(200)
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
```

```
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
      COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
      CCMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
      CCMMON /COMG3/ CSF,RS,SIF,XB,XNS1
      COMMON /COMRX/ RSH,XSH
      CCMMON /COMVSP/ VSPP1,VSPP2
      COMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
      COMMON /INV2/ XNSA,XNSIVO,XNSIV1,XNSTMP,NAN
      CCMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      CCMMCN /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
C
      DO 10 N=2,IE
      AA(N)=AA(N-1)+DN(N-1)*(R2(N-1)*U2(N-1)+R2(N)*U2(N))/2.
10    BB(N)=BB(N-1)+DN(N-1)*(R2(N-1)*U2(N-1)*XN(N-1)+R2(N)*U2(N)*XN(N))/
     12.
      IF (S.GE.0.0001) GO TO 30
C
C     STAGNATION PCINT
C
      AIA=8.*BB(IE)*RRS2*UUS2*CSF2/DS-DS
      BIB=4.*AA(IE)*RRS2*UUS2*RS2/DS-DS
      CIC=-DS
      ROT=BIB*BIB-AIA*CIC
      XNS=(-BIB+SQRT(ROT))/AIA
      IF (XJFAC.LT.0.5) XNS=1.0/(RRS2*USP*AA(IE)-1.0)
C
C     SHOCK-LAYER THICKNESS
C
      XNS2=XNS1/2.0
      XNST=XNS1*2.0
      IF (XNS.GT.XNST) XNS=XNST
      IF (XNS.LE.0.0) XNS=XNS1
      IF (XNS.LT.XNS2) XNS=XNS2
      XNS=0.8*XNS1+0.2*XNS
      XNSTMP=XNS
      IF (NAN.EQ.-1) XNS=XNSTMP
      XNSIV0=0.0
      XNSIV1=0.0
      DO 20 N=1,IE
C
C     NORMAL VELOCITY PROFILE
C
      CO2(N)=XNS*(RS2**XJFAC*AA(N)+XNS*CSF2*XJFAC*BB(N))*RRS2*UUS2
      VC(N)=8.*XNS*(AA(N)*RS2+XNS*BB(N)*CSF2)*RRS2*UUS2/(DS*DS*(1.+XNS*X
     1N(N))**2*RC(N))
      IF (XJFAC.LT.0.5) VC(N)=XNS*AA(N)*RRS2*USP/((1.0+XNS*XN(N))*RC(N))
20    CCNTINUE
      GO TO 50
C
C     S GREATER THAN ZERO
C
30    AIA=BB(IE)*CSF2*RRS2*UUS2
      BIB=AA(IE)*RS2*RRS2*UUS2/2.
      CIC=-CO1(IE)+(RS+CNS*CSF)**JFAC*((1.+CK*CNS)*RRS*VVS-XNSP(I)*RRS*U
     1US)*DS
      ROT=BIB*BIB-AIA*CIC
      XNS=(-BIB+SQRT(ROT))/AIA
      IF (XJFAC.LT.0.5) XNS=-CIC/(RRS2*UUS2*AA(IE))
C
C     SHCCK-LAYER THICKNESS
C
      XNSIV1=0.0
      AIA=CSF*(2.00*RRS*UUS*BB(IE)-CSF)
      BIB=RS*(RRS*UUS*AA(IE)-CSF)
      CIC=-RS**2
      ROT=BIB*BIB-AIA*CIC
      XNSIV0=-BIB/AIA
```

```fortran
      IF (ROT.GE.0.00) XNSIV1=XNSIVO+SQRT(ROT)/AIA
      IF (XJFAC.LT.0.5) XNSIV1=RS/(RRS*UUS*AA(IE)-CSF)
      XNS2=XNS1/2.0
      IF (XNS.LT.XNS2) XNS=XNS2
      XNSTMP=XNS
      XNSA=(XNSTMP+XNSIV1)/2.0
      IF (NAN.EQ.1) XNS=XNSIV1
      IF (NAN.EQ.0) XNS=XNSA
      IF (NAN.EQ.-1) XNS=XNSTMP
      IF (NAN.EQ.-2) XNS=XNSIV1
      DO 40 N=1,IE
C
C     NORMAL VELOCITY PROFILE
C
      CO2(N)=XNS*(RS2**XJFAC*AA(N)+XNS*CSF2*XJFAC*BB(N))*RRS2*UUS2
      VI=(CO2(N)-CO1(N))/DS
      VC(N)=-VI/(RRS*VVS*RC(N)*(1.+CK*CNS*XN(N))*(RS+CNS*XN(N)*CSF)**JFA
     1C)+XNSP(I)*XN(N)*UUS*UC(N)/(VVS*(1.+CK*CNS*XN(N)))
40    CONTINUE
50    CONTINUE
      IF (S.GE.0.0001) GO TO 60
      XNS1=XNS
60    CNS=(XNS1+XNS)/2.
      XSH=XB-CNS*SIF
      RSH=RS+CNS*CSF
      IF (THIN.GE.0.0) GO TO 70
      IF (NITER.GT.1) GO TO 70
      VPG=(VSPP1+VSPP2)/2.0
70    CONTINUE
      DO 110 N=1,IE
      IF (THIN.GE.0.0) GO TO 80
      IF (NITER.GT.1) GO TO 80
      VGS(N)=(VCI2(N)-VCI1(N))/DS
      VG(N)=(VCI1(N)+VCI2(N))/2.
80    CONTINUE
      RNSH(N)=CNS/(1.+CK*CNS*XN(N))
      IF (S.GE.0.0001) GO TO 90
      V1(N)=VC(N)
      RCSF(N)=CNS/(1.+CK*CNS*XN(N))
      GO TO 100
90    RCSF(N)=CSF*CNS/(RS+CNS*XN(N)*CSF)
100   V2(N)=VC(N)
      VCD(N)=VC(N)*VVS
110   VS(N)=(V2(N)-V1(N))/DS
      IF (THIN.GE.0.0) GO TO 120
      CALL DERIV3 (VO,XN,IE,1,VON)
      CALL DERIV3 (VG,XN,IE,1,VGN)
120   CALL DERIV3 (V2,XN,IE,1,V2N)
      RETURN
      END
```

```fortran
      SUBROUTINE NMOMNT
C
C     SUBROUTINE NMOMNT SOLVES THE N MOMENT EQUATION
C
C     SUBROUTINE NMOMNT CALLS SUBROUTINE SHVALS.
C
C     SUBROUTINE NMOMNT IS CALLED BY MAIN.
C
      COMMON /COMARL/ XNSP(202),XSOL(200)
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
```

```
      COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
      COMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
      COMMON /COMSO/ PPSO,TTSO,VVSO,UUSO,NSOLD
      COMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
      COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
C
C
      DIMENSION P21(51), P21N(51), P22(51), P22N(51), P33(51), P33N(51)
C
C     SET EDGE VALUES
C
      P21N(IE)=RRS2*UUS2**2*CK2*XNS/(PPS2*(1.+CK2*XNS))
      P21(IE)=1.0
      P22N(IE)=-RRS2*VVS*VVS*((1.-UUS2*XNSP(I)/(VVS*(1.+CK2*XNS)))*V2N(I
     1E)+UUS2*XNS*VSP/VVS/(VVS*(1.+CK2*XNS)))/PPS2
      P22(IE)=0.0
      P2N(IE)=P21N(IE)
      P2(IE)=1.
      RC(IE)=1.0
      IF (THIN.GE.0.0) GO TO 10
      P33N(IE)=-RRS2*VVS2*VVS2*((1.-UUS2*XNSPM/(VVS2*(1.+CK2*XNS)))*VGN(
     1IE)+UUS2*XNS*VPG/VVS2/(VVS2*(1.+CK2*XNS)))/PPS2
      P33(IE)=0.0
      P2N(IE)=P2N(IE)+P33N(IE)
10    CONTINUE
      PC(IE)=1.
      PCN(IE)=(P1N(IE)+P2N(IE))/2.
      IF (S.LE.0.0001) GO TO 20
      PFAC(IE)=(-XNSP(I)*PCN(IE)/CNS+PSP/PPS)/UUS
20    CONTINUE
      PE(IE)=1.
      PS(IE)=0.
      R2(IE)=1.
      IF (S.GE.0.0001) GO TO 40
      CALL SHVALS (1.00,0.00,1.00,0.00,TTSO,VVSO,UUSO,PPSO,1)
      PON(IE)=0.0
      IF (THIN.GE.0.0) GO TO 30
      PON(IE)=VVSO*VON(IE)/PPSO
30    CONTINUE
      PO(IE)=1.0
      P1(IE)=1.
      P1N(IE)=P2N(IE)
      R1(IE)=1.
      V1(IE)=1.
40    KON=IM
      SMALL=1.0E-6
C
C     CALCULATE DERIVATIVE
C
      DO 80 N=1,IM
C
C     INTEGRATE, TRAPAZOIDAL RULE, FROM THE SHOCK TO THE BODY
C
      P21N(KON)=RRS2*UUS2**2*CK2*XNS*R2(KON)*U2(KON)**2/(PPS2*(1.+CK2*XN
     1S*XN(KON)))
C
C     TVSL CONTRIBUTION
C
      P21(KON)=P21(KON+1)-DN(KON)*(P21N(KON+1)+P21N(KON))/2.
      P22N(KON)=-RRS2*VVS*VVS*((R2(KON)*V2(KON)-R2(KON)*U2(KON)*UUS2*XNS
     1P(I)*XN(KON)/(VVS*(1.+CK2*XNS*XN(KON))))*V2N(KON)+UUS2*XNS*R2(KON)
     2*U2(KON)*(VS(KON)+VSP*V2(KON)/VVS)/(VVS*(1.+CK2*XNS*XN(KON))))/PPS
     32
C
C     PSEUDO - FVSL CONTRIBUTION
C
      P22(KON)=P22(KON+1)-DN(KON)*(P22N(KON+1)+P22N(KON))/2.
      P2N(KON)=P21N(KON)
      P2(KON)=P21(KON)
```

```
      IF (P2(KON).LT.SMALL) P2(KON)=SMALL
      IF (THIN.GE.0.0) GO TO 50
C
C     FVSL CONTRIBUTION
C
      P33N(KON)=-RRS2*VVS2*VVS2*((R2(KON)*VG(KON)-R2(KON)*U2(KON)*UUS2*XN
     1NSPM*XN(KON)/(VVS2*(1.+CK2*XNS*XN(KON))))*VGN(KON)+UUS2*XNS*R2(KON
     2)*U2(KON)*(VGS(KON)+VPG*VG(KON)/VVS2)/(VVS2*(1.+CK2*XNS*XN(KON))))
     3/PPS2
      P33(KON)=P33(KON+1)-DN(KON)*(P33N(KON+1)+P33N(KON))/2.
      P2N(KON)=P2N(KON)+P33N(KON)
      P2(KON)=P2(KON)+P33(KON)
      IF (P2(KON).LT.SMALL) P2(KON)=SMALL
   50 CONTINUE
      R2(KON)=P2(KON)*EMBAR(KON)/(T2(KON)*EMBAR(IE))
      IF (S.GE.0.0001) GO TO 70
      PON(KON)=0.0
      IF (THIN.GE.0.0) GO TO 60
      PON(KON)=VVSO*PO(KON)*VO(KON)*VON(KON)/(PPSO*T2(KON))*(EMBAR(KON)/
     1EMBAR(IE))
   60 CONTINUE
      PO(KON)=PO(KON+1)-DN(KON)*(PON(KON+1)+PON(KON))/2.
      P1(KON)=P2(KON)
      P1N(KON)=P2N(KON)
      R1(KON)=R2(KON)
      V1(KON)=V2(KON)
   70 PE(KON)=P21(KON)+P22(KON)
      PC(KON)=(P1(KON)+P2(KON))/2.
      RC(KON)=(R2(KON)+R1(KON))/2.0
      PCN(KON)=(P1N(KON)+P2N(KON))/2.
      PS(KON)=(P2(KON)-P1(KON))/DS
      IF (S.LE.0.0001) GO TO 80
      PFAC(KON)=(PS(KON)-XNSP(I)*XN(KON)*PCN(KON)/CNS+PSP*PC(KON)/PPS)/U
     1US
   80 KON=KON-1
      RETURN
      END
```

```
      SUBROUTINE RESET
C
C     SUBROUTINE RESET PRINTS THE SOLUTION DATA AND RESETS VARIABLES
C     FOR THE NEXT SOLUTION STATION
C
C     SUBROUTINE RESET IS CALLED BY MAIN.
C
      COMMON /COMARL/ XNSP(202),XSOL(200)
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
      COMMON /COMBC/ CAINF,CAW,CINF6(6),CIWW6(6)
      COMMON /COMDBL/ AJB(51,6),AJM(51,6),CC(51,6),CCL(51,6),CCN(51,6),C
     1PI(51,6),C1(51,6),C2(51,6),C20(51,6),DW(51,6),HI(51,6),WO(51,6),W1
     2(51,6)
      COMMON /COMFS/ PINF,REYIN,RINF,TINF,UINF
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
      COMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
      COMMON /COMG3/ CSF,RS,SIF,XB,XNS1
      COMMON /COMNS/ NS
      COMMON /COMPRF/ SPRF(10),NSPRF
      COMMON /COMREF/ CONREF,CPREF,HREF,PREF,RREF,TREF,UREF,VSREF,WREF
      COMMON /COMRX/ RSH,XSH
      COMMON /COMSML/ SMALLT
      COMMON /COMSUM/ CPJSUM(51),HDWSUM(51),HWSUM(51),HJSUMW
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```
      COMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
      COMMON /COMW/ CIW(6),CIWW(6),CPIW(6),HIW(6),HTFLB,TB,TCNW,TW
      COMMON /COMXR/ ALP,ALT,BRAD,BO,CDF,CDFD,CDF1,CDF2,CDP,CDPD,CDP1,CD
     1P2,OLDSLP,PHI,SEND,WVFAC,XNSO,IEND,IUN,KPLTTP,NITMIN,NITTOT,NTOT,N
     2TPL,NTW
      COMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
      COMMON /INV2/ XNSA,XNSIVO,XNSIV1,XNSTMP,NAN
      COMMON /KNTR/ KNTR1,KNTW1,KNTW2
      COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      COMMON /PRLE/ SIGM,XLE
      COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
      COMMON /TITLE/ KTITLE(20)
      DIMENSION TA(51)
      DIMENSION XM(51), ED(51)
      DATA BLNK/2H  /,BNO/2HNC/
C
      IF (S.GE.0.0001) GO TO 20
      CRNI=1.00
      XNSO=CNS
      SUM=0.0
      DO 10 J=1,NS
10    SUM=SUM+CINF(J)*HINF(J)
      HTINF=0.5+SUM/HREF
C
C     GLOBAL ITERATION HEADER DATA
C
      WRITE (6,180) UINF,PINF,TINF,CAINF,TB,BRAD,SIGM,XLE,XNSO,ALT
      CNT=BLNK
      CWS=BLNK
      CSS=BLNK
      CCA=BLNK
      IF (THIN.EQ.-1.) CNT=BNO
      IF (SWFAC.EQ.-1.) CWS=BNO
      IF (SSFAC.EQ.-1.) CSS=BNO
      IF (CAT.EQ.-1.) CCA=BNO
      WRITE (6,190) CNT,CWS,CSS,CCA,IE,IEND,DS
      IF (NSPRF.NE.0) WRITE (6,200) (SPRF(NK),NK=1,NSPRF)
      WRITE (6,210) BO,EPS,REYIN,REYSH,TREF,UREF,RREF,PREF,K
20    REFAC=RRS*VVS*CNS/(EPS*EPS*VISCO)
      CFCH=2.*UUS*RRS*VVS*VISC(1)*(UCN(1)-CK*CNS*UC(1))/REFAC
      HEAT=TTS*RRS*VVS*(CONO*CON(1)*TCNW/VISCO+UUS*UUS*VISC(1)*UC(1)*UCN
     1(1)/TTS)/REFAC+EPS*EPS*HJSUMW/CNS
      STAN=HEAT/(HTINF-HTFLB)
      XNSP(I)=(XNS-XNS1)/DS
      EDMAX=0.0
      NEDMAX=1
      DO 70 N=1,IE
      IF (I.GT.1) GO TO 40
      VO(N)=VC(N)
      U2O(N)=U2(N)
      T2O(N)=T2(N)
      DO 30 J=1,NS
      C2O(N,J)=C2(N,J)
30    CONTINUE
40    CONTINUE
      GAMN=CPST(N)*CPREF/(CPST(N)*CPREF-R/EMBAR(N))
      GAMMM1=GAMN-1.0
C
C     MACH NUMBER PROFILE
C
      XM(N)=SQRT((UUS*UUS*UC(N)*UC(N)+VVS*VVS*VC(N)*VC(N))/((GAMMM1)*TTS
     1*TC(N)))
      TA(N)=TC(N)*TTS*TREF
      IF (NS.EQ.2) GO TO 50
C
C     ELECTRON NUMBER DENSITY PROFILE
C
      ED(N)=0.515360*RC(N)*RRS*RREF*CC(N,5)*6.025E23/EMI(5)
      IF (EDMAX.LT.ED(N)) NEDMAX=N
      IF (EDMAX.LT.ED(N)) EDMAX=ED(N)
```

```
50    CONTINUE
      U1(N)=U2(N)
      V1(N)=V2(N)
      T1(N)=T2(N)
      SUM=0.0
      DO 60 J=1,NS
      SUM=SUM+CC(N,J)*HI(N,J)
      C1(N,J)=C2(N,J)
60    CONTINUE
      R1(N)=R2(N)
      P1(N)=P2(N)
      IF (THIN.GE.0.0) VCI2(N)=VC(N)
      IF (THIN.LT.0.0) VCI2(N)=WVFAC*VC(N)+(1.0-WVFAC)*VCI1(N)
70    CO1(N)=CO2(N)
      XNEDMX=XN(NEDMAX)
      YEDMAX=XNEDMX*XNS*BRAD*12.0
      DO 80 N=1,IE
80    VCI2(N)=VCI2(N)/VCI2(IE)
      IF (ABS(VVS).LE.0.0100) GO TO 90
C
C     WRITE NORMAL PROFILE TO DISC
C
      WRITE (NTW) S,VVS,VSP,VCI2
      KNTW1=KNTW1+1
90    CONTINUE
      PWALL=PPS*PC(1)
      IF (S.LE.0.0001) GO TO 100
      CDP2=4.*RS*SIF*PWALL
      CDF2=2.*RS*CSF*CFCH
      CDPD=CDPD+(CDP1+CDP2)*DS/2.
      CDFD=CDFD+(CDF1+CDF2)*DS/2.
      CDP=CDPD/(RS*RS)
      CDF=CDFD/(RS*RS)
100   IF (S.GE.0.0001) GO TO 110
      HEATO=HEAT
      PWALO=PWALL
      CDF=0.0
      CDP=2.0*PWALL
110   CDTOT=CDF+CDP
      CDP1=CDP2
      CDF1=CDF2
      QDOT=HEAT*RINF*UINF**3/778.00
      QQO=HEAT/HEATO
      PWRAT=PWALL/PWALO
      XNS1=XNS
      UUS1=UUS2
      VVS1=VVS2
      TTS1=TTS2
      PPS1=PPS2
      RRS1=RRS2
      XSOL(I)=S
      AVSLP=(OLDSLP+XNSP(I))/2.0
      SRN=S*BRAD
C
C     PRINT SOLUTION DATA
C
      WRITE (6,360) KTITLE
      WRITE (6,250) S,XB,RS,CNS,XNSP(I),XSH,RSH,NITER,NITTOT,NTOT,I,K
      WRITE (8,240) XNSP(I),XNS,XSH,RSH
      TWALL=TW*TREF
      WRITE (6,260) DS,CFCH,HEAT,STAN,CDF,CDP,CDTOT,PWALL,TWALL,PWRAT
      WRITE (1,320) K,I,S,NITER,XNS,XNSP(I),CFCH,HEAT,STAN,PWRAT,QQO,SRN
     1,QDOT
      IF (KPLTTP.NE.0) WRITE (NTPL) K,I,XSOL(I),XB,RS,XSH,RSH,CNS,CFCH,S
     1TAN,PWRAT
      WRITE (3,330) K,I,NITER,S,XNS,XNSTMP,XNSIV1,XNSA,EDMAX,XNEDMX,YEDM
     1AX,S,SRN
      WRITE (6,270)
      WRITE (6,280) OLDSLP,XNSPM,XNSP(I),ALP,PHI,CK,CK2
      WRITE (6,290) UUS,VVS,TTS,RRS,PPS,VPG
      USHSTR=UUS*UREF
```

```
      VSHSTR=VVS*UREF
      TSHSTR=TTS*TREF
      TSHSTK=TSHSTR/1.80
      WRITE (6,300) USHSTR,VSHSTR,TSHSTR
      WRITE (6,310) TSHSTK
      IF (ABS(1.00-S/SEND).LE.SMALLT) GO TO 140
      IF (NSPRF.EQ.0) GO TO 130
      DO 120 NK=1,NSPRF
      IF (S.EQ.0.00) GO TO 140
      IF (SPRF(NK).EQ.0.00) GO TO 120
      IF (ABS(1.00-S/SPRF(NK)).LE.SMALLT) GO TO 140
120   CONTINUE
130   CONTINUE
      IF ((I+4)/5*5.NE.(I+4)) GO TO 170
140   CONTINUE
C
C     PRINT PROFILES
C
      WRITE (6,220)
      WRITE (6,230) (N,XN(N),UC(N),VC(N),TC(N),RC(N),PC(N),PE(N),CC(N,1)
     1,CAEQ(N),XM(N),TA(N),N=1,IE)
      IF (NS.EQ.2) GO TO 160
      WRITE (6,340) (NSPI(J),J=1,NS)
      DO 150 N=1,IE
      YORN=XN(N)*XNS
      YIN=YORN*BRAD*12.00
      YCM=YIN*2.540
      WRITE (6,350) N,YORN,(CC(N,J),J=1,NS),ED(N),YIN,YCM
150   CONTINUE
160   CONTINUE
170   CONTINUE
      RETURN
C
C
C
180   FORMAT (1H1,//5X,4HUINF,8X,4HPINF,10X,4HTINF,10X,5HCAINF,7X,2HTB,1
     11X,4HBRAD,9X,2HPR,9X,2HLE,9X,3HYSH,10X,3HALT/1X,E12.3,2E14.5,E12.3
     22,2E13.4,2E11.2,E13.4,E12.3)
190   FORMAT (1H0,A2,17H THIN SHOCK LAYER,2X,A2,10H WALL SLIP,2X,A2,11H 
     1SHOCK SLIP,2X,A2,9H CAT WALL,15H NO STEPS IN Y=,I3,15H NO STEPS IN
     2 S=,I3,13H S STEP SIZE=,F5.3)
200   FORMAT (1H0,31HSOLUTIONS TO BE OBTAINED AT S =,10F9.2)
210   FORMAT (1H0,3X,5HTW/TS,4X,3HEPS,6X,6HREYINF,7X,5HREYSH,8X,4HTREF,9
     1X,4HUREF,9X,4HRREF,9X,4HPREF,6X,4HITER/1X,F7.4,F9.4,6E13.4,I4)
220   FORMAT (1H0,2X,1HN,4X,5HY/YSH,6X,5HU/USH,6X,5HV/VSH,6X,5HT/TSH,7X,
     15HR/RSH,5X,11HP/PSH(APPR),3X,5HP/PSH,7X,2HCA,10X,4HCAEQ,8X,3H XM,9
     2X,7HT DEG R)
230   FORMAT (1X,I3,2F11.6,F12.6,F11.6,6F12.6,F12.2)
240   FORMAT (1H ,64X,4F15.10)
250   FORMAT (1H0,5X,1HS,11X,1HX,11X,1HR,11X,3HYSH,9X,4HYSHP,8X,3HXSH,9X
     1,3HRSH,5X,7HNO ITER,4X,6HNITTOT,4X,4HNTOT,3X,1HI,5X,1HK/7F12.6,I6,
     27X,I5,4X,I5,2X,I3,4X,I1)
260   FORMAT (1H0,5X,2HDS,10X,2HCF,10X,4HHEAT,8X,4HSTAN,8X,3HCDF,9X,3HCO
     1P,9X,5HCDTOT,7X,5HPWALL,7X,5HTWALL,7X,5HPW/PO/10F12.6)
270   FORMAT (1H0,2X,8HYSHP ( S,2X,13HYSHP ( S+DS/2,2X,8HNEW YSHP,2X,12H
     1ALPHA(S+DS/2,1X,10HPHI(S+DS/2,3X,7HKAPPA(S,2X,12HKAPPA(S+DS/2)
280   FORMAT (1H ,7F12.6)
290   FORMAT (1H0,8X,3HUSH,10X,3HVSH,10X,3HTSH,10X,3HRSH,10X,3HPSH,10X,3
     1HVPG/3X,6F13.6)
300   FORMAT (3X,3F13.2)
310   FORMAT (3X,26X,F13.2//)
320   FORMAT (2X,I1,2X,I3,F12.6,1X,I4,9F12.6)
330   FORMAT (2X,I1,2X,I3,1X,I4,5F12.6,1PE12.4,0PF12.6,3F12.6)
340   FORMAT (1H0,4X,1HN,4X,4HY/RN,6(9X,A4),10X,5HE-/CC,6X,4HY IN,9X,4HY
     1 CM)
350   FORMAT (1H ,1X,I3,F13.5,7E13.5,2F12.5)
360   FORMAT (///5X,6H****  ,20A4,6H  ****//)
      END
```

```
      SUBROUTINE RTEDTA                                                 RDTA
C                                                                       RDTA
C     SUBROUTINE RTEDTA READS THE REACTION RATE DATA FROM UNIT IUN      RDTA
C     FOR DISSOCIATING OXYGEN AND MULTI-COMPONENT AIR                   RDTA
C                                                                       RDTA
C     SUBROUTINE RTEDTA IS CALLED BY MAIN.                              RDTA
C                                                                       RDTA
      COMMON /COMSET/ RATE2(15,6),RATE6(15,6),ZSUB2(5,6),ZSUB6(5,6),KRTIRDTA
     1TL(18),KREQ2(15,6),NAME2(11),NJ2,NR2,NZ2,KREQ6(15,6),NAME6(11),NJ6RDTA
     2,NR6,NZ6                                                          RDTA
      COMMON /COMXR/ ALP,ALT,BRAD,BO,CDF,CDFD,CDF1,CDF2,CDP,CDPD,CDP1,CDRDTA
     1P2,OLDSLP,PHI,SEND,WVFAC,XNSO,IEND,IUN,KPLTTP,NITMIN,NITTOT,NTOT,NRDTA
     2TPL,NTW                                                           RDTA
      DATA KTST/3HLOG/                                                  RDTA
      NS2=2                                                             RDTA
      NS6=6                                                             RDTA
      DO 10 I=1,6                                                       RDTA
      DO 10 J=1,5                                                       RDTA
      ZSUB2(J,I)=0.                                                     RDTA
      ZSUB6(J,I)=0.                                                     RDTA
10    CONTINUE                                                          RDTA
      READ (IUN,80) (KRTITL(I),I=1,18)                                  RDTA
C                                                                       RDTA
C     DISSOCIATING OXYGEN                                               RDTA
C                                                                       RDTA
      READ (IUN,90) NJ2,NR2,NZ2                                         RDTA
      READ (IUN,100) (NAME2(I),I=1,NJ2)                                 RDTA
      DO 20 I=1,NR2                                                     RDTA
      READ (IUN,110) (KREQ2(I,J),J=1,6),(RATE2(I,K),K=1,6)              RDTA
      IF (KTST.NE.KRTITL(1)) GO TO 20                                   RDTA
      RATE2(I,1)=ALOG(RATE2(I,1))                                       RDTA
      RATE2(I,4)=ALOG(RATE2(I,4))                                       RDTA
20    CONTINUE                                                          RDTA
      NZ2=NJ2-NS2                                                       RDTA
      IF (NZ2.LE.0) GO TO 40                                            RDTA
      DO 30 I=1,NZ2                                                     RDTA
30    READ (IUN,120) (ZSUB2(I,J),J=1,NS2)                               RDTA
C                                                                       RDTA
C     MULTI-COMPONENT AIR                                               RDTA
C                                                                       RDTA
40    READ (IUN,90) NJ6,NR6,NZ6                                         RDTA
      READ (IUN,100) (NAME6(I),I=1,NJ6)                                 RDTA
      DO 50 I=1,NR6                                                     RDTA
      READ (IUN,110) (KREQ6(I,J),J=1,6),(RATE6(I,K),K=1,6)              RDTA
      IF (KTST.NE.KRTITL(1)) GO TO 50                                   RDTA
      RATE6(I,1)=ALOG(RATE6(I,1))                                       RDTA
      RATE6(I,4)=ALOG(RATE6(I,4))                                       RDTA
50    CONTINUE                                                          RDTA
      NZ6=NJ6-NS6                                                       RDTA
      IF (NZ6.LE.0) GO TO 70                                            RDTA
      DO 60 I=1,NZ6                                                     RDTA
60    READ (IUN,120) (ZSUB6(I,J),J=1,NS6)                               RDTA
70    CONTINUE                                                          RDTA
      RETURN                                                            RDTA
C                                                                       RDTA
C                                                                       RDTA
C                                                                       RDTA
80    FORMAT (A3,17A4)                                                  RDTA
90    FORMAT (3I3,71X)                                                  RDTA
100   FORMAT (20A4)                                                     RDTA
110   FORMAT (6(1X,A4),2(E10.0,F6.0,F4.0),10X)                          RDTA
120   FORMAT (6F10.5,20X)                                               RDTA
      END                                                               RDTA
```

```
      SUBROUTINE SET
C
C     SUBROUTINE SET INITIALIZES THE PROFILES FOR EACH GLOBAL ITERATION
C
C     SUBROUTINE  SET   CALLS SUBROUTINE DERIV3.
C
C     SUBROUTINE  SET   IS CALLED BY MAIN.
C
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
      COMMON /COMDBL/ AJB(51,6),AJM(51,6),CC(51,6),CCL(51,6),CCN(51,6),C
     1PI(51,6),C1(51,6),C2(51,6),C20(51,6),DW(51,6),HI(51,6),WO(51,6),W1
     2(51,6)
      COMMON /COMEDG/ CIE(6),TCIE
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
      COMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
      COMMON /COMNS/ NS
      COMMON /COMSO/ PPSO,TTSO,VVSO,UUSO,NSOLD
      COMMON /COMW/ CIW(6),CIWW(6),CPIW(6),HIW(6),HTFLB,TB,TCNW,TW
      COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
C
      DO 20 N=1,IE
      RNSH(N)=CNS/(1.+CK*CNS*XN(N))
      RCSF(N)=CNS/(1.+CK*CNS*XN(N))
      U1(N)=XN(N)
      IF (K.GT.1) U1(N)=U20(N)
      U2(N)=U1(N)
      UC(N)=U1(N)
      UC1(N)=U2(N)
      V1(N)=XN(N)
      IF (THIN.LE.0.0) V1(N)=VO(N)
      V2(N)=V1(N)
      VC(N)=V1(N)
      IF (THIN.GT.0.00.AND.K.EQ.1) VO(N)=0.00
      VCD(N)=VC(N)*VVSO
      T1(N)=1.0-(1.0-XN(N))*(1.0-TW/TTSO)
      IF (K.GT.1) T1(N)=T20(N)
      T2(N)=T1(N)
      TC(N)=T1(N)
      T21(N)=T2(N)
      P1(N)=1.0
      P2(N)=1.0
      PC(N)=1.0
      PE(N)=1.0
      PS(N)=0.0
      PO(N)=1.0
      PON(N)=0.0
      R1(N)=P1(N)/T1(N)
      R2(N)=R1(N)
      RC(N)=R1(N)
      CAEQ(N)=0.0
      CPST(N)=1.0
      PFAC(N)=1.0
      PCN(N)=0.0
      P1N(N)=0.0
      P2N(N)=0.0
      DO 10 J=1,NS
      C1(N,J)=CINF(J)
      IF (NS.EQ.NSOLD) C1(N,J)=C20(N,J)
      C2(N,J)=C1(N,J)
      CC(N,J)=C1(N,J)
      CCL(N,J)=CC(N,J)
10    CONTINUE
20    CONTINUE
```

```
      DO 30 J=1,NS
      CIW(J)=CC(1,J)
   30 CIE(J)=CC(IE,J)
      CALL DERIV3 (UC,XN,IE,1,UCN)
      DO 60 J=1,NS
      DO 40 N=1,IE
   40 Q1(N)=C1(N,J)
      CALL DERIV3 (Q1,XN,IE,1,Q2)
      DO 50 N=1,IE
      CCN(N,J)=Q2(N)
   50 CONTINUE
   60 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SET2
C
C     SUBROUTINE SET2 SETS THE FREESTREAM AND WALL SPECIES CONCENTRA-
C     TIONS AND SETS THE STOICHIOMETRIC COEFFICIENT ARRAYS
C
C     SUBROUTINE SET2 IS CALLED BY MAIN.
C
      DIMENSION INAME(20), IREACT(20,6)
      COMMON /COMABZ/ ALPHSB(15,11),BETASB(15,11),ZSUB(5,6),ALSUB(15),BE
     1TSUB(15),GAMMMI(15,6),GAMMPL(15,6)
      COMMON /COMBC/ CAINF,CAW,CINF6(6),CIWW6(6)
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMNS/ NS
      COMMON /COMNS2/ NJ,NR,NSM1,NZ
      COMMON /COMSET/ RATE2(15,6),RATE6(15,6),ZSUB2(5,6),ZSUB6(5,6),KRTI
     1TL(18),KREQ2(15,6),NAME2(11),NJ2,NR2,NZ2,KREQ6(15,6),NAME6(11),NJ6
     2,NR6,NZ6
      COMMON /COMW/ CIW(6),CIWW(6),CPIW(6),HIW(6),HTFLB,TB,TCNW,TW
      COMMON /RTECON/ CR0(15),CR1(15),CR2(15),DR0(15),DR1(15),DR2(15)
      DATA IBLANK/4H    /
      DO 10 I=1,20
      INAME(I)=IBLANK
      DO 10 J=1,6
      IREACT(I,J)=IBLANK
   10 CONTINUE
      DO 20 J=1,11
      DO 20 KR=1,15
      ALPHSB(KR,J)=0.0
      BETASB(KR,J)=0.0
   20 CONTINUE
      DO 30 N=1,6
      DO 30 J=1,5
      ZSUB(J,N)=0.0
   30 CONTINUE
      IF (NS.NE.2) GO TO 70
C
C     DISSOCIATING OXYGEN
C
      NJ=NJ2
      NR=NR2
      NZ=NJ-NS
      CINF(1)=CAINF
      CINF(2)=1.00-CAINF
      CIWW(1)=CAW
      CIWW(2)=1.00-CAW
      DO 40 I=1,NJ
   40 INAME(I)=NAME2(I)
```

```
      DO 50 I=1,NR
      CR0(I)=RATE2(I,1)
      CR1(I)=RATE2(I,2)
      CR2(I)=RATE2(I,3)
      DR0(I)=RATE2(I,4)
      DR1(I)=RATE2(I,5)
      DR2(I)=RATE2(I,6)
      DO 50 J=1,6
50    IREACT(I,J)=KREQ2(I,J)
      NN2=NJ-NZ
      IF (NZ.LE.0) GO TO 110
      IF (NN2.LE.0) GO TO 110
      DO 60 I=1,NZ
      DO 60 J=1,NN2
60    ZSUB(I,J)=ZSUB2(I,J)
      GO TO 110
70    CONTINUE
C
C     MULTI-COMPONENT AIR
C
      NJ=NJ6
      NR=NR6
      NZ=NJ-NS
      DO 80 I=1,NJ
80    INAME(I)=NAME6(I)
      DO 90 I=1,NR
      CR0(I)=RATE6(I,1)
      CR1(I)=RATE6(I,2)
      CR2(I)=RATE6(I,3)
      DR0(I)=RATE6(I,4)
      DR1(I)=RATE6(I,5)
      DR2(I)=RATE6(I,6)
      DO 90 J=1,6
      CINF(J)=CINF6(J)
      CIWW(J)=CIWW6(J)
90    IREACT(I,J)=KREQ6(I,J)
      NN2=NJ-NZ
      IF (NZ.LE.0) GO TO 110
      DO 100 I=1,NZ
      DO 100 J=1,NN2
100   ZSUB(I,J)=ZSUB6(I,J)
110   CONTINUE
C
C     STOICHIOMETRIC COEFFICIENT ARRAYS
C
      DO 130 I=1,NR
      DO 130 K=1,NJ
      DO 130 J=1,3
      IF (INAME(K).NE.IREACT(I,J)) GO TO 120
      ALPHSB(I,K)=ALPHSB(I,K)+1.0
120   IF (INAME(K).NE.IREACT(I,J+3)) GO TO 130
      BETASB(I,K)=BETASB(I,K)+1.0
130   CONTINUE
      DO 150 KR=1,NR
      ALSUB(KR)=0.00
      BETSUB(KR)=0.00
      DO 140 J=1,NJ
      ALSUB(KR)=ALSUB(KR)+ALPHSB(KR,J)
140   BETSUB(KR)=BETSUB(KR)+BETASB(KR,J)
      ALSUB(KR)=ALSUB(KR)-1.00
150   BETSUB(KR)=BETSUB(KR)-1.00
      DO 200 KR=1,NR
      DO 190 J=1,NS
      IF (BETASB(KR,J)-ALPHSB(KR,J)) 160,170,180
160   GAMMPL(KR,J)=0.00
      GAMMMI(KR,J)=-(BETASB(KR,J)-ALPHSB(KR,J))
      GO TO 190
170   GAMMPL(KR,J)=0.00
      GAMMMI(KR,J)=0.00
      GO TO 190
180   GAMMPL(KR,J)=BETASB(KR,J)-ALPHSB(KR,J)
```

```
      GAMMMI(KR,J)=0.00
190   CONTINUE
200   CONTINUE
C
C     PRINT REACTION RATE DATA AND ARRAYS
C
      WRITE (6,280) (KRTITL(I),I=1,18)
      WRITE (6,290)
      DO 210 I=1,NR
      EXPCRO=EXP(CRO(I))
      EXPDRO=EXP(DRO(I))
210   WRITE (6,300) I,(IREACT(I,J),J=1,6),CRO(I),EXPCRO,CR1(I),CR2(I),DR
     1O(I),EXPDRO,DR1(I),DR2(I)
C
C     ALPHSB(NR,NJ) AND BETASB(NR,NJ)
C
      WRITE (6,310) NR,NJ,(INAME(I),I=1,NJ)
      DO 220 I=1,NR
220   WRITE (6,320) I,ALSUB(I),I,(ALPHSB(I,J),J=1,NJ)
      WRITE (6,330) NR,NJ,(INAME(I),I=1,NJ)
      DO 230 I=1,NR
230   WRITE (6,320) I,BETSUB(I),I,(BETASB(I,J),J=1,NJ)
      IF (NZ.LE.0) GO TO 250
C
C     ZSUB(NZ,NS)
C
      WRITE (6,340) NZ,NN2,(INAME(I),I=1,NN2)
      DO 240 I=1,NZ
      NN1=NN2+I
240   WRITE (6,350) INAME(NN1),(ZSUB(I,J),J=1,NN2)
250   CONTINUE
C
C     GAMMPL(NR,NS) AND GAMMMI(NR,NS)
C
      WRITE (6,360) NR,NS
      DO 260 I=1,NR
260   WRITE (6,370) I,(GAMMPL(I,J),J=1,NS)
      WRITE (6,380) NR,NS
      DO 270 I=1,NR
270   WRITE (6,370) I,(GAMMMI(I,J),J=1,NS)
      RETURN
C
C
C
280   FORMAT (//1H0,A3,17A4)
290   FORMAT (4HONR ,13X,8HREACTION,17X,3HCRO,8X,8HEXP(CRO),8X,3HCR1,8X,
     13HCR2,7X,3HDRO,8X,8HEXP(DRO),10X,3HDR1,6X,3HDR2)
300   FORMAT (1H ,I2,2X,3(1X,A4),1H=,3(A4,1X),2(2X,F12.7,1X,E11.4,3X,2(1
     1X,F8.1),1X))
310   FORMAT (1H0,18X,7HALPHSB(,I2,1H,,I2,1H),/,3H NR,3X,5HALSUB,7X,2HNR
     1,4X,20(2X,A4))
320   FORMAT (1H ,I2,1X,F6.1,8X,I2,2X,20(2X,F4.0))
330   FORMAT (1H0,18X,7HBETASB(,I2,1H,,I2,1H),/,3H NR,2X,6HBETSUB,6X,2HN
     1R,4X,20(2X,A4))
340   FORMAT (19H0             ZSUB(,I2,1H,,I2,1H),/,1H0,6X,20(2X,A4))
350   FORMAT (1H ,A4,20(2X,F4.1))
360   FORMAT (11H0   GAMMPL(,I2,1H,,I2,1H))
370   FORMAT (1H ,I2,15(2X,F4.0))
380   FORMAT (11H0   GAMMMI(,I2,1H,,I2,1H))
      END
```

```
      SUBROUTINE SHVALS (SP,CP,SPB,CPB,TTSH,VRSH,URSH,PPSH,ID)
C
C     SUBROUTINE SHVALS CALCULATES THE PROPERTIES BEHIND THE SHOCK
C
C     SUBROUTINE SHVALS CALLS SUBRCUTINES HCP, AND VISCON.
C
C     SUBROUTINE SHVALS IS CALLED BY MAIN AND SUBROUTINE NMOMNT.
C
      COMMON /COMEDG/ CIE(6),TCIE
      COMMON /COMFS/ PINF,REYIN,RINF,TINF,UINF
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMNS/ NS
      COMMON /COMREF/ CONREF,CPREF,HREF,PREF,RREF,TREF,UREF,VSREF,WREF
      COMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
      COMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
      COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
C
      DIMENSION HII(6), HFAC(6), CPII(6)
C
      CALL HCP (TCIE,CPII,HII,HFAC)
      CALL VISCON (CIE,CPII,VSTIE,CSTIE,TCIE)
      VISCO=VSTIE/VSREF
      CONO=CSTIE/CONREF
      TTS2TR=TTS2*TREF
      CALL HCP (TTS2TR,CPII,HII,HFAC)
      SUM1=0.0
      SUMCDH=0.0
      SUMCHF=0.0
      DO 10 J=1,NS
      SUM1=SUM1+CIE(J)/EMI(J)
      SUMCDH=SUMCDH+CINF(J)*(HINF(J)-DELHIF(J))/HREF
      SUMCHF=SUMCHF+CINF(J)*HFAC(J)/CPREF
   10 CONTINUE
      EMBARE=1.0/SUM1
      RMCP=R/(EMBARE*CPREF)
C
      URSH=CP/(1.00+EPS**2*VISCO*UPSH/(XNS*SP))
      TTSH=((0.50*(URSH-CP)**2+0.50*(SP**2-VRSH**2)+SUMCDH))/(SUMCHF+EPS
     1**2*CONO*TPSH/(XNS*SP))
      PPSH=PINF/(RINF*UINF**2)+SP*(VRSH+SP)
      RRSH=PPSH/(TTSH*RMCP)
      VRSH=-SP/RRSH
      GO TO (40,20), ID
   20 CONTINUE
      TTS2=TTSH
      PPS2=PPSH
      RRS2=RRSH
      UUS2=URSH*SPB+VRSH*CPB
      VVS2=-URSH*CPB+VRSH*SPB
      IF (S.GE..0001) GO TO 30
      UUS1=-UUS2
      VVS1=VVS2
      TTS1=TTS2
      PPS1=PPS2
      RRS1=RRS2
   30 CONTINUE
      UUS=(UUS1+UUS2)/2.00
      VVS=(VVS1+VVS2)/2.00
      TTS=(TTS1+TTS2)/2.00
      PPS=(PPS1+PPS2)/2.00
      RRS=(RRS1+RRS2)/2.00
      USP=(UUS2-UUS1)/DS
      VSP=(VVS2-VVS1)/DS
      TSP=(TTS2-TTS1)/DS
      PSP=(PPS2-PPS1)/DS
      RSP=(RRS2-RRS1)/DS
   40 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SMOMNT
C
C     SUBROUTINE SMOMNT SOLVES THE S MOMENTUM EQUATION
C
C     SUBROUTINE SMOMNT CALLS SUBROUTINES DERIV3, AND SOLVE.
C
C     SUBROUTINE SMOMNT IS CALLED BY MAIN.
C
      COMMON /BODY/ HANGLE,XJFAC,IGEOM,JFAC
      COMMON /COMARL/ XNSP(202),XSOL(200)
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
      COMMON /COMFAC/ CCFAC,UFAC
      COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
      COMMON /COMG1/ CP,CPB,SP,SPB
      COMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
      COMMON /COMTST/ DIFI(8),DIF,XU25
      COMMON /COMUV/ URSH,VRSH
      COMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
      COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
C
      DIMENSION U11(51)
C
      DO 10 N=1,IE
C
C     CALCULATE COEFFICIENTS FOR PARTIAL DIFFERENTIAL EQUATION
C
      A1(N)=REFAC*(UUS*XNSP(I)*RNSH(N)*RC(N)*UC(N)*XN(N)/(VVS*CNS)-RC(N)
     1*VC(N))/VISC(N)+RVISC(N)+CK*RNSH(N)+RCSF(N)*XJFAC
      A2(N)=-REFAC*(USP*RNSH(N)*RC(N)*UC(N)/VVS+CK*RNSH(N)*RC(N)*VC(N))/
     1VISC(N)-CK*RNSH(N)*RVISC(N)-(CK*RNSH(N)+RCSF(N)*XJFAC)*CK*RNSH(N)
      A3(N)=-REFAC*PPS*RNSH(N)*PFAC(N)/(VISC(N)*RRS*VVS)
10    A4(N)=-REFAC*UUS*RNSH(N)*RC(N)*UC(N)/(VISC(N)*VVS)
C
C     CALCULATE SLIP VARIABLES
C
      CS1=SP*SPB*UUS2*XNS/(EPS*EPS*VISCO*URSH)-CK2*XNS/(1.+CK2*XNS)
      CS2=-SP*XNS*(CP+VVS2*CPB)/(EPS*EPS*VISCO*URSH)
      E1=0.0
      F1=0.0
C
      CALL SOLVE (U1,U2,E1,F1,CRNI,1.00,CS1,CS2,SSFAC)
C
      UUS2G=UUS2
      SMALL=1.0E-6
      DO 20 N=2,IE
      IF (U2(N).LE.0.0) U2(N)=SMALL
      IF (U2(N).GT.1.15) U2(N)=1.15
20    CONTINUE
      CALL DERIV3 (U2,XN,IE,1,Q1)
      U2NIE=Q1(IE)
      IF (SSFAC) 60,60,30
30    UPSH=U2NIE-CK2*XNS*U2(IE)/(1.+CK2*XNS)
      UUS2=U2(IE)*UUS2G
      IF (S.GE.0.0001) GO TO 40
      UUS1=-UUS2
40    UUS=(UUS2+UUS1)/2.0
      DO 50 N=1,IE
50    U2(N)=U2(N)*UUS2G/UUS2
      GO TO 70
60    UPSH=0.
70    CONTINUE
      DO 110 N=1,IE
```

```
      U11(N)=U1(N)
      IF (S.GE.0.0001) GO TO 90
      IF (NITER.GT.20) GO TO 80
      U1(N)=U2(N)
      GO TO 90
80    CONTINUE
      U1(N)=UFAC*U1(N)+(1.0-UFAC)*U2(N)
90    UC(N)=(U1(N)+U2(N))/2.
      IF (UC1(N).EQ.0.0) GO TO 100
C
C     CALCULATES PROFILE DIFFERENCE
C
      DIFF=ABS(1.0-U2(N)/UC1(N))
      IF (DIFF.GT.DIF) DIF=DIFF
100   CONTINUE
      UC1(N)=U2(N)
110   CONTINUE
      CALL DERIV3 (UC,XN,IE,1,UCN)
      RETURN
      END
```

```
      SUBROUTINE SMOOTH (ZD,Z,R,NPTS,RF,RP,NU,RPP)
C
C     SMOOTHES DATA OVER 2*NU POINTS USING A
C     WALKING LEAST-SQUARES CURVE FIT FOR     R = A*Z**B
C
C     RETURNS RF, RP AND RPP FROM ARRAY R
C     CORRESPONDING TO ZD IN ARRAY Z
C
C     NPTS=NUMBER OF POINTS IN ARRAYS Z AND R
C
C     SUBROUTINE SMOOTH IS CALLED BY SUBROUTINES GEOM, AND INTRPS.
C
      DIMENSION A(10)
      DIMENSION Z(NPTS), R(NPTS)
C
C
10    CONTINUE
      NP=NPTS
      NS=NP-NU
      DO 20 I=NU,NS
      IF (ZD.GE.(Z(I)-1.0E-6).AND.ZD.LE.(Z(I+1)+1.0E-6)) GO TO 30
C
C        ASSUMES THAT Z(I) .LT. Z(I+1)
C
20    CONTINUE
      NU=NU-1
      IF (NU.GE.1) GO TO 10
      STOP
30    JF=I-NU+1
      JL=I+NU
      A(1)=JL-JF+1
      DO 40 I=2,10
40    A(I)=0.0
      DO 50 I=JF,JL
      A(2)=ALOG(R(I))
      A(3)=A(3)+A(2)
      A(4)=ALOG(Z(I))
      A(5)=A(5)+A(4)
      A(6)=A(6)+A(4)*A(4)
50    A(7)=A(7)+A(4)*A(2)
      A(8)=A(5)*A(5)-A(1)*A(6)
      A(9)=A(5)*A(3)-A(1)*A(7)
      A(10)=A(5)*A(7)-A(3)*A(6)
      BB=A(9)/A(8)
      AA=EXP(A(10)/A(8))
      RF=AA*ZD**BB
```

```
      RP=AA*BB*ZD**(BB-1.0)
      RPP=AA*BB*(BB-1.0)*ZD**(BB-2.0)
      RETURN
      END
```

```
      SUBROUTINE SMTHPR (S,YS,XX,YX,NPX,NNU)
C
C     SUBROUTINE SMTHPR INTERPOLATES FOR YS IN THE ARRAY YX
C     CORRESPONDING TO S IN THE ARRAY XX
C
C     SUBROUTINE SMTHPR CALLS SUBROUTINE INTRPS.
C
C     SUBROUTINE SMTHPR IS CALLED BY MAIN AND SUBROUTINE VPRFLE.
C
      DIMENSION XX(NPX), YX(NPX)
C
C     NPX = NUMBER OF POINTS IN XX AND YX
C
      SMALL=1.0E-5
C
C
      YMIN=100.
      XMIN=100.
      DO 10 N=1,NPX
      IF (YMIN.GT.YX(N)) YMIN=YX(N)
      IF (XMIN.GT.XX(N)) XMIN=XX(N)
10    CONTINUE
C
C     SHIFT COORDINATES
C
      IF (XMIN.LE.0.0) XMINX=ABS(XMIN)+SMALL
      IF (YMIN.LE.0.0) YMINX=ABS(YMIN)+SMALL
      IF (YMIN.GT.0.0) YMINX=0.0
      IF (XMIN.GT.0.0) XMINX=0.0
      XMIN=XMINX
      YMIN=YMINX
      DO 20 N=1,NPX
      XX(N)=XX(N)+XMIN
20    YX(N)=YX(N)+YMIN
      S=S+XMIN
C
C     INTERPOLATE
C
      CALL INTRPS (S,YS,XX,YX,NPX,NNU,DUM)
C
C     RESHIFT COORDINATES
C
      S=S-XMIN
      YS=YS-YMIN
      DO 30 N=1,NPX
      XX(N)=XX(N)-XMIN
      YX(N)=YX(N)-YMIN
30    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SOLVE (W1,W2,E1,F1,CRNI,W2IE,CS1,CS2,SSFAC)
C
C     SUBROUTINE SOLVE RETURNS THE SOLUTION OF PARABOLIC PARTIAL
C     DIFFERENTIAL EQUATIONS IN STANDARD FORM
C
C     SUBROUTINE SOLVE  CALLS SUBROUTINE DERIV3.
C
C     SUBROUTINE SOLVE  IS CALLED BY SUBROUTINES ENERGY, SMOMNT, AND
C                               SPECIE.
C
      COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
      DIMENSION W1NN(51), W1N(51), W1(51)
      DIMENSION E(51), F(51), W2(51)
      E(1)=E1
      F(1)=F1
      CALL DERIV3 (W1,XN,IE,1,W1N)
      CALL DERIV3 (W1N,XN,IE,1,W1NN)
      DO 10 N=2,IM
C
C     CALCULATE RECURSION FORMULAS OUTWARD
C
      A=(2.00-A1(N)*DN(N))/(DN(N-1)*(DN(N)+DN(N-1)))*CRNI
      B=((-2.0+A1(N)*(DN(N)-DN(N-1)))/(DN(N)*DN(N-1))+A2(N))*CRNI+A4(N)/
     1DS
      C=(2.00+A1(N)*DN(N-1))/(DN(N)*(DN(N)+DN(N-1)))*CRNI
      D=-(W1NN(N)+A1(N)*W1N(N)+A2(N)*W1(N))*(1.00-CRNI)-A3(N)+A4(N)*W1(N
     1)/DS
      E(N)=-C/(B+A*E(N-1))
   10 F(N)=(D-A*F(N-1))/(B+A*E(N-1))
      IF (SSFAC) 30,30,20
   20 SK1=CS1+(DN(IM-1)+2.00*DN(IM))/(DN(IM)*(DN(IM)+DN(IM-1)))-(DN(IM-1
     1)+DN(IM))*E(IM)/(DN(IM-1)*DN(IM))-DN(IM)*(B*E(IM)+C)/(A*DN(IM-1)*(
     2DN(IM)+DN(IM-1)))
      SK2=-CS2+(DN(IM-1)+DN(IM))*F(IM)/(DN(IM-1)*DN(IM))+DN(IM)*(B*F(IM)
     1-D)/(A*DN(IM-1)*(DN(IM-1)+DN(IM)))
      W2(IE)=SK2/SK1
      GO TO 40
   30 W2(IE)=W2IE
   40 KON=IM
      DO 50 N=2,IE
C
C     CALCULATE FUNCTION INWARD
C
      W2(KON)=E(KON)*W2(KON+1)+F(KON)
   50 KON=KON-1
      RETURN
      END
```

```
      SUBROUTINE SPECIE
C
C     SUBROUTINE SPECIE SOLVES THE SPECIES EQUATIONS
C
C     SUBROUTINE SPECIE CALLS SUBROUTINES ADJUST, DERIV3, AND SOLVE.
C
C     SUBROUTINE SPECIE IS CALLED BY MAIN.
C
      COMMON /BODY/ HANGLE,XJFAC,IGEOM,JFAC
      COMMON /COMARL/ XNSP(202),XSOL(200)
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
      COMMON /COMDBL/ AJB(51,6),AJM(51,6),CC(51,6),CCL(51,6),CCN(51,6),C
```

```
     1PI(51,6),C1(51,6),C2(51,6),C20(51,6),DW(51,6),HI(51,6),WO(51,6),W1
     2(51,6)
      COMMON /COMEDG/ CIE(6),TCIE
      COMMON /COMFAC/ CCFAC,UFAC
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMON /COMG/ CAT,CNS,CRNI,REFAC,SSFAC,SWFAC,THIN,VPG,I,K,NITER
      COMMON /COMG1/ CP,CPB,SP,SPB
      COMMON /COMG2/ CK,CK2,CSF2,RS2,SIF2,XB2,XNSPM
      COMMON /COMNS/ NS
      COMMON /COMNS2/ NJ,NR,NSM1,NZ
      COMMON /COMSML/ SMALLT
      COMMON /COMSUM/ CPJSUM(51),HDWSUM(51),HWSUM(51),HJSUMW
      COMMON /COMTST/ DIFI(8),DIF,XU25
      COMMON /COMW/ CIW(6),CIWW(6),CPIW(6),HIW(6),HTFLB,TB,TCNW,TW
      COMMON /INSH/ CONO,S,UPSH,XNS,EPS,TPSH,VISCO
      COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      COMMON /PRLE/ SIGM,XLE
      COMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
C
      DIMENSION AJBN(51), AJMN(51)
C
      SMALL=1.0D-40
      CMAX=1.00-SMALLT
C
      DO 80 J=1,NSM1
C
C     SOLVES FOR ONE LESS THAN THE NUMBER OF SPECIES
C
      DO 10 N=1,IE
      Q1(N)=AJB(N,J)
10    Q2(N)=AJM(N,J)
      CALL DERIV3 (Q1,XN,IE,1,AJBN)
      CALL DERIV3 (Q2,XN,IE,1,AJMN)
      AJBN(1)=AJBN(2)
      AJBN(IE)=AJBN(IM)
      DO 20 N=1,IE
C
C     CALCULATE COEFFICIENTS FOR PARTIAL DIFFERENTIAL EQUATIONS
C
      A1(N)=REFAC*VISCO*(UUS*XNSP(I)*RNSH(N)*RC(N)*UC(N)*XN(N)/(VVS*CNS)
     1-RC(N)*VC(N))/AJB(N,J)+AJBN(N)/AJB(N,J)+CK*RNSH(N)+RCSF(N)*XJFAC
      A2(N)=-REFAC*VISCO*CNS*RC(N)*W1(N,J)/(VVS*AJB(N,J))
      A3(N)=REFAC*VISCO*CNS*RC(N)*WO(N,J)/(VVS*AJB(N,J))+AJMN(N)/AJB(N,J
     1)+(AJM(N,J)/AJB(N,J))*(CK*RNSH(N)+XJFAC*RCSF(N))
20    A4(N)=-REFAC*VISCO*UUS*RNSH(N)*RC(N)*UC(N)/(VVS*AJB(N,J))
      FAC=CONO*XLE/CPST(IE)
C
C     CALCULATE SLIP VARIABLES
C
      CS1=XNS*SP/(EPS*EPS*FAC)
      CS2=-XNS*SP*CINF(J)/(EPS*EPS*FAC)
      DO 30 N=1,IE
30    Q1(N)=C1(N,J)
      IF (CAT) 40,40,50
40    CONTINUE
C
C     NON-CATALYTIC WALL
C
      E1=1.0
      F1=0.0
      GO TO 60
50    CONTINUE
C
C     CATALYTIC WALL
C
      E1=0.0
      F1=CIWW(J)
C
60    CALL SOLVE (Q1,Q2,E1,F1,CRNI,CINF(J),CS1,CS2,SSFAC)
```

```
C
      DO 70 N=1,IE
      C2(N,J)=Q2(N)
70    C1(N,J)=Q1(N)
80    CONTINUE
      DO 100 N=1,IE
      CSUM=0.0
      DO 90 J=1,NSM1
90    CSUM=CSUM+C2(N,J)
      C2(N,NS)=1.0-CSUM
C
C     LAST SPECIES FROM SUM OF NS-1 SPECIES
C
100   CONTINUE
      DO 140 J=1,NS
      DO 130 N=1,IE
      IF (S.GE.0.0001) GO TO 120
      IF (NS.EQ.6) GO TO 110
      IF (NITER.GT.20) GO TO 110
      C1(N,J)=C2(N,J)
      GO TO 120
110   CONTINUE
      C1(N,J)=CCFAC*C1(N,J)+(1.0-CCFAC)*C2(N,J)
120   CC(N,J)=(C1(N,J)+C2(N,J))/2.
130   CONTINUE
      CIW(J)=CC(1,J)
      CIE(J)=CC(IE,J)
140   CONTINUE
      DO 160 J=1,NS
      DO 150 N=2,IM
C
C     BOUND SPECIES
C
      IF (CC(N,J).LE.SMALL) CC(N,J)=SMALL
      IF (CC(N,J).GT.CMAX) CC(N,J)=CMAX
150   CONTINUE
160   CONTINUE
C
      DO 190 J=1,NSM1
      DO 170 N=1,IE
170   Q1(N)=CC(N,J)
      CALL DERIV3 (Q1,XN,IE,1,Q2)
      DO 180 N=1,IE
180   CCN(N,J)=Q2(N)
190   CONTINUE
      DO 240 N=1,IE
C
C     CALCULATE PRODUCT SUMS
C
      SUM1=0.00
      SUM2=0.00
      SUM3=0.00
      SUM4=0.00
      SUM5=0.00
      DO 200 J=1,NSM1
      SUM1=SUM1+CC(N,J)
      SUM2=SUM2+CCN(N,J)
      SUM3=SUM3+W0(N,J)
      SUM4=SUM4+W1(N,J)*CC(N,J)
      SUM5=SUM5+DW(N,J)
200   CONTINUE
      CC(N,NS)=1.00-SUM1
      CCN(N,NS)=-SUM2
      W0(N,NS)=-SUM3
      W1(N,NS)=-SUM4/CC(N,NS)
      DW(N,NS)=-SUM5
      DO 220 J=1,NS
      IF (CCL(N,J).EQ.0.00) GO TO 210
      DIFF=ABS(1.00-CC(N,J)/CCL(N,J))
      IF (DIFF.GT.DIFI(J+2)) DIFI(J+2)=DIFF
```

```
210   CCNTINUE
      CCL(N,J)=CC(N,J)
220   CONTINUE
      CPJSUM(N)=0.0
      HDWSUM(N)=0.0
      HWSUM(N)=0.0
      DO 230 J=1,NS
      CPJSUM(N)=CPJSUM(N)-CPI(N,J)*(AJM(N,J)+AJB(N,J)*CCN(N,J))/CNS
      HDWSUM(N)=HDWSUM(N)+DW(N,J)*HI(N,J)
230   HWSUM(N)=HWSUM(N)+(WO(N,J)-W1(N,J)*CC(N,J))*HI(N,J)
240   CCNTINUE
      HJSUMW=0.0
      DO 250 J=1,NS
250   HJSUMW=HJSUMW+HI(1,J)*(AJM(1,J)+AJB(1,J)*CCN(1,J))
      RETURN
      END


      SUBRCUTINE THERM (ISKI,BRAD,CCNC,VISCO,EPS,VIS2)
C
C     SUBROUTINE THERM CALCULATES THERMODYNAMIC PROPERTIES
C
C     SUBROUTINE THERM  CALLS SUBRCUTINES DERIV3, HCP, HCPA, VISCNA,
C                                VISCON, AND WISUB.
C
C     SUBROUTINE  THERM IS CALLED BY MAIN.
C
      COMMON /COMAR1/ AA(51),BB(51),CAEQ(51),CON(51),CO1(51),CO2(51),CPS
     1T(51),EMBAR(51),PC(51),PCN(51),PE(51),PFAC(51),PS(51),PO(51),PON(5
     21),P1(51),P1N(51),P2(51),P2N(51),Q1(51),Q2(51),RC(51),RCON(51),RCS
     3F(51),RNSH(51),RVISC(51),R1(51),R2(51),TC(51),T1(51),T2(51),T20(51
     4),T21(51),UC(51),UCN(51),UC1(51),U1(51),U2(51),U20(51),VC(51),VCD(
     551),VCI1(51),VCI2(51),VG(51),VGN(51),VGS(51),VISC(51),VS(51),VO(51
     6),VON(51),V1(51),V2(51),V2N(51)
      CCMMON /COMDBL/ AJB(51,6),AJM(51,6),CC(51,6),CCL(51,6),CCN(51,6),C
     1PI(51,6),C1(51,6),C2(51,6),C20(51,6),DW(51,6),HI(51,6),WO(51,6),W1
     2(51,6)
      CCMMON /COMFS/ PINF,REYIN,RINF,TINF,UINF
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      CCMMON /COMNS/ NS
      COMMCN /COMREF/ CONREF,CPREF,HREF,PREF,RREF,TREF,UREF,VSREF,WREF
      COMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
      CCMMON /COMW/ CIW(6),CIWW(6),CPIW(6),HIW(6),HTFLB,TB,TCNW,TW
      COMMON /OUTSH/ PPS,PPS1,PPS2,PSP,REYSH,RRS,RRS1,RRS2,RSP,TSP,TTS,T
     1TS1,TTS2,USP,UUS,UUS1,UUS2,VSP,VVS,VVS1,VVS2
      CCMMCN /PRLE/ SIGM,XLE
      CCMMON /SOLV/ A1(51),A2(51),A3(51),A4(51),DN(52),DS,XN(52),IE,IM
C
      DIMENSION VST(51), CST(51), VISCN(51), CONN(51)
      DIMENSION HFAC(6)
C
      GO TC (10,30), ISKI
10    CONTINUE
      CAEQW=0.00
C
C     OXYGEN PROPERTIES- DAVIS AIAA PAPER
C
      EMI(1)=16.00
      EMI(2)=32.00
      B1=EXP(-11.692729)
      B2=EXP(-9.550244)
      B3=SQRT(8.00+8.00*EMI(1)/EMI(2))
C
      C01=44.92777
      C02=45.94634
      D01=37.83461
      D02=38.85627
      C11=59400.
      C12=59400.
      D11=0.0
```

```
      D12=0.00
      C21=-1.000
      C22=-1.000
      D21=-0.5000
      D22=-0.5000
C
      CALL HCP (TINF,CPIFS,HINF,HFAC)
      HREF=UINF*UINF
C
C     FREESTREAM AND REFERENCE CONDITIONS
C
      EMBRFS=0.0
      CPINF=0.0
      DO 20 J=1,NS
      CPINF=CPINF+CPIFS(J)*CINF(J)
      EMBRFS=EMBRFS+CINF(J)/EMI(J)
20    CONTINUE
      EMBRFS=1.0/EMBRFS
      TREF=UINF*UINF/CPINF
      PINF=RINF*R*TINF/EMBRFS
      RREF=RINF
      UREF=UINF
      PREF=RINF*UINF*UINF
      CPREF=CPINF
      WREF=UINF/BRAD
C
      CALL VISCON (CINF,CPIFS,VSREF,AKAYRF,TREF)
      WRITE (6,130) VSREF
      CCNREF=VSREF*CPREF
C
C
      CALL VISCON (CINF,CPIFS,VSINF,AKAINF,TINF)
      WRITE (6,140) VSINF
      EPS=SQRT(VSREF/(RINF*UINF*BRAD))
      REYIN=RINF*UINF*BRAD/VSINF
      TW=TB/TREF
      GO TO 90
30    CONTINUE
      VSMALL=1.0E-40
C
      CALL HCPA (TC,IE,HREF,CPREF,TTS,TREF,HI,CPI)
      IF (NS.NE.2) CALL VISCNA (TC,CC,CPI,IE,VST,CST,TTS,TREF,CPREF)
C
      DO 50 N=1,IE
C
C     REACTION RATES AND PRODUCTION TERMS FOR DISSOCIATING OXYGEN
C
      TST=TC(N)*TTS*TREF
      RST=RC(N)*RRS*RREF
      TK=TST/1.80
      RBAR=0.515360*RST
      EKF1=EXP(C01-C11/TK)*TK**C21
      IF (EKF1.LT.VSMALL) EKF1=VSMALL
      EKF2=EXP(C02-C12/TK)*TK**C22
      IF (EKF2.LT.VSMALL) EKF2=VSMALL
      EKB1=EXP(D01-D11/TK)*TK**D21
      EKB2=EXP(D02-D12/TK)*TK**D22
      WODIM=RBAR*(0.50*(1.00-CC(N,1))*EKF1+CC(N,1)*EKF2)/EMI(1)
      WO(N,1)=WODIM/WREF
      W1DIM=WODIM+2.00*RBAR**2*CC(N,1)*(0.50*(1.00-CC(N,1))*EKB1+CC(N,1)
     1*EKB2)/(EMI(1)*EMI(1))
      W1(N,1)=W1DIM/WREF
      DWDTK=RBAR*((1.00-CC(N,1))*(0.50*(1.00-CC(N,1))*EKF1*(-1.00+C21+C1
     11/TK)+CC(N,1)*EKF2*(-1.00+C22+C12/TK))+2.00*RBAR*CC(N,1)**2*(0.50*
     2(1.00-CC(N,1))*EKB1*(2.00-D21-D11/TK)+CC(N,1)*EKB2*(2.00-D22-D12/T
     3K))/EMI(1))/(EMI(1)*TK)
      DW(N,1)=UREF*BRAD*DWDTK/(CPREF*1.80)
      DW(N,2)=-DW(N,1)
      WO(N,2)=-WO(N,1)
      W1(N,2)=-W1(N,1)*CC(N,1)/CC(N,2)
      AEQ=0.50*(1.00-CAEQ(N))*EKF1+CAEQ(N)*EKF2
```

```
      IF (AEQ.LT.VSMALL) AEQ=VSMALL
      BEQ=(0.50*(1.00-CAEQ(N))*EKB1+CAEQ(N)*EKB2)*2.00*RBAR/EMI(1)
      ROOT=1.00+4.00*BEQ/AEQ
      IF (ROOT.LE.0.0) WRITE (6,100) AEQ,BEQ,CAEQ(N),RBAR,RC(N),RRS,RREF
     1,TST,TC(N),TTS,TREF
      CAEQ(N)=AEQ*(-1.00+SQRT(1.00+4.00*BEQ/AEQ))/(2.00*BEQ)
      IF (RST.LE.0.0) WRITE (6,110) RST,RC(N),RRS,RREF,PC(N),EMBAR(N)
      IF (TST.LE.0.0) WRITE (6,120) TST,TC(N),TTS,TREF
C
C     PRODUCTION TERMS FOR MULTI-COMPONENT AIR
C
      IF (NS.NE.2) CALL WISUB (RST,TST,N)
C
      CPST(N)=0.0
      SUM=0.0
      DO 40 J=1,NS
      SUM=SUM+CC(N,J)/EMI(J)
      CPST(N)=CPST(N)+CC(N,J)*CPI(N,J)
40    CONTINUE
      EMBAR(N)=1.0/SUM
      IF (NS.NE.2) GO TO 50
C
C     VISCOSITY AND THERMAL CONDUCTIVITY FOR DISSOCIATING OXYGEN
C
      CPA=CPI(N,1)*CPREF
      CPM=CPI(N,2)*CPREF
      VST1=B1*TK**(0.0184896*ALOG(TK)+0.4558107)
      VST2=B2*TK**(0.0389680*ALOG(TK)+0.0094176)
      B4=(1.00+SQRT(VST1/VST2)*(EMI(2)/EMI(1))**0.250)**2/B3
      VST(N)=(CC(N,1)*VST1/(EMI(1)*B4/EMI(2)+(1.00-EMI(1)*B4/EMI(2))*CC(
     1N,1))+(1.00-CC(N,1))*VST2/(1.00-(1.00-VST2*B4/VST1)*CC(N,1)))*0.00
     22088550
      CON1=VST1*R*(CPA*EMI(1)/R+1.250)/EMI(1)
      CON2=VST2*R*(CPM*EMI(2)/R+1.250)/EMI(2)
      CST(N)=(CC(N,1)*CON1/(EMI(1)*B4/EMI(2)+(1.00-EMI(1)*B4/EMI(2))*CC(
     1N,1))+(1.00-CC(N,1))*CON2/(1.00-(1.00-VST2*B4/VST1)*CC(N,1)))*0.00
     22088550
50    CONTINUE
      VISCO=VST(IE)/VSREF
      CONO=CST(IE)/CONREF
      DO 60 N=1,IE
      VISC(N)=VST(N)/VST(IE)
      CON(N)=CST(N)/CST(IE)
C
C     DIFFUSIONAL FLUX TERMS
C
      AJB(N,1)=CST(N)*XLE/(CPST(N)*CONREF)
      AJB(N,2)=AJB(N,1)
      AJB(N,3)=AJB(N,1)
      AJB(N,4)=AJB(N,1)
      AJB(N,5)=AJB(N,1)
      AJB(N,6)=AJB(N,1)
      AJM(N,1)=0.0
      AJM(N,2)=0.0
      AJM(N,3)=0.0
      AJM(N,4)=0.0
      AJM(N,5)=0.0
      AJM(N,6)=0.0
60    CONTINUE
      CALL DERIV3 (VISC,XN,IE,1,VISCN)
      CALL DERIV3 (CON,XN,IE,1,CONN)
      DO 70 N=2,IM
      RVISC(N)=VISCN(N)/VISC(N)
      RCON(N)=CONN(N)/CON(N)
70    CONTINUE
      RCON(1)=RCON(2)
      RCON(IE)=RCON(IM)
      RVISC(1)=RVISC(2)
      RVISC(IE)=RVISC(IM)
C
C     SHOCK REYNOLDS NUMBER
```

```
C
      REYSH=RINF*UINF*BRAD/VST(IE)
      TR=T2(1)*TTS2*TREF
C
      CALL HCP (TR,CPIW,HIW,HFAC)
      CALL VISCON (CIW,CPIW,VIS,AKAY,TR)
      VIS2=VIS/(VSREF*VISCO)
C
C     WALL CONDITIONS
C
      TK=TB/1.80
      RW=PC(1)*PPS/(TW*R*(1.00+CAEQW*(EMI(2)/EMI(1)-1.00))/(CPINF*EMI(2)
     1))
      TST=TB
      RST=RREF*RW
      RBAR=0.515360*RST
      EKF1=EXP(C01-C11/TK)*TK**C21
      IF (EKF1.LT.VSMALL) EKF1=VSMALL
      EKF2=EXP(C02-C12/TK)*TK**C22
      IF (EKF2.LT.VSMALL) EKF2=VSMALL
      EKB1=EXP(D01-D11/TK)*TK**D21
      EKB2=EXP(D02-D12/TK)*TK**D22
      CALL HCP (TST,CPIW,HIW,HFAC)
      HAW=HIW(1)/HREF
      HMW=HIW(2)/HREF
      AEQ=0.50*(1.00-CAEQW)*EKF1+CAEQW*EKF2
      IF (AEQ.LT.VSMALL) AEQ=VSMALL
      BEQ=(0.50*(1.00-CAEQW)*EKB1+CAEQW*EKB2)*2.00*RBAR/EMI(1)
      CAEQW=AEQ*(-1.00+SQRT(1.00+4.00*BEQ/AEQ))/(2.00*BEQ)
      HTFLB=CAEQW*HAW+(1.00-CAEQW)*HMW
      HW=0.0
      DO 80 J=1,NS
80    HW=HW+CIW(J)*HIW(J)/HREF
      IF (NS.NE.2) HTFLB=HW
90    CONTINUE
      RETURN
C
C
C
100   FORMAT (1H0,5X,3HAEQ,9X,3HBEQ,8X,4HCAEQ,8X,4HRBAR,8X,2HRC,10X,3HRR
     1S,9X,4HRREF,8X,3HTST,9X,2HTC,10X,3HTTS,9X,4HTREF,//1X,1PE12.4,10E1
     22.4)
110   FORMAT (1H0,5X,3HRST,9X,2HRC,10X,3HRRS,9X,4HRREF,8X,2HPC,10X,5HEMB
     1AR//1X,6E12.4)
120   FORMAT (1H0,5X,3HTST,9X,2HTC,10X,3HTTS,9X,4HTREF//1X,4E12.4)
130   FORMAT (1H0,7HVSREF =,E16.8)
140   FORMAT (10H0  VSINF =,E16.8)
      END
```

```
      FUNCTION TLU (NTABLE,Z,X,XSTAR,NFLAG)
C
C     FUNCTION TLU IS A ONE-DIMENSIONAL TABLE LOOK-UP PROGRAM.
C     CORRESPONDING VALUES OF X (ALWAYS INCREASING) AND Z ARE STORED
C     IN THE ARRAYS X(1)...X(NTABLE) AND Z(1)...Z(NTABLE).  USING
C     LINEAR INTERPOLATION, THIS FUNCTION WILL GENERATE A VALUE OF Z
C     CORRESPONDING TO A SPECIFIED VALUE OF X = XSTAR.
C
C     FUNCTION TLU IS CALLED BY SUBROUTINE INTERP.
C
      DIMENSION X(NTABLE), Z(NTABLE)
C
C
C     ..... CHECK TO SEE IF XSTAR LIES WITHIN THE SCOPE OF THE
C           TABULATED VALUES X(1)...X(NTABLE) .....
C
      NFLAG=0
```

```
      IF (XSTAR.LT.X(1)) GO TO 10
      IF (XSTAR.LE.X(NTABLE)) GO TO 20
   10 NFLAG=1
      TLU=0.0
      RETURN
C
C     ..... SEARCH TO FIND TWO SUCCESSIVE ENTRIES,
C        X(I-1) AND X(I), BETWEEN WHICH XSTAR LIES .....
C
   20 I=1
   30 IF (X(I).GT.XSTAR) GO TO 40
      IF (I.GE.NTABLE) GO TO 40
      I=I+1
      GO TO 30
C
C     ..... LINEARLY INTERPOLATE TO FIND CORRESPONDING VALUE OF Z .....
C
   40 TLU=Z(I-1)+(XSTAR-X(I-1))*(Z(I)-Z(I-1))/(X(I)-X(I-1))
      RETURN
C
      END
```

```
      SUBROUTINE VISCNA (TC,CC,CPI,IE,VST,CST,TTS,TREF,CPREF)
C
C     SUBROUTINE VISCNA COMPUTES VISCOSITY (AMU) AND
C     CONDUCTIVITY (AKAY) FOR A TEMPERATURE ARRAY
C
C     SUBROUTINE VISCNA IS CALLED BY SUBROUTINE THERM.
C
      COMMON /COMNS/ NS
      COMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
      DIMENSION VST(51), CST(51), TC(51), CC(51,6), CPI(51,6)
C
C
      DIMENSION CI(6), CPII(6)
C
      DIMENSION AMUI(6), XI(6)
C
C
      AMUFAC=2.205E-3/3.280833E-2/32.1750
C
C     AMUFAC CONVERTS AMUI FROM GM/(CM-SEC) TO LBF-SEC/FT**2
C
      DO 50 NN=1,IE
C
      DO 10 J=1,NS
      CI(J)=CC(NN,J)
      CPII(J)=CPI(NN,J)*CPREF
   10 CONTINUE
      T=(TC(NN)*TTS*TREF)/1.80
C
      ALOGT=ALOG(T)
C
      DO 20 N=1,NS
      XI(N)=CI(N)/EMI(N)
   20 AMUI(N)=EXP(VSC(N))*T**(VSA(N)*ALOGT+VSB(N))*AMUFAC
      AMU=0.00
      AKAY=0.00
      DO 40 N=1,NS
      AKAYI=AMUI(N)/EMI(N)*(CPII(N)*EMI(N)/R+1.250)*R
      FAC=0.00
      DO 30 J=1,NS
      PHI=(1.00+SQRT(AMUI(N)/AMUI(J))*(EMI(J)/EMI(N))**0.250)**2/SQRT(8.
     1)/(1.00+EMI(N)/EMI(J))**0.50
   30 FAC=FAC+XI(J)*PHI
      FAC=XI(N)/FAC
      AMU=AMU+AMUI(N)*FAC
```

```
40    AKAY=AKAY+AKAYI*FAC
      VST(NN)=AMU
      CST(NN)=AKAY
50    CONTINUE
C
C     UNITS OF CONDUCTIVITY          LBF/(SEC-DEG R)
C     UNITS OF VISCOSITY             LBF-SEC/FT**2
C
      RETURN
      END
```

```
      SUBROUTINE VISCON (CI,CPI,AMU,AKAY,TR)
C
C     SUBROUTINE VISCON COMPUTES VISCOSITY (AMU) AND
C     CONDUCTIVITY (AKAY) FOR A SINGLE TEMPERATURE
C
C     SUBROUTINE VISCON IS CALLED BY SUBROUTINES SHVALS, AND THERM.
C
      COMMON /COMNS/ NS
      COMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
C
      DIMENSION CI(6), CPI(6)
C
      DIMENSION AMUI(6), XI(6)
C
C
      T=TR/1.80
      ALOGT=ALOG(T)
      AMUFAC=2.205E-3/3.280833E-2/32.1750
C
C     AMUFAC CONVERTS AMUI FROM GM/(CM-SEC) TO LBF-SEC/FT**2
C
      DO 10 N=1,NS
      XI(N)=CI(N)/EMI(N)
10    AMUI(N)=EXP(VSC(N))*T**(VSA(N)*ALOGT+VSB(N))*AMUFAC
      AMU=0.00
      AKAY=0.00
      DO 30 N=1,NS
      AKAYI=AMUI(N)/EMI(N)*(CPI(N)*EMI(N)/R+1.250)*R
      FAC=0.00
      DO 20 J=1,NS
      PHI=(1.00+SQRT(AMUI(N)/AMUI(J))*(EMI(J)/EMI(N))**0.250)**2/SQRT(8.
     1)/(1.00+EMI(N)/EMI(J))**0.50
20    FAC=FAC+XI(J)*PHI
      FAC=XI(N)/FAC
      AMU=AMU+AMUI(N)*FAC
30    AKAY=AKAY+AKAYI*FAC
C
C     UNITS OF CONDUCTIVITY          LBF/(SEC-DEG R)
C     UNITS OF VISCOSITY             LBF-SEC/FT**2
C
      RETURN
      END
```

```
      SUBROUTINE VPRFLE (S,VP,V,IE,NTR,ICALL)
C
C     SUBROUTINE VPRFLE RETRIEVES THE NORMAL VELOCITY PROFILE
C     FROM TAPE OR DISC STORAGE
C
C     SUBROUTINE VPRFLE CALLS SUBROUTINES INTERP, AND SMTHPR.
C
C     SUBROUTINE VPRFLE IS CALLED BY MAIN.
C
      COMMON /KNTR/ KNTR1,KNTW1,KNTW2
      DIMENSION V(51), V1(51), ST(9), VST(9), VSPT(9), VT(51,9), DUM(8)
      NPX=8
      NNU=4
      IF (ICALL.NE.1) GO TO 30
      DO 20 N=1,NPX
      READ (NTR) ST(N),VST(N),VSPT(N),V1
      DO 10 K=1,IE
10    VT(K,N)=V1(K)
20    CONTINUE
      KNTR1=KNTR1+NPX
30    IF (S.LE.ST(NPX/2+1)) GO TO 80
40    CONTINUE
      IF (KNTR1.GE.KNTW2) GO TO 80
      READ (NTR) ST(NPX+1),VST(NPX+1),VSPT(NPX+1),V1
      KNTR1=KNTR1+1
      DO 50 N=1,IE
50    VT(N,NPX+1)=V1(N)
      DO 70 N=1,NPX
      ST(N)=ST(N+1)
      VST(N)=VST(N+1)
      VSPT(N)=VSPT(N+1)
      DO 60 K=1,IE
60    VT(K,N)=VT(K,N+1)
70    CONTINUE
      IF (S.GT.ST(NPX/2+1)) GO TO 40
80    CONTINUE
      CALL INTERP (S,ST,VSPT,NPX,VP)
      DO 100 K=1,IE
      DO 90 J=1,NPX
90    DUM(J)=VT(K,J)
      CALL SMTHPR (S,V(K),ST,DUM,NPX,NNU)
100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE WISUB (RHON,T,N)
C
C     SUBROUTINE WISUB COMPUTES REACTION RATES WI/RHO AND THEIR
C     DERIVATIVES WITH RESPECT TO THETA
C
C     SUBROUTINE WISUB IS CALLED BY SUBROUTINE THERM.
C
      COMMON /COMABZ/ ALPHSB(15,11),BETASB(15,11),ZSUB(5,6),ALSUB(15),BE
     1TSUB(15),GAMMMI(15,6),GAMMPL(15,6)
      COMMON /COMDBL/ AJB(51,6),AJM(51,6),CC(51,6),CCL(51,6),CCN(51,6),C
     1PI(51,6),C1(51,6),C2(51,6),C20(51,6),DW(51,6),HI(51,6),W0(51,6),W1
     2(51,6)
      COMMON /COMNS/ NS
      COMMON /COMNS2/ NJ,NR,NSM1,NZ
      COMMON /COMREF/ CONREF,CPREF,HREF,PREF,RREF,TREF,UREF,VSREF,WREF
      COMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
      COMMON /RTECON/ CR0(15),CR1(15),CR2(15),DR0(15),DR1(15),DR2(15)
C
      DIMENSION GAMMA(11), EKF(15), EKB(15), ELF(15), ELB(15)
C
      TK=T/1.80
      RHO=RHON
      RHOBR=.515360*RHO
```

```
      DO 10 I=1,NR
      EKF(I)=TK**CR2(I)*EXP(CRO(I)-CR1(I)/TK)
10    EKB(I)=TK**DR2(I)*EXP(DRO(I)-DR1(I)/TK)
C
      DC 20 J=1,NS
      GAMMA(J)=CC(N,J)/EMI(J)
      IF (GAMMA(J).LE.1.0E-20) GAMMA(J)=1.0E-20
20    CONTINUE
      IF (NZ) 30,60,30
30    NN=NS
      DO 50 I=1,NZ
      TERM1=0.0
      DO 40 J=1,NS
40    TERM1=TERM1+ZSUB(I,J)*GAMMA(J)
      NN=NN+1
50    GAMMA(NN)=TERM1
60    DO 110 I=1,NR
      TERM1=1.0
      TERM2=1.0
      DO 100 J=1,NJ
      IF (ALPHSB(I,J)) 70,80,70
70    TERM1=TERM1*GAMMA(J)**ALPHSB(I,J)
80    IF (BETASB(I,J)) 90,100,90
90    TERM2=TERM2*GAMMA(J)**BETASB(I,J)
100   CONTINUE
      ELF(I)=EKF(I)*RHOBR**ALSUB(I)*TERM1
110   ELB(I)=EKB(I)*RHOBR**BETSUB(I)*TERM2
      DO 130 I=1,NS
      TERM1=0.0
      TERM2=0.0
      TERM3=0.00
      DO 120 J=1,NR
      TERM1=TERM1+(GAMMPL(J,I)*ELF(J)+GAMMMI(J,I)*ELB(J))
      TERM2=TERM2+(GAMMPL(J,I)*ELB(J)+GAMMMI(J,I)*ELF(J))
      TERM3=TERM3+(GAMMPL(J,I)*ELB(J)+GAMMMI(J,I)*ELF(J))/GAMMA(I)
120   CONTINUE
      WO(N,I)=TERM1*EMI(I)/WREF
      W1(N,I)=TERM3/WREF
130   CCNTINUE
      DO 150 I=1,NS
      TERM1=0.0
      DC 140 J=1,NR
140   TERM1=TERM1+(BETASB(J,I)-ALPHSB(J,I))*((CR2(J)+CR1(J)/TK-ALSUB(J))
     1*ELF(J)-(DR2(J)+DR1(J)/TK-BETSUB(J))*ELB(J))
      DW(N,I)=TERM1*TREF*EMI(I)/(WREF*TK*1.80)
150   CONTINUE
      RETURN
      END
```

```
      BLOCK DATA
      CCMMON /COMEL/ ELN(6),ELO(6)
      COMMON /COMFSA/ CINF(6),CPIFS(6),DELHIF(6),HINF(6)
      COMMCN /COMTAB/ CPTAB(50,6),HTAB(50,6),TMPTAB(50),NTAB
      CCMMON /COMVS/ EMI(6),VSA(6),VSB(6),VSC(6),R,NSPI(6)
C
C
      DIMENSION TMTAB(49)
      DIMENSION HTABO(49), HTABO2(49), HTABNO(49), HTABN(49), HTBNOP(49)
     1, HTABN2(49)
      DIMENSION CPTBO(49), CPTBO2(49), CPTBNO(49), CPTBN(49), CPNOPL(49)
     1, CPTBN2(49)
C
      EQUIVALENCE (TMTAB(1),TMPTAB(1))
C
      EQUIVALENCE (CPTAB(1,1),CPTBO(1)), (CPTAB(1,2),CPTBO2(1)), (HTAB(1
     1,1),HTABO(1)), (HTAB(1,2),HTABO2(1))
C
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      EQUIVALENCE (HTAB(1,3),HTABNO(1)), (HTAB(1,4),HTABN(1)), (HTAB(1,5BLKD
     1),HTBNOP(1)), (HTAB(1,6),HTABN2(1))                               BLKD
      EQUIVALENCE (CPTAB(1,3),CPTBNO(1)), (CPTAB(1,4),CPTBN(1)), (CPTAB(BLKD
     11,5),CPNOPL(1)), (CPTAB(1,6),CPTBN2(1))                           BLKD
C                                                                       BLKD
      DATA NSPI/4HO   ,4HO2  ,4HNO  ,4HN   ,4HNO+ ,4HN2  /              BLKD
C                                                                       BLKD
      DATA DELHIF/.1661E+09,0.00,.3225E+08,.3619E+09,.35403E+09,0.00/   BLKD
      DATA ELO/1.00,2.00,1.00,0.00,1.00,0.00/                           BLKD
      DATA ELN/2*0.00,3*1.00,2.00/                                      BLKD
      DATA EMI/16.00,32.00,30.010,14.020,30.010,28.040/                 BLKD
C                                                                       BLKD
      DATA VSA/.19558E-01,.38271E-01,.42501E-01,.85863E-02,.42501E-01,.4BLKD
     18349E-01/                                                         BLKD
      DATA VSB/.4385110,.21076E-01,-.0188740,.64630,-.0188740,-.0224850/BLKD
      DATA VSC/-11.62350,-9.59890,-9.61970,-12.5810,-9.61970,-9.98270/  BLKD
      DATA R/4.9686E4/                                                  BLKD
C                                                                       BLKD
      DATA NTAB/49/                                                     BLKD
C                                                                       BLKD
      DATA TMTAB/180.00000,900.00000,1260.00000,2700.00000,4140.00000,54BLKD
     100.00000,6660.00000,8100.00000,9540.00000,10800.00000,12060.00000,BLKD
     213500.00000,14760.00000,16200.00000,17460.00000,18900.00000,20250.BLKD
     300000,21600.00000,22950.00000,24300.00000,25650.00000,27000.00000,BLKD
     428800.00000,30600.00000,32400.00000,34200.00000,36000.00000,37800.BLKD
     500000,39600.00000,41400.00000,43200.00000,46800.00000,50400.00000,BLKD
     654000.00000,57600.00000,61200.00000,64800.00000,68400.00000,72000.BLKD
     700000,75600.00000,79200.00000,82800.00000,86400.00000,90000.00000,BLKD
     893600.00000,97200.00000,100800.00000,104400.00000,108000.00000/   BLKD
      DATA HTABO/8253.71500,8279.54920,8172.09720,7984.16950,7916.94750,BLKD
     17891.34800,7887.37350,7904.83620,7939.37050,7978.02000,8020.31550,BLKD
     28069.38630,8110.80550,8155.02560,8190.56130,8227.80260,8260.20880,BLKD
     38291.50390,8323.33120,8357.78720,8397.23470,8444.20880,8523.21350,BLKD
     48626.56590,8759.82080,8927.42220,9132.17100,9375.02160,9654.78500,BLKD
     59968.28450,10310.45050,11053.82080,11824.55870,12563.48510,13225.1BLKD
     62800,13782.82390,14227.41900,14562.59050,14799.52640,14952.70070,1BLKD
     75037.08810,15066.45870,15052.84530,15006.23110,14934.78420,14844.9BLKD
     89830,14741.95890,14629.70300,14511.31330/                         BLKD
      DATA CPTBO/8865.31690,7950.19860,7868.98760,7796.03850,7792.09530,BLKD
     17830.47890,7917.76120,8057.90100,8208.72820,8329.93440,8432.34790,BLKD
     28523.63600,8582.59620,8631.07240,8662.86830,8695.99430,8734.28390,BLKD
     38791.44460,8880.51070,9015.34600,9209.87690,9477.18480,9966.06260,BLKD
     410623.32420,11456.38650,12458.64620,13608.52530,14870.15960,16196.BLKD
     504290,17530.78270,18816.85850,21031.77550,22518.45350,23158.59660,BLKD
     623025.59210,22307.05450,21220.01610,19954.59510,18650.21160,17396.BLKD
     705690,16240.63850,15205.48750,14294.03080,13500.33790,12813.64320,BLKD
     812221.50690,11711.53610,11272.12040,10892.94790/                  BLKD
      DATA HTABO2/5442.28040,5525.27520,5660.18100,6144.76350,6446.82470BLKD
     1,6651.08050,6823.28230,6987.30820,7158.77460,7284.89420,7413.30620BLKD
     2,7533.80050,7630.36960,7730.70200,7809.62840,7889.67370,7954.92420BLKD
     3,8011.09910,8058.35480,8097.23910,8128.14310,8151.53620,8171.87810BLKD
     4,8180.95370,8179.85840,8169.92210,8152.08390,8127.59540,8097.39550BLKD
     5,8062.42320,8023.46070,7936.69470,7841.87030,7742.78970,7642.08180BLKD
     6,7541.63990,7442.77060,7346.31100,7252.82440,7162.62390,7075.85800BLKD
     7,6992.58150,6912.76310,6836.31680,6763.13300,6693.07870,6626.01310BLKD
     8,6561.78750,6500.25340/                                           BLKD
      DATA CPTBO2/5442.78110,5814.05940,6167.59330,6834.31390,7184.23320BLKD
     1,7451.99480,7675.14520,7911.73680,8126.57830,8314.42770,8469.65180BLKD
     2,8612.51440,8713.67610,8798.87720,8845.82000,8869.36960,8864.75360BLKD
     3,8837.29210,8789.41040,8723.69050,8642.32300,8547.49860,8404.08840BLKD
     4,8245.73470,8077.21010,7902.66120,7725.91380,7549.93310,7377.16020BLKD
     5,7209.39450,7047.93480,6746.98460,6477.36880,6238.66470,6028.67400BLKD
     6,5844.39230,5682.66650,5540.46900,5415.05360,5304.01040,5205.27410BLKD
     7,5117.05290,5037.86050,4966.40570,4901.62470,4842.60200,4788.57080BLKD
     8,4738.87410,4692.95620/                                           BLKD
      DATA HTABNO/5803.44300,5846.32680,5946.01920,6414.05380,6711.53740BLKD
     1,6878.11700,6996.76500,7097.75060,7176.04280,7258.54830,7333.63680BLKD
     2,7417.06830,7500.75020,7578.53350,7647.90690,7727.86770,7802.86440BLKD
     3,7877.21860,7950.29630,8021.52190,8090.35290,8156.30560,8239.01130BLKD
     4,8314.88400,8383.20620,8443.27690,8494.92110,8537.80490,8572.09530BLKD
     5,8598.04250,8615.98030,8629.82990,8618.14950,8585.86150,8537.47120BLKD
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6,8477.15010,8408.06880,8333.14720,8254.43780,8173.61770,8091.97150BLKD
7,8010.42550,7929.70540,7850.29520,7772.57030,7696.76440,7623.03590BLKD
8,7551.47660,7482.12830/                                           BLKD
 DATA CPTBNO/5803.88520,6030.56050,6361.44180,7129.76330,7370.99740BLKD
1,7471.03190,7535.83320,7591.78240,7659.02000,7767.48100,7910.98340BLKD
2,8128.31430,8292.54940,8465.21940,8614.31170,8779.17250,8924.59370BLKD
3,9058.33460,9178.47610,9283.59990,9372.37110,9443.62170,9509.94980BLKD
4,9542.15440,9540.23540,9505.44450,9440.36780,9348.42620,9233.79120BLKD
5,9100.88470,8953.87820,8633.41750,8299.15720,7970.01950,7657.72680BLKD
6,7368.56960,7105.06760,6867.36260,6654.24500,6463.78730,6293.78710BLKD
7,6142.01670,6006.34860,5884.82220,5775.69360,5677.41960,5588.63170BLKD
8,5508.15360,5434.96740/                                           BLKD
 DATA HTABN/8879.45150,8879.45150,8879.45150,8879.45150,8880.09490,BLKD
18887.61930,8917.78850,9000.41430,9143.09240,9311.82910,9509.91280,BLKD
29755.32360,9973.12090,10212.86600,10407.67900,10608.94410,10776.30BLKD
3450,10924.97010,11058.69400,11182.49860,11302.12090,11423.56630,11BLKD
4598.39750,11799.32300,12036.15490,12315.22000,12638.87770,13005.41BLKD
5210,13409.38990,13842.37520,14293.87670,15206.67390,16062.09960,16BLKD
6797.81350,17382.64570,17812.21730,18099.37890,18265.59550,18333.86BLKD
7940,18326.18410,18261.12730,18153.89080,18016.80670,17858.75800,17BLKD
8687.16170,17507.236700,17322.98650,17137.34220,16952.44860/       BLKD
 DATA CPTBN/8879.45150,8879.45150,8879.45150,8879.48720,8887.15460,BLKD
18955.12470,9168.72200,9633.82460,10278.61990,10902.39680,11504.047BLKD
230,12095.92130,12498.14760,12818.67760,12990.81010,13094.59710,131BLKD
339.01090,13171.96830,13232.16370,13355.50360,13573.24730,13910.327BLKD
440,14574.19290,15496.96310,16666.05560,18040.22000,19552.96980,211BLKD
520.58890,22651.56890,24056.90340,25260.99070,26867.21500,27309.208BLKD
610,26742.28440,25481.00430,23851.90290,22109.66700,20420.15580,188BLKD
772.19670,17502.71490,16316.82200,15302.91870,14442.11330,13713.637BLKD
880,13097.49250,12575.71540,12132.82860,11755.71350,11433.41420/   BLKD
 DATA HTBNOP/5803.34290,5817.96010,5871.11440,6255.80070,6558.14010BLKD
1,6737.54310,6867.65460,6979.16930,7067.15630,7134.68580,7200.93050BLKD
2,7283.25240,7367.06780,7481.71950,7601.33540,7746.62310,7930.17260BLKD
3,8184.63060,8401.06050,8629.66310,8863.68870,9097.21370,9398.90230BLKD
4,9680.56740,9935.03370,10158.21320,10348.18700,10505.28860,10631.1BLKD
50350,10728.05100,10798.96780,10874.64030,10880.81420,10836.76240,1BLKD
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803500,9254.81600,9143.85200,9037.05950/                           BLKD
 DATA CPNOPL/5803.67660,5896.15220,6127.51630,6944.80380,7257.42200BLKD
1,7384.22970,7461.18700,7527.28150,7600.90150,7698.27450,7850.01150BLKD
2,8112.67920,8431.84680,8899.73110,9390.14200,10078.45260,10776.858BLKD
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488.84230,14253.87000,14242.27300,14084.92100,13816.18790,13468.945BLKD
560,13071.56090,12646.89410,12212.38240,11360.62930,10575.37120,987BLKD
68.38370,9271.66920,8748.63650,8299.38240,7913.58640,7581.70390,729BLKD
75.33330,7047.30790,6831.59550,6643.16530,6477.84560,6332.16570,620BLKD
83.23880,6088.66220,5986.41680,5894.83400/                         BLKD
 DATA HTABN2/6215.97350,6232.14830,6290.19010,6704.01580,7026.35980BLKD
1,7216.76720,7354.34270,7471.39130,7561.19300,7625.34720,7681.07450BLKD
2,7739.74180,7791.07230,7854.80660,7918.96980,8041.84490,8176.78420BLKD
3,8335.02960,8487.00160,8655.81860,8839.03220,9033.24650,9302.58890BLKD
4,9574.79090,9840.46940,10091.58150,10321.87190,10527.14050,10704.9BLKD
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71610,10533.66410,10400.15460,10267.80690,10137.78260,10010.88610,9BLKD
8887.47470,9767.995300,9652.44800,9541.01140/                      BLKD
 DATA CPTBN2/6216.33090,6318.17880,6568.89780,7440.77530,7769.81270BLKD
1,7901.82980,7980.46100,8041.63940,8090.10140,8132.94230,8187.60620BLKD
2,8281.83130,8408.37930,8660.24220,9024.84630,9507.85740,10049.9380BLKD
30,10622.58100,11220.24580,11833.72810,12436.12920,13002.24860,1366BLKD
40.85950,14172.10960,14513.47920,14681.57240,14688.00660,14554.9440BLKD
50,14309.81920,13980.78180,13594.01540,12733.17430,11857.14140,1103BLKD
66.87140,10302.92680,9662.45670,9110.90360,8638.66970,8235.00470,78BLKD
789.51550,7592.94390,7337.35460,7116.09000,6923.60040,6755.31060,66BLKD
807.44930,6476.90670,6361.09130,6257.87610/                        BLKD
 END                                                               BLKD
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