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A THIN-SHOCK-LAYER SOLUTION FOR NONEQUILIBRIUM, INVISCID HYPERSONIC FLOWS IN EARTH, MARTIAN, AND VENUSIAN ATMOSPHERES

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16. Abstract

An approximate inverse solution is presented for the nonequilibrium flow in the inviscid shock layer about a vehicle in hypersonic flight. The method is based upon a thin-shock-layer approximation and has the advantage of being applicable to both subsonic and supersonic regions of the shock layer. The relative simplicity of the method makes it ideally suited for programing on a digital computer with a significant reduction in storage capacity and computing time required by other more exact methods. Comparison of nonequilibrium solutions for an air mixture obtained by the present method is made with solutions obtained by two other methods. Additional cases are presented for entry of spherical nose cones into representative Venusian and Martian atmospheres. A digital computer program written in FORTRAN language is presented that permits an arbitrary gas mixture to be employed in the solution. The effects of vibration, dissociation, recombination, electronic excitation, and ionization are included in the program.

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A THIN-SHOCK-LAYER SOLUTION FOR NONEQUILIBRIUM, INVISCID HYPERSONIC FLOWS IN EARTH, MARTIAN, AND VENUSIAN ATMOSPHERES

By William L. Grose
Langley Research Center

SUMMARY

An approximate inverse solution is presented for the nonequilibrium flow in the inviscid shock layer about a vehicle in hypersonic flight. The method is based upon a thin-shock-layer approximation and has the advantage of being applicable to both subsonic and supersonic regions of the shock layer. The relative simplicity of the method makes it ideally suited for programing on a digital computer with a significant reduction in storage capacity and computing time required by other more exact methods.

Comparison of nonequilibrium solutions for an air mixture obtained by the present method is made with solutions obtained by two other methods. Additional cases are presented for entry of spherical nose cones into representative Venusian and Martian atmospheres.

A digital computer program written in FORTRAN language is presented that permits an arbitrary gas mixture to be employed in the solution. The effects of vibration, dissociation, recombination, electronic excitation, and ionization are included in the program.

INTRODUCTION

The feasibility of planetary exploration has been the impetus for extensive research into problems associated with atmospheric entry of a blunted-nose vehicle. For the extreme velocities encountered, the gas flow in the shock layer about the vehicle can experience a severe departure from thermodynamic equilibrium. Analysis of the inviscid regime of the shock layer becomes rather complex and requires the simultaneous solution of the basic fluid-dynamic equations plus a system of coupled nonlinear equations governing the nonequilibrium rate processes. A further complication arises since the character of the system of fluid-dynamic partial differential equations changes from elliptic to hyperbolic as the flow changes from subsonic to supersonic.

Consequently, numerous techniques, each having its own peculiar advantages and disadvantages, have been used to investigate nonequilibrium blunt-body flows. The following techniques are discussed in reference 1: Newtonian approximations (refs. 2 and 3); streamtube method (refs. 4 to 6); inverse marching integration (refs. 7 to 10); integral relations (refs. 11 to 14); artificial viscosity and time asymptotic finite differences (refs. 15 and 16); series truncation (ref. 17); and boundary-layer-type approximations (refs. 18 to 20).

The present method is based upon the thin-shock-layer assumptions of Maslen (ref. 21). It requires specification of a shock shape and solves for the resultant body. This disadvantage is inherent in inverse methods, since, in general, the flow over a specified body is desired and the shock shape is not known. However, subsequent experience demonstrated that many desired body shapes could be obtained with some minor experimentation with the assumed shock shape. The analysis depends upon casting the governing flow equations in shock-oriented coordinates and then performing a Von Mises transformation so that the independent variables become the stream function and distance along the shock. An approximation is made to the momentum equation in the direction normal to the shock that enables it to be readily integrated. From this equation the pressure distribution in the Von Mises plane can be determined independently of the chemistry within the shock layer. The chemical and vibrational rate equations can then be integrated along streamlines. Transformation from the Von Mises plane to physical space is accomplished by numerical quadrature.

This approximate method of solution possesses three distinct advantages:

(1) Applicability throughout the subsonic and supersonic regions of an inviscid shock layer;

(2) Capability of handling a realistic model of an arbitrary gas mixture with a large number of chemical species and reactions in terms of reasonable computer memory storage; and

(3) Suitability for programing on a digital computer with significant reductions in computing times as compared with most existing methods.

Results obtained by use of this method for nonequilibrium air are compared with results from two other computational methods. Additional results are presented for entry of spherical nose cones into representative Venusian and Martian atmospheres.

This solution has been programed in FORTRAN IV and is presented with instructions for usage in appendix A by Barbara L. Weigel of the Langley Research Center. The program has the capability of handling up to 50 reactions and 25 species and includes the effects of vibrational relaxation, dissociation, vibration-dissociation coupling, electronic excitation, and ionization.

SYMBOLS

A	coefficient in equation (56)
A_j	frequency factor in rate constant for jth reaction
a	speed of sound, cm/sec
$a_{i,j}$	correlation integers for ith species in jth reaction (see appendix B)
B_j	temperature exponent in rate constant for jth reaction
c_i	mass fraction of ith species
E_j	activation energy in rate constant for jth reaction, K
e	internal energy per unit mass, ergs/g
$e_{e,i}$	electronic energy per unit mass of ith species, ergs/g
e_i	internal energy per unit mass of ith species, ergs/g
$e_{v,i}$	vibrational energy per unit mass of ith species, ergs/g
$\bar{e}_{v,i}$	equilibrium vibrational energy per unit mass of ith species, ergs/g
f_i	correlation factor: $f_i = 0$ for monatomic species; $f_i = 1$ for all other species
$g_{i,l}$	degeneracy of lth electronic energy level of ith species
ΔH_i	standard heat of formation at 0 K of ith species, ergs/mole
h	static enthalpy per unit mass, ergs/g
$\tilde{h} = h/V_\infty^2$	
K_j	rate constant for jth reaction, $(\text{moles})^{1-n}(\text{cm})^{3n-3}\text{sec}^{-1}$, where n is order of reaction

L_i	number of electronic energy levels for ith species
M	Mach number; general species in appendix B
M_f	$M_f = 0$, vibrational equilibrium; $M_f = 1$, vibrational nonequilibrium
m_j	code indicating which species to use when calculating coupling factor for jth reaction
N_i	number of vibrational energy levels included in dissociation energy of ith species
n	order of reaction
p	pressure, dynes/cm2
$\tilde{p} = p/\rho_\infty V_\infty^2$	
q_k	general parameter representing either vibrational energy per unit mass or mass fraction of kth species
R	universal gas constant, 8.3147×10^7 ergs/mole-K
R_c	shock radius of curvature, cm
R_j	rate of reaction j per unit mass of mixture
$R_{j,j+1}$	ratio of forward rate to reverse rate of reaction j per unit mass of mixture
R_n	nose radius of body, cm
r	perpendicular distance from symmetry axis, cm
$\tilde{r} = r/R_N$	
$[S_i]$	moles per unit volume of ith species, moles/cm3
S_J	$S_J = 1$ if $\nu_{I+1,j} = 0$; $S_J = \frac{a_{i,j}C_i}{\mu_i}$ if $\nu_{I+1,j} = 1$

T	temperature, K
$\tilde{T} = T/T_\infty$	
$T_{v,i}$	vibrational temperature of ith species, K
t	time, sec
u	velocity component in x-direction, cm/sec
V	velocity, cm/sec
v	velocity component in y-direction, cm/sec
x	distance along shock, cm
$\tilde{x} = x/R_n$	
y	distance normal to shock, cm
$\tilde{y} = y/y_b$	
z	distance along symmetry axis, cm
$\tilde{z} = z/R_n$	
$\alpha_{i,k}$	coefficient in vibrational relaxation time expression
$\beta_{i,k}$	temperature exponent in vibrational relaxation time expression
Δ_i	dissociation energy of ith species, K
δ	function defined in equation (49)
$\epsilon_{i,l}$	energy of lth electronic level of ith species, K
Θ_i	characteristic vibrational temperature, K
θ	local shock inclination angle (see fig. 1)

Λ	function defined in equation (47)
λ	scale factor $(1 - y)/R_c$
μ	molecular weight of gas mixture, g/mole
μ_i	molecular weight of ith species, g/mole
$\nu_{i,j}$	stoichiometric coefficient of ith reactant in jth reaction
$\nu'_{i,j}$	stoichiometric coefficient of ith product in jth reaction
$\nu_{I+1,j}$	stoichiometric coefficient of general species (see appendix B) in jth reaction
ρ	mass density, g/cm^3
$\tilde{\rho} = \rho/\rho_\infty$	
$\sigma_{i,k}$	coefficient in vibrational relaxation time expression
$\tau_{i,k}$	vibrational relaxation time of ith species due to vibrational energy exchange with kth species, sec
ϕ	angular position coordinate (fig. 1)
ϕ_j	coupling factor defined in equation (40)
ψ	stream function, g/sec
Ω	function defined in equation (48)
ω_k	general parameter in rate equation representing either the rate of production or rate of change of vibrational energy of species k

Subscripts:

b	body
s	shock

∞ free stream

0 behind shock on symmetry axis

ANALYSIS

Governing Equations

The solution described herein is an inverse method designed to take advantage of the characteristically thin shock layer that forms about a smooth axisymmetric body in hypersonic flight. If the shock-oriented coordinate system shown in figure 1 is adopted, the steady flow of an adiabatic, inviscid gas subject to nonequilibrium rate processes is governed by the following equations:

Continuity equation:

$$\frac{\partial}{\partial x}(\rho u r) + \frac{\partial}{\partial y}(\rho v \lambda r) = 0 \tag{1}$$

Momentum equations:

$$u \frac{\partial u}{\partial x} + \lambda v \frac{\partial u}{\partial y} - \frac{uv}{R_c} + \frac{1}{\rho}\frac{\partial p}{\partial x} = 0 \tag{2}$$

$$u \frac{\partial v}{\partial x} + \lambda v \frac{\partial v}{\partial y} + \frac{u^2}{R_c} + \frac{\lambda}{\rho}\frac{\partial p}{\partial y} = 0 \tag{3}$$

Energy equation:

$$h + \frac{u^2}{2} + \frac{v^2}{2} = \text{Constant} \tag{4}$$

Rate equation:

$$u \frac{\partial q_k}{\partial x} + \lambda v \frac{\partial q_k}{\partial y} = \lambda \omega_k\left(p,\rho,q_1, \ldots, q_N\right) \tag{5}$$

Equation of state:

$$h = h\left(p,\rho,q_1, \ldots, q_N\right) \tag{6}$$

In view of the thin shock layer, it is convenient to perform a Von Mises transformation. The stream function can be defined from the continuity equation by its partial derivatives,

$$\frac{\partial \psi}{\partial x} = \rho v r \lambda \tag{7}$$

and

$$\frac{\partial \psi}{\partial y} = -\rho u r \tag{8}$$

which leads to the transformation relationship

$$\left(\frac{\partial}{\partial x}\right)_{\psi} = \frac{\partial}{\partial x} + \frac{\lambda v}{u}\frac{\partial}{\partial y} \tag{9}$$

The resulting expressions for the momentum and rate equations are

$$\left(\frac{\partial u}{\partial x}\right)_{\psi} - \frac{v}{R_c} + \frac{\lambda v r}{u}\left(\frac{\partial p}{\partial \psi}\right)_{x} + \frac{1}{\rho u}\left(\frac{\partial p}{\partial x}\right)_{\psi} = 0 \tag{10}$$

$$\left(\frac{\partial v}{\partial x}\right)_{\psi} + \frac{u}{R_c} - \lambda r\left(\frac{\partial p}{\partial \psi}\right)_{x} = 0 \tag{11}$$

$$\left(\frac{\partial q_k}{\partial x}\right)_{\psi} = \frac{\lambda \omega_k}{u} \tag{12}$$

A differential form of the energy equation results from differentiating equation (4) and combining it with equations (2) and (3)

$$\left(\frac{\partial h}{\partial x}\right)_{\psi} = \frac{1}{\rho}\left(\frac{\partial p}{\partial x}\right)_{\psi} \tag{13}$$

The concept of a thin shock layer now makes certain simplifying approximations feasible. The flow within the inviscid shock layer is nearly parallel to the shock itself, except near the stagnation point. The term $\left(\frac{\partial v}{\partial x}\right)_{\psi}$ was neglected and the assumption was made that $\lambda \approx 1$. To this order of approximation, equations (11) and (12) become

$$\left(\frac{\partial p}{\partial \psi}\right)_{x} = \frac{u}{R_c r} \tag{14}$$

$$\left(\frac{\partial q_k}{\partial x}\right)_{\psi} = \frac{\omega_k}{u} \tag{15}$$

Adopting the approximation of Maslen (ref. 21), by using the values of r and u immediately behind the shock, allows equation (14) to be integrated along a normal to the shock and results in

$$p(x,\psi) = p_s(x) + \frac{u_s(x)}{R_c(x)\, r_s(x)}\left[\psi - \psi_s(x)\right] \tag{16}$$

At the shock

$$\psi_s = \frac{\rho_\infty V_\infty r_s^2}{2} \tag{17}$$

and on the body the boundary condition is

$$\psi_b = 0 \tag{18}$$

The effect of the approximations is to uncouple equation (11) from the remaining equations so that the resulting expression for the pressure (eq. (16)) is independent of the shock-layer chemistry and is a function only of the geometry and chemistry of the shock itself.

From the requirement of constant energy,

$$h + \frac{u^2}{2} + \frac{v^2}{2} = h_0 + \frac{v_0^2}{2} \tag{19}$$

Since the flow is nearly parallel to the shock, the approximation

$$v^2 - v_0^2 << u^2 \tag{20}$$

is made, and the following expression for the velocity u results:

$$u = \left[2\left(h_0 - h\right)\right]^{1/2} \tag{21}$$

In summary, equations (6), (13), (15), (16), and (21) form a determinate system of equations that can be integrated stepwise along streamlines to yield p, ρ, h, u, and q_k in the Von Mises plane. In addition to the boundary conditions of equations (17) and (18), the oblique shock relations (ref. 22) must be satisfied.

By noting the geometry of figure 1, the transformation back into physical (x,y) space can be accomplished by integrating equation (8) at constant x. The resulting expression

$$r = \left(r_s^2 - 2 \cos \theta \int_{\psi}^{\psi_s} \frac{d\psi}{\rho u}\right)^{1/2} \tag{22}$$

can be readily evaluated numerically.

The most important implication of the preceding analysis is that the equations are now applicable uniformly from the subsonic region through the supersonic region, except along the symmetry axis where the transformation is not well behaved.

Thermodynamic Model for a Reacting Gas

The gas under consideration is assumed to be a mixture of ideal gases. (See ref. 23.) The internal energy of the gas includes contributions from translation, rotation, vibration, dissociation, electronic excitation, and ionization.

The thermal equation of state is given by

$$p = \rho \frac{RT}{\mu} \tag{23}$$

with the mixture molecular weight given by

$$\mu = \left(\sum_{i=1}^{I} \frac{c_i}{\mu_i} \right)^{-1} \tag{24}$$

The mass fraction c_i is subject to the constraint

$$\sum_{i=1}^{I} c_i = 1 \tag{25}$$

The internal energy of the ith species can be expressed as

$$e_i = \frac{3}{2} \frac{RT}{\mu_i} + f_i \frac{RT}{\mu_i} + e_{v,i} + \frac{R}{\mu_i} \frac{\sum_{l=1}^{L_i} g_{i,l} \epsilon_{i,l} \exp\left(\frac{-\epsilon_{i,l}}{T}\right)}{\sum_{l=1}^{L_i} g_{i,l} \exp\left(\frac{-\epsilon_{i,l}}{T}\right)} + \frac{\Delta H_i}{\mu_i} \tag{26}$$

where the rotational (rigid rotor) and electronic energy modes are assumed to be in equilibrium with the translational mode. In the computer program to be described subsequently, two options exist for computing the vibrational (linear harmonic oscillator) energy. In the first option, the vibrational mode is assumed to be in equilibrium with the translational mode and $e_{v,i}$ is calculated from

$$e_{v,i} = \frac{f_i R \Theta_i}{\mu_i \left[\exp\left(\frac{\Theta_i}{T}\right) - 1 \right]} \tag{27}$$

The second option is for vibrational nonequilibrium and $e_{v,i}$ is determined by integration of the vibrational rate equation along a streamline.

Since a mixture of ideal gases has been assumed, the total energy is

$$e = \sum_{i=1}^{I} c_i e_i \tag{28}$$

The enthalpy is defined as

$$h = e + \frac{p}{\rho} \tag{29}$$

By referring to the previous equations, it can be seen that

$$h = h\left(p;\rho;e_{v,1}, \ldots, e_{v,I};c_1, \ldots, c_I\right) \tag{30}$$

which agrees with the form stated in equation (6).

Rate Equations

The general rate expression given in equation (5) must be specialized for chemical processes and for vibrational relaxation. The resultant equation must be capable of describing a system of chemical species (i = 1,2,3, . . ., I) and the associated kinetic reactions (j = 1,2,3, . . ., J).

Chemical processes.- An arbitrary one-step chemical reaction can be described by

$$\sum_{i=1}^{I} \nu_i S_i \longrightarrow \sum_{i=1}^{I} \nu_i' S_i \tag{31}$$

The law of mass action (ref. 23) requires the rate of production of a species to be proportional to the product of the concentrations of the reacting species, each concentration being raised to a power equal to its stoichiometric coefficient. The net rate of production of S_i per unit mass of mixture is then

$$\frac{d\left(\frac{[S_i]}{\rho}\right)}{dt} = \frac{K}{\rho}\left(\nu_i' - \nu_i\right) \prod_{i=1}^{I} [S_i]^{\nu_i} \tag{32}$$

Since

$$[S_i] = \frac{\rho c_i}{\mu_i} \tag{33}$$

equation (32) can be generalized for a system of J simultaneous reactions and put in the form of equation (12). As a result,

$$\left[\left(\frac{\partial c_i}{\partial x}\right)_{\psi}\right]_j = \frac{K_j \mu_i}{\rho u}\left(\nu_{i,j}' - \nu_{i,j}\right) \prod_{i=1}^{I} \left(\frac{\rho c_i}{\mu_i}\right)^{\nu_{i,j}} \tag{34}$$

The total rate of production is

$$\left(\frac{\partial c_i}{\partial x}\right)_\psi = \sum_{j=1}^{J} \left[\left(\frac{\partial c_i}{\partial x}\right)_\psi\right]_j \tag{35}$$

The specific reaction rate constant is given by

$$K_j = A_j T^{B_j} \exp\left(\frac{-E_j}{T}\right) \tag{36}$$

Equation (34) is applicable to opposing reactions if the forward and reverse reactions are treated separately.

If the rate constants for the reaction of a chemical species with several catalytic species are the same, provision can be made to incorporate all these catalysts into a single reaction by introducing a "general species." (See appendix B.) The resulting rate expression is now

$$\left[\left(\frac{\partial c_i}{\partial x}\right)_\psi\right]_j = \left[\frac{K_j \mu_i}{\rho u}\left(\nu'_{i,j} - \nu_{i,j}\right) \prod_{i=1}^{I} \left(\frac{\rho c_i}{\mu_i}\right)^{\nu_{i,j}}\right]\left[\rho \sum_{i=1}^{I} \frac{c_i a_{i,j}}{\mu_i}\right]^{\nu_{I+1,j}} \tag{37}$$

Vibrational relaxation.- If the vibrational rate equation developed in reference 24 for a multicomponent gas mixture is written in the form of equation (12), the result is

$$\left(\frac{\partial e_{v,i}}{\partial x}\right)_\psi = \frac{1}{u} \sum_{k=1}^{I} \frac{c_k}{\tau_{i,k}}\left(\bar{e}_{v,i} - e_{v,i}\right) \tag{38}$$

where $\bar{e}_{v,i}$ is the equilibrium vibrational energy from equation (27) and $e_{v,i}$ is the vibrational energy. The relaxation time $\tau_{i,k}$ can be expressed as

$$\tau_{i,k} = \frac{\alpha_{i,k} T^{\beta_{i,k}} \exp\left(\sigma_{i,k} T^{-1/3}\right)}{p\left[1 - \exp\left(\frac{-\Theta_i}{T}\right)\right]} \tag{39}$$

which is of the form predicted by classical Landau-Teller theory. Although equations (38) and (39) were formulated on the assumption of a system of harmonic oscillators having a single vibrational mode, polyatomic molecules with several vibrational modes can be handled in the computer program if it is assumed that they are independent of one another and the relaxation frequencies for the individual modes are combined into a single equivalent frequency. (See ref. 23.)

Coupling of vibrational relaxation and dissociation.- It has been pointed out in the literature (for example, refs. 25 to 28) that the processes of vibrational relaxation and dissociation do not occur independently, but rather each process influences the other. The CVD (coupled-vibration-dissociation) model of Hammerling et al. (ref. 25) was chosen for this analysis. Without discussing the relative merits of the various other coupling models, it should be noted that another model could be incorporated into this method with little difficulty.

Since molecules with vibrational energy less than that corresponding to equilibrium with the translational energy do not dissociate as readily as predicted by the dissociation rate constant for vibrational equilibrium, the CVD model develops a correction to the rate constant. From reference 25 the coupling coefficient is

$$\phi_j = \frac{1}{N_i}\left\{\frac{1 - \exp\left[-N_i\left(\frac{\Theta_i}{T_{v,i}} - \frac{\Theta_i}{T}\right)\right]}{\exp\left(\frac{\Theta_i}{T_{v,i}} - \frac{\Theta_i}{T}\right) - 1}\right\}\left[\frac{\exp\left(\frac{\Theta_i}{T_{v,i}}\right) - 1}{\exp\left(\frac{\Theta_i}{T}\right) - 1}\right] \tag{40}$$

The number of vibrational states N_i is the smallest integer so that

$$N_i > \frac{\Delta_i}{\Theta_i} \tag{41}$$

Inserting the coupling coefficient in equation (37) results in

$$\left[\left(\frac{\partial c_i}{\partial x}\right)_\psi\right]_j = \left[\frac{\phi_j K_j \mu_i}{\rho u}\left(\nu'_{i,j} - \nu_{i,j}\right)\prod_{i=1}^{I}\left(\frac{\rho c_i}{\mu_i}\right)^{\nu_{i,j}}\right]\left[\rho\sum_{i=1}^{I}\frac{c_i a_{i,j}}{\mu_i}\right]^{\nu_{I+1,j}} \tag{42}$$

For a dissociation reaction, ϕ_j can be calculated from equation (40); for other reactions, ϕ_j is unity.

SOLUTION PROCEDURE

Initial Conditions

An inverse method presupposes specification of the shock shape. In all cases described herein, an analytical expression of the form

$$r_s = r_s(z) \tag{43}$$

was used. From this relationship, θ, R_c, and x can be given by

$$\theta = \arc\tan\left(\frac{dr_s}{dz}\right) \tag{44}$$

$$R_c = \frac{\left[1 + \left(\frac{dr_s}{dz}\right)^2\right]^{3/2}}{\left|\frac{d^2r_s}{dz^2}\right|} \tag{45}$$

and

$$x = \int_0^{r_s} \frac{dr_s}{\sin\theta} \tag{46}$$

After determining the shock parameters, initiation of the solution begins with calculation of free-stream conditions. With selected values of p_∞, T_∞, V_∞, and a specified gas composition, equations (23) to (28) can be utilized to calculate μ_∞, ρ_∞, and e_∞.

The next step requires determining the state of the gas immediately behind the shock wave. The shock wave is assumed to be a discontinuity, translational, rotational, and electronic contributions to the internal energy of the gas reaching instantaneous equilibrium at the translational temperature behind the shock T_s. The vibrational energy may be treated as being in equilibrium with the other energy modes or optionally it may be described by a system of harmonic oscillators with a Boltzmann distribution about a nonequilibrium vibrational temperature. Species concentrations are assumed to be frozen through the shock.

An iterative procedure is required to solve the oblique-shock-conservation relations. From the shock geometry and the free-stream conditions, the following parameters can be calculated:

$$\Lambda(x) = \rho_\infty V_\infty \sin\theta \tag{47}$$

$$\Omega(x) = p_\infty + \rho_\infty V_\infty^2 \sin^2\theta \tag{48}$$

$$\delta(x) = e_\infty + \frac{p_\infty}{\rho_\infty} + \frac{V_\infty^2 \sin^2\theta}{2} \tag{49}$$

With an initial estimate of T_s, the energy e_s can be determined from equations (26) to (28). The temperature and energy are further related by

$$T_s = \frac{2\mu_\infty(\delta - e_s)\sqrt{\Omega^2 - 2\Lambda^2(\delta - e_s)}}{R\left[\Omega + \sqrt{\Omega^2 - 2\Lambda^2(\delta - e_s)}\right]} \tag{50}$$

Equation (50) can be iterated until subsequent values of T_s differ by a sufficiently small amount. After convergence

$$p_s = \sqrt{\Omega^2 - 2\Lambda^2(\delta - e_s)} \tag{51}$$

$$\rho_s = \frac{p_s\mu_\infty}{RT_s} \tag{52}$$

$$h_s = e_s + \frac{p_s}{\rho_s} \tag{53}$$

$$u_s = V_\infty \cos\theta \tag{54}$$

The pressure distribution in the x,ψ plane can now be calculated from equation (16).

Integration Method

Since the initial conditions and the pressure distribution have been determined, equations (13), (37), and (38) can be integrated stepwise along streamlines. It was found that for the cases investigated herein, the system of equations exhibited the so-called "stiff" behavior. (See refs. 29 and 30.) The integration scheme proposed by Treanor (ref. 31) was chosen for its ability to handle the stiff equations with significant reductions in computational times compared with both the fourth-order Runge-Kutta method (ref. 32) and the Adams-Moulton method using the fourth-order Runge-Kutta method for starting (ref. 33).

A special problem occurs for the $\psi = 0$ or body streamline. On all other streamlines the integration begins immediately behind the shock and proceeds from there. However, on the Z-axis the transformation of the governing equations is ill-behaved since x and ψ are both zero. Therefore, the integration cannot proceed from behind the shock along the stagnation streamline with the equations in their present form.

The $\psi = 0$ streamline integration was accomplished in the following manner. The initial interval Δx on the shock wave was divided into five subintervals. The rate equations were integrated from behind the shock at each subinterval to the point $x = \Delta x$. The values of the variables as a function of ψ were then extrapolated along $x = \Delta x$ to the body ($\psi = 0$). Integration along the $\psi = 0$ streamline can proceed from there. Five subintervals were decided to be adequate after experimenting with up to 15 subintervals.

Transformation to Physical Space

Upon completion of the integration along streamlines, the thermodynamic properties, the velocity u, and the species concentrations are known functions of x and ψ. Equation (22) can then be evaluated numerically by Simpson's rule to obtain r. Evaluation of the flow field is thus completed.

RESULTS AND DISCUSSION

In order to investigate the capabilities of the present method of solution, cases have been computed for numerous shock shapes and gas mixtures. A number of representative cases have been selected for presentation. Case I is a comparison of results for nonequilibrium air with the more exact inverse method of reference 8. Case II is a comparison of the results for nonequilibrium air with the streamtube method used in reference 34. Cases III, IV, and V present results for entry of spherical nose cones into representative Martian and Venusian atmospheres.

Case I

This example was computed to compare with the results of reference 8 for a catenary shock $\left(R_{c,0} = 2.11 \text{ cm}\right)$ with a free-stream velocity of 7.01×10^5 cm/sec at 61 km. The reactions and rates given in appendix C are the same as those used in reference 8. Vibrational equilibrium was assumed.

Figure 2 indicates excellent agreement with the results of reference 8 for the body shape and the location of a streamline crossing the shock at an angle θ of 81° $\left(x/R_{c,0} = 0.16\right)$. The variations of the temperature, pressure, density, and species mole fractions along this streamline are compared with the corresponding results from reference 8 in figures 3, 4, 5, and 6, respectively. As should be expected, the effect of neglecting the velocity gradient term in equation (11) is to predict the pressure to be lower than the actual value at a given x. This effect can be expected to diminish as the flow proceeds away from the stagnation region and becomes more nearly parallel to the shock.

Initially, the flow along this streamline exhibits behavior similar to that behind a normal-shock wave with density increasing with sharply falling temperature. However, as the flow expands away from the nose, the density reaches a maximum and begins to decrease as the temperature continues to decrease.

Concentrations of N, O, NO, and e^- shown in figure 6 indicate very good agreement with the results of reference 8. The greatest error occurs for NO shown in figure 6(c), the present method predicting the concentrations about 20 percent too high at worst.

Variations of the pressure, temperature, density, and species concentrations across the shock layer at $\theta \approx 81^\circ$ are shown in figures 7, 8, 9, and 10, respectively. Again, the agreement with the results of reference 8 is good. From this comparison it may be concluded that the present method gives good agreement with the exact method near the stagnation region which represents a severe test of the approximations inherent in the present method.

Case II

This example was selected for comparison with the nonequilibrium air results of reference 34 for flow over a 9° half-angle cone with a spherical nose (30.48-cm diameter) at an altitude of 47.5 km. The equation

$$r_s^2 = -0.3625 z_s^2 + 36.064 z_s - 0.1767 r_s z_s \tag{55}$$

was fitted in the nose region to the shock points computed in reference 34. Although Evans, and others, used a sophisticated system of 13 species and 54 reactions, the approximate air model used in case I was used for this comparison. Vibrational nonequilibrium was assumed.

It can be seen in figure 11 that the present method predicts the body shape extremely well. A comparison of the surface pressures and temperatures as calculated by both methods is presented in figures 12 and 13, respectively. In general, the agreement is seen to be good. There is a discrepancy in the temperature calculations close to the symmetry axis, but this condition improves rapidly with increasing distance. Both methods are admittedly inaccurate in the region where the discrepancy occurs. Finally, the electron concentration on the body surface is shown in figure 14. The prediction of the present method is understandably lower since the reaction scheme permits only the NO^+ ion. Agreement improves further back on the surface. This result might be expected since figure 7 of reference 34 indicates NO^+ is the major ion present after the flow expands past the sphere-cone tangency point.

Case III

This case was computed for ballistic entry into a Venusian atmosphere. It was found that shock shapes of the form given by

$$z_s = \frac{r_s^2}{1 + A r_s} \tag{56}$$

would generate bodies that approximate part of a sphere-cone. The parameter A represents the slope of the asymptote of the shock for large values of r_s. For sufficiently large apex angles under appropriate conditions, the flow over the face of a truncated sphere-cone is subsonic, the sonic point being on the body at the sharp corner where the transition to supersonic flow occurs. There is a resultant rapid drop in pressure near the corner. It should be noted that a shock shape of the form of equation (56) can be used to calculate the flow in the shock layer up to the point where the rapid pressure drop occurs, but another equation would be required for the shock where it "bends" as the flow expands around the sonic corner. However, in this rapidly expanding flow region, the approximations inherent in this method of analysis would not be valid.

According to recently available information on Venus (ref. 35), the atmosphere is almost entirely carbon dioxide. Therefore, a 100-percent CO_2 mixture was assumed and the kinetic reactions and rates shown in appendix C were used. Vibrational nonequilibrium was assumed. The free-stream conditions are

$$V_\infty = 8.69 \times 10^5 \text{ cm/sec}$$

$$\rho_\infty = 1.4175 \times 10^{-6} \text{ g/cm}^3$$

$$T_\infty = 200 \text{ K}$$

The assumed shock (A = 1.732) and the computed body which approximates a 57° half-angle sphere-cone are shown in figure 15. Pressure, density, and temperature variations along streamlines crossing the shock at $\tilde{x} = 0.5$ and 2.0 are presented in figures 16, 17, and 18, respectively. Figure 16 indicates that the pressure along both streamlines approaches the same constant level as the flow progresses away from the shock as would be expected for cone flow.

Species concentrations along these streamlines are shown in figure 19. Figure 19(a) indicates that the CO_2 disappears rapidly with increasing distance while the C and O concentrations increase along the inner streamline ($\tilde{x} = 0.5$). The CO concentration increases to a maximum and then decreases. Figure 19(b) shows similar behavior along the outer streamline ($\tilde{x} = 2.0$). This behavior is the same as that observed by Howe, Viegas, and Sheaffer (ref. 36) behind normal shocks in CO_2 at slightly different ambient conditions. Their gas model however did not include the effects of vibrational relaxation or ionization. Figure 19(c) indicates that the concentrations of the electrons and the C^+ and O^+ ions increase with distance whereas CO^+ reaches a maximum and then begins to decrease along the inner streamline ($\tilde{x} = 0.5$). The same behavior is exhibited along the outer streamline ($\tilde{x} = 2.0$) except that the CO^+ has not reached a maximum and begun to decrease, as shown in figure 19(d). Along both streamlines, the dominant electron-producing reaction is the ionization of CO. The C_2 concentrations shown in figures 19(e) and 19(f) are several decades lower than the concentrations of the other species.

The pressure and temperature distributions along the surface of the body are shown in figures 20 and 21, respectively. Figure 22 presents species concentrations along the body surface. On the body surface the longer particle residence times have allowed more CO dissociation and resulted in most of the electrons being formed from ionization of C and O. This result is in contrast to the results shown along the inner and outer streamlines.

Figure 23 is a profile of the static enthalpy across the shock layer at $\tilde{x} = 2.0$. It can be seen that the enthalpy increases sharply near the body. This region near the body is known as the entropy layer. Gas particles in this region have experienced a much larger rise in entropy from traversing the shock closer to the stagnation streamline and, as a result, much of the kinetic energy was converted to thermal energy. Pressure and temperature profiles across the shock layer at $\tilde{x} = 2.0$ are shown in figure 24. A typical electron concentration profile across the shock layer is shown in figure 25. It can be seen that the concentration builds up rapidly within the entropy layer near the body.

Case IV

This example was selected to represent entry into a possible Martian atmosphere having a composition of 95 percent CO_2 and 5 percent A by mass. The free-stream conditions are:

$$V_\infty = 4.572 \times 10^5 \text{ cm/sec}$$

$$\rho_\infty = 1.068 \times 10^{-5} \text{ g/cm}^3$$

$$T_\infty = 200 \text{ K}$$

The scheme of kinetic reactions and rates used in this example is given in appendix C. Vibrational nonequilibrium was assumed. After some experimentation it was found that a shock shape of the form

$$z_s = \frac{r_s^2}{1 + 1.89 r_s} \qquad (57)$$

resulted in the body shown in figure 26 which closely approximates a 60° half-angle sphere-cone with a 1-cm nose radius. Pressure and temperature variations along streamlines crossing the shock at $\tilde{x} = 0.4$ and 1.6 are shown in figures 27 and 28.

Species concentrations along these same streamlines are presented in figure 29. The CO_2 concentration decreases rapidly with increasing distance as it dissociates into

CO and O and results in the increasing concentrations of these species shown in figure 29(a). It is seen from figure 29(c) that the dominant ion present is CO^+.

Figure 30 illustrates the pressure and temperature variations along the surface of the body. Species concentrations along the body are presented in figure 31. It can be seen that the peak electron concentration on the surface occurs near the nose. The electrons are seen to result primarily from ionization of CO as was the case on the streamlines within the shock layer.

The sudden rise in static enthalpy within the entropy layer is shown in figure 32 for $\tilde{x} = 1.6$. Pressure and temperature profiles across the shock layer at this value of $\tilde{x}$ are shown in figure 33. Figure 34 illustrates the variation in the electron concentration across the shock layer. A marked increase in electron concentration is observed within the entropy layer.

Investigation of the assumed reaction mechanism for this case indicates that the chemical kinetics are controlled predominantly by two-body collision processes. Since the three-body recombination reactions are relatively unimportant, the remainder of the reactions are two-body collisions having the same density dependence. For specified initial temperature and species concentrations, the time (or distance) variation of all variables can then be scaled with respect to density. Practically, this concept of binary scaling (ref. 8) means that for a given flight velocity, flows will be similar if the product of ambient density and nose radius is held constant. For this particular case the results would then apply for a body with nose radius of 30.48 cm and $\rho_\infty = 3.5 \times 10^{-7}$ g/cm3. These conditions might be typical of a Viking-type entry on Mars.

To demonstrate the validity of the binary scaling assumption, it is necessary to assess the importance of three-body recombination reactions for this system. Define the rate of reaction j per unit mass of mixture as

$$R_j = \left[\frac{K_j}{\rho} \prod_{i=1}^{I} \left(\frac{\rho c_i}{\mu_i}\right)^{\nu_{i,j}}\right] \left(\rho \sum_{i=1}^{I} \frac{c_i a_{i,j}}{\mu_i}\right)^{\nu_{I+1,j}} \tag{58}$$

and define the ratio

$$R_{j,j+1} = R_j / R_{j+1} \tag{59}$$

The ratio $R_{j,j+1}$ can then be used to judge the relative importance of the forward rate to the reverse rate of a reaction.

Shown in figure 35 are the ratios along the inner streamline ($\tilde{x} = 0.4$) of the forward rate for the system of reactions as numbered in appendix C for this case. It can be seen that $R_{j,j+1} >> 1$ for all the reactions involving three-body recombinations except $R_{3,4}$ which indicates that the recombination of C and O to form CO is becoming more important far from the shock on this streamline. However, at the furthermost point, $R_{3,4} \approx 6$; therefore, the assumption that the flow along this streamline can be scaled is probably still a reasonable approximation. A true test of the validity of binary scaling in this case would require repeating the calculation for various values of ρ_∞ for constant $\rho_\infty R_n$ and comparing the results.

Case V

This example is similar to Case IV with the same free-stream conditions and kinetic reactions, but with a composition of 50 percent CO_2 and 50 percent A by mass. After some experimentation it was found that the shock shape given by

$$z_s = \frac{r_s^2}{1 + 1.98 r_s} \tag{60}$$

results in the body shown in figure 36 which closely approximates a 60° half-angle sphere-cone with a 1-cm nose radius. The shock standoff distance is greater for this case than that for Case IV because of the lower density ratio across the shock for this mixture. Pressure and temperature variations along streamlines crossing the shock at $\tilde{x} = 0.4$ and 1.6 are shown in figures 37 and 38. Comparing figures 28 and 38 shows that the temperature in the shock layer is about 10 percent higher for this case. The variations of species concentrations along these streamlines are presented in figure 39. Comparison with figure 29 from Case IV shows essentially the same behavior. Again, the predominant ion is CO^+. The electron concentrations are somewhat higher for this case because of the higher temperature in the shock layer.

Pressure and temperature variations on the body surface are shown in figure 40. Figure 41 illustrates variations of species concentrations on the surface. The only obvious difference in the profiles from those of Case IV appears in the electron concentration. In the previous case the profile reached a maximum near the sphere-cone juncture and then decreased. For this case the profile decreases monotonically with increasing distance.

Existence of the entropy layer is again demonstrated by the rapid increase in static enthalpy near the surface shown in figure 42 for $\tilde{x} = 1.6$. Pressure and temperature distributions across the shock layer at this value of $\tilde{x}$ are shown in figure 43. The variation in electron concentration across the shock layer at this value of $\tilde{x}$ is shown in figure 44 to be about a factor of 10 higher than that for Case IV.

The ratio of forward reaction rates to reverse reaction rates for this reaction system as given in appendix C is shown in figure 45. It can be seen that all $R_{j,j+1} >> 1$ for the three body recombination reactions. Thus, the binary-scaling assumption appears to be justifiable for this case.

CONCLUDING REMARKS

An approximate inverse solution is presented for the nonequilibrium flow in the inviscid shock layer about a vehicle in hypersonic flight. A number of representative cases have been presented. Case I is a comparison of results for nonequilibrium air with the more exact inverse method. Case II is a comparison of the results for nonequilibrium air with the streamtube method. Cases III, IV, and V present results for entry of spherical nose cones into representative Martian and Venusian atmospheres. From the foregoing analysis and results, the following observations can be made.

The method of solution as programed herein can handle a realistic model of an arbitrary gas mixture with large numbers of chemical reactions and species. A larger number of reactions and/or species could be easily accommodated by increasing the dimensioning of the appropriate variables in the FORTRAN program. The gas model permits consideration of vibrational relaxation, dissociation, recombination, ionization, electronic excitation, and vibration-dissociation coupling. With relative ease the gas model could be made more sophisticated. For example, the vibrational partition function could include effects of anharmonicity or a more realistic vibration-dissociation coupling model could be included.

Many flow-field solutions suffer the disadvantage of being valid only in the subsonic (or supersonic) region of a shock layer. Another method is required to solve the supersonic (or subsonic) region so that the solutions match in the transonic zone. The approximations inherent in the method presented herein avoid this difficulty and render the method applicable for subsonic and supersonic flows.

The solution offers little difficulty in programing for use on a digital computer as evidenced by the program described herein. Primarily because of the approximations made to the governing equations, this method offers the possibility of significant reductions in computing time. The required computing time for Case I on the Control Data 6600 digital computer was 79 seconds. The remaining 4 cases required between 5 and 14 minutes of time, Case II requiring the maximum time. These times are based upon calculating 20 streamlines. This result appears to be a significant reduction in the times reported in most of the existing literature on nonequilibrium flow fields.

The accuracy of the present method compared extremely well with the inverse marching integration technique for Case I and the streamtube method for Case II. Although the method fails on the Z-axis and the approximations are crude close to the stagnation point, the requirements of a thin shock layer and a smooth symmetric body are not so restrictive that application of the method is unduly hindered.

For Case III the electron concentrations were found to be greatest near the body in the entropy layer. In this region the electrons are produced primarily from ionization of C and O atoms. Within the shock layer, but outside the entropy layer, the concentrations are lower and the major ion present is CO^+.

For Case IV the electron concentrations were found to be greatest in the entropy layer. Throughout the shock layer the major ion present is CO^+. Maximum electron concentration occurred near the nose on the body.

The assumption of binary scaling for this system of reactions used in this case appeared to be a justifiable approximation. It was evident, however, that the recombination of C and O to form CO is the critical reaction in determining the validity of this assumption.

The larger percentage of argon for Case V compared with Case IV results in the argon acting as a nondissociating diluent with resulting higher temperatures in the shock layer. The electron concentrations are correspondingly higher. Maximum concentrations exist in the entropy layer. The binary-scaling assumption again appears to be justifiable for case V.

It should be emphasized that the systems of reactions chosen for these cases are merely representative and by no means definitive. Possible inaccuracies may arise if an incomplete reaction mechanism is used.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., October 28, 1971.

APPENDIX A

A COMPUTER PROGRAM TO DETERMINE THE FLOW FIELD IN A NONEQUILIBRIUM SHOCK LAYER ABOUT A SMOOTH SYMMETRIC BODY TRAVELING AT HYPERSONIC SPEEDS USING AN INVERSE TECHNIQUE

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Introduction

This appendix describes the digital computer program (LRC Program D1290) developed to support the study of an inverse technique (shock-shape specified) for determining the flow field in a nonequilibrium shock layer about a smooth symmetric body traveling at hypersonic speeds. The problem description, development of governing equations, symbols, method of solution, and results are discussed in the text of this paper.

Problem Description

The problem of determining the flow field in a shock layer about a smooth symmetric body behind a specified shock shape may be divided into six parts:

(1) Computation of the shock geometry $\left(x_s,\ z_s,\ r_s,\ R_c,\ \cos\theta, \text{ and } \sin\theta\right)$ from a definition supplied by the user. (See fig. 1)

(2) Computation of the free-stream quantities $\left(\mu_\infty,\ \rho,\ a_\infty,\ M_\infty, \text{ and } e_\infty\right)$

(3) Computation of quantities immediately behind the shock $\left(e_s,\ T_s,\ p_s,\ \rho_s,\ u_s, \text{ and } \psi_s\right)$

(4) Computation of pressures, and their derivatives, in the flow field $\left(p(x,\psi) \text{ and } \frac{dp}{dx}(x,\psi)\right)$

(5) Integration along streamlines from a point just behind the shock to a point sufficiently downstream to define the flow field

(6) Computation of physical space quantities r, y, and z, at specified points in the flow field to give a good body and flow field definition

Numerical Methods

The numerical methods used for the development of this program include

(1) A modified Runge-Kutta integration scheme designed for chemical problems (ref. 31)

(2) The Newton-Raphson iteration method (ref. 37, p. 192)

(3) Numerical differential equations (ref. 38, p. 96)

(4) Simpson's Rule integration technique (ref. 39, p. 137)

(5) Trapezoidal Rule integration technique (ref. 39, p. 142)

Subprograms

The subprograms used are given in the following listing:

FORTRAN name	Called by	Function
SHOCKG	D1290	to compute the shock geometry and store on tape 10
FDPDX	D1290	to evaluate the pressure p and its derivative $\dot{p}$ and store on tapes
FOFTS	ITR1	to evaluate T_s
ITR1	BASIC	to iterate for e
ITR1	D1290	to iterate for T_s
CALINTH	D1290	to obtain the integration technique
BASIC	CALINTH	to evaluate the derivatives $\dot{h}$, $\dot{c}_i$, and $\dot{e}_{v,i}$ for $i = 1,I$
FOFE	ITR1	to evaluate e
CHECK	CALINTH	to test results of an integration step and accept or reject the results

Subprogram SHOCKG(DELX,ZSTERM,IZTERM) is called by D1290 to compute the shock geometry parameters and store them on tape 10. This subroutine must be supplied by the user to define the shock shape desired. The calling sequence must contain the two input quantities DELX and ZSTERM and a generated integer, IZTERM, the number of x values computed in the subroutine. The user must store the following parameters on tape 10: x, z, r, R_c, cos θ, and sin θ. These six parameters must be computed at each x from $x = 0$ to $x \geqq$ ZSTERM and x must be in increments of DELX/5 to DELX and increments of DELX thereafter until $x \geqq$ ZSTERM where

x distance along shock, cm

z distance along symmetry axis, cm

r perpendicular distance from symmetry axis to shock, cm

R_c radius of curvature of shock, cm

θ local shock inclination angle, radians

STOP 13 has been used for error stops in this subroutine. In the sample case, the following shock shape was defined:

$$z = \cosh r - 1.0$$

$$x = \sqrt{2z + z^2}$$

$$\cos \theta = \frac{x}{\sqrt{x^2 + 1.0}}$$

$$R_c = 1.0 + x^2$$

Iteration of e

To encourage iteration to an acceptable value of e and thereby reduce instability, the following tests have been used:

(1) If the maximum number of iterations (10) is exceeded before convergence is reached, a new estimate of e is computed and the iteration is again attempted. The program will restart this iteration twice. If convergence is not reached, the program will terminate with STOP 66.

(2) If the converged e is greater than h and a negative T results, e is set equal to h - 0.000001 * h and one more iteration on e is attempted.

(3) If, after this maneuver, e is again greater than h, a trigger is set to restart the integration interval at one-fourth the current computing interval.

Testing Results of Integration

After an integration interval has been computed, several tests are made to decide whether to

(1) Continue,

(2) Recompute at one-fourth the current computing interval, or

(3) Stop the case.

Trial and error has proved that recomputing at a smaller interval sometimes prevents instabilities and error conditions from developing.

Stagnation Streamline

The stagnation $\psi = 0.0$ streamline is computed after the streamlines

$$\psi = \frac{\Delta x}{5},\ \frac{2\Delta x}{5},\ \frac{3\Delta x}{5},\ \text{and}\ \frac{4\Delta x}{5}$$

have been integrated to $x = \Delta x$. Values of e, T, h, c_i, and e_i $(i = 1,I)$ at $\psi = 0.0$ are obtained by extrapolation. Then $T_{v,i}$ $(i = 1,I)$, u, ρ, p, and $\dot{p}$ values are computed and the $\psi = 0.0$ streamline is integrated from Δx to $x \geqq$ ZSTERM.

Negative u^2

In the evaluation of the derivatives if u^2 becomes negative, the integration is discontinued and an attempt is made to compute the physical space values for the calculated flow field.

Input

The data input is loaded by using FORTRAN IV NAMELIST. One card, 80 columns, is read in by FORMAT (8A10) for case identification. The input symbols are as follows:

FORTRAN name	Symbol	Description
$NAM1	- - - - - - -	- - - - - - - -
DELX	Δx	increment along shock, cm
ZSTERM		length of symmetry axis, z, cm

FORTRAN name	Symbol	Description
IMAX	I	maximum number of species i, ≦25
JMAX	J	maximum number of reactions j, ≦50
MJ	m_j	an array containing an integer indicating which species i to use to calculate the coupling factor ϕ_j for reaction j
M	M_f	1, vibrational nonequilibrium; 0, vibrational equilibrium
R	R	universal gas constant, ergs/mole-K
GAMMA	γ	ratio of frozen specific heats
CIINF	$c_{i,\infty}$	an array containing free-stream mass fraction for each species i
PINF	p_∞	free-stream pressure, dynes/cm^2
TINF	T_∞	free-stream temperature, K
VINF	V_∞	free-stream velocity, cm/sec
MUI	μ_i	an array containing molecular weight for each species i, g/mole
BJ	B_j	an array containing temperature exponent for each reaction j in Arrhenius-type rate equation
EJ	E_j	an array of activation energies for each reaction j, K
AIJ	$a_{i,j}$	a two-dimensional array of correlation factors for ith species in jth reaction

FORTRAN name	Symbol	Description
NUIJ	$\nu_{i,j}$	a two-dimensional array of stoichiometric coefficients of ith reactant in jth reaction
NUPIJ	$\nu'_{i,j}$	a two-dimensional array of stoichiometric coefficients for ith product in jth reaction
ALPIK	$\alpha_{i,k}$	a two-dimensional array of coefficients in vibrational relaxation time expression
BETAIK	$\beta_{i,k}$	a two-dimensional array of temperature exponents in vibrational relaxation time expression
SIGIK	$\sigma_{i,k}$	a two-dimensional array of coefficients in vibrational relaxation time expression
THETAI	Θ_i	an array containing characteristic vibrational temperature K for each species i
DGENI	g_i	an array of factors for each species i to permit approximating a polyatomic molecule by a diatomic molecule
FI	f_i	an array of correlation factors for each species i, 0.0 for monatomic species and 1.0 for all others
DELHI	ΔH_i	an array of standard heat of formation at 0 K for each species i, ergs/mole
DELI	Δ_i	an array of dissociation energy for each species i, K
EVI	$e_{v,i}$	an array of vibrational energy per unit mass for each species i, ergs/g

FORTRAN name	Symbol	Description
LI	L_i	an array containing number of electronic levels for each species i
GIL	$g_{i,l}$	a two-dimensional array containing degeneracy of LI electronic levels for each species i
EPSIIL	$\epsilon_{i,l}$	a two-dimensional array containing energy of LI electronic levels for each species i, ^{o}K
AJ	A_j	an array containing frequency factor, $cm^{3n}/mole^{n}$-sec, for each reaction j in Arrhenius-type rate equation
XI		the initial computing interval. If no XI is input, 0.0001220703125 will be used
ELE1		an array of [2(IMAX) + 1] values used by integration scheme to control size of computing interval. $0.0 < ELE1 \leqq 64.0$
ELE2		an array of [2(IMAX) + 1] values used by integration scheme to control size of computing interval. $ELE2 < ELE1$
XPST		an array of x values at which physical space calculations are desired. They must be multiples of DELX. The program sets XPST(1) = DELX and XPST(NXPST) = [(x at ZSTERM) + 100.0]
NXPST		number of values in XPST array $\leqq 100$
IPF		PRINT ANSWERS every IPF integration; IPF = 5 unless input otherwise

FORTRAN name	Symbol	Description
CIMAX		maximum computing interval; if CIMAX is not input, 0.0625 will be used
TIMER		time, in decimal seconds, requested on JOB card. If case does not terminate in time estimated on JOB card, data for pickup will be stored on tape 13. If TIMER is not input, 3600.0 or 1 hour will be used
IPICKUP		= 1 to pickup case from tape 13 = 0 unless input
IBUG		an array of 15 integers which must be input as 0 to trigger debug printouts at critical points (see Program Listing)

$

With some cases, difficulties were encountered in starting the integration. When this condition occurred, the input quantities XI, ELE1, ELE2, and CIMAX were varied until the integration proceeded.

After reading in NAMELIST input, read in the IMAX species (10 spaces per species, 8 species per card) by Format (8A10) and the JMAX reactions by the same FORMAT using 20 spaces per reaction, 4 reactions per card. If the species and reactions are not read in, IMAX/8 + JMAX/4 blank cards must be put in the deck. If (IMAX/8) and (JMAX/4) are not whole numbers, they should be rounded to the next whole number.

Sample Input

A sample input follows:

```
    SHOCK SHAPE NEQA     GROSE,12-17-68  7 SPECIES,14 REACTIONS              0000
$NAM1
M=0,
MUI(1)= 28.016,32.000,14.008,16.000,30.008,30.008,5.4862E-4,
CIINF(1)=0.768,.232,.0,.0,.0,.0,.0,
 PINF=1.98E2,
TINF = 253.8,
VINF = 7.02E5,
```

```
R     = 8.31469E7,
GAMMA= 1.4,
THETAI(1)= 3392.14,2275.0,1.0,1.0,2739.0,3421.0,1.0,
GIL(1,1 )= 1.0,3.0,6.0,2.0,4*0.,
GIL(1,2 )= 3.0,2.0,1.0,3.0,1.0,3.0,2*0.,
GIL(1,3 )= 4.,6.,4.,6.,4*0.,
GIL(1,4 )= 5.,3.,1.,5.,1.,3*0.,
GIL(1,5 )= 2.,2.,2.,4.,2.,4.,2.,4.,
GIL(1,6 )= 1.,6.,3.,5*0.,
GIL(1,7 )= 1.,7*0.,
DGENI(1)= 20*1.0,
EPSIIL(1, 1)= 0.,71592.,85343.,99212., 4*0.,
EPSIIL(1, 2)= 0.,11342.,18879.,51385.,52104.,71026., 2*0.,
EPSIIL(1, 3)= 0.,27659.,27670.,41496., 4*0.,
EPSIIL(1, 4)= 0.,  228.,  326.,22831.,48622., 3*0.,
EPSIIL(1, 5)= 0.,  174.,63597.,65381.,76676.,75361.,87568.,86359.,
EPSIIL(1, 6)= 0.,57528.,84205., 5*0.,
EPSIIL(1, 7)= 8*0.,
LI(1)= 4,6,4,5,8,3,1,
FI(1)= 1.,1.,0.,0.,1.,1.,0.,
DELHI(1)=0.,0.,4.707E12,2.4681E12,9.0073E11,1.0826E13,0.,
DELI(1)= 114981.,60500.,0.,0.,76883.,127698.,0.,
MJ(1)= 2,4,5,3,1,3,2,5,1,5,1,5,6,3,
 MJ(11)= 6,3,0,0,
AJ(1)= 1.2E21,1.0E18,5.2E21,1.3E21,3.0E21,1.67E20,1.0E12,2.38E11,5.0E13,
       1.11E13,9.1E24,4.79E23,1.8E21,2.17E11,
 AJ(11)= 1.8E21,2.17E11,0,0,
BJ(1)= -1.5,-1.0,-1.5,-1.5,-1.5,-1.5,0.5,0.5,0.,0.,-2.5,-2.5,-1.5,0.12,
 BJ(11)= -1.5,0.12,0,0,
EJ(1)=  59380.,0., 75490.,0., 113260.,0., 3120., 19130., 38000.,0.,
 EJ(11)= 0.,31858.,0,0,
NUIJ(1, 1)= 0,1,0,0,0,0,0,1,
NUIJ(1, 2)= 0,0,0,2,0,0,0,1,
NUIJ(1, 3)= 0,0,0,0,1,0,0,1,
NUIJ(1, 4)= 0,0,1,1,0,0,0,1,
NUIJ(1, 5)= 1,0,0,0,0,0,0,1,
NUIJ(1, 6)= 0,0,2,0,0,0,0,1,
NUIJ(1, 7)= 0,1,1,0,0,0,0,0,
NUIJ(1, 8)= 0,0,0,1,1,0,0,0,
NUIJ(1, 9)= 1,0,0,1,0,0,0,0,
NUIJ(1,10)= 0,0,1,0,1,0,0,0,
NUIJ(1,11)= 0,0,0,0,0,1,1,0,
NUIJ(1,12)= 0,0,1,1,0,0,0,0,
NUPIJ(1, 1)= 0,0,0,2,0,0,0,
NUPIJ(1, 2)= 0,1,0,0,0,0,0,
NUPIJ(1, 3)= 0,0,1,1,0,0,0,
NUPIJ(1, 4)= 0,0,0,0,1,0,0,
NUPIJ(1, 5)= 0,0,2,0,0,0,0,
NUPIJ(1, 6)= 1,0,0,0,0,0,0,
NUPIJ(1, 7)= 0,0,0,1,1,0,0,
NUPIJ(1, 8)= 0,1,1,0,0,0,0,
NUPIJ(1, 9)= 0,0,1,0,1,0,0,
NUPIJ(1,10)= 1,0,0,1,0,0,0,
NUPIJ(1,11)= 0,0,1,1,0,0,0,
NUPIJ(1,12)= 0,0,0,0,0,1,1,
AIJ(1, 1)= 6*1.0,
AIJ(1, 2)= 6*1.0,
AIJ(1, 3)= 6*1.0,
AIJ(1, 4)= 6*1.0,
AIJ(1, 5)= 6*1.0,
AIJ(1, 6)= 6*1.0,
AIJ(1, 7)= 7*0,
AIJ(1, 8)= 7*0,
AIJ(1, 9)= 7*0,
AIJ(1,10)= 7*0,
```

```
AIJ(1,11)= 7*0,
AIJ(1,12)= 7*0,
ALPIK(1, 1)= 7*5.675E-4,
ALPIK(1, 2)= 7*1.443E-7,
ALPIK(1, 3)= 7*0,
ALPIK(1, 4)= 7*0,
ALPIK(1, 5)= 7*1.513E-4,
ALPIK(1, 6)= 7*1.513E-4,
ALPIK(1, 7)= 7*0.,
BETAIK(1, 1)=7*-.09952,
BETAIK(1, 2)=7*0.37177,
BETAIK(1, 3)=7*0.,
BETAIK(1, 4)=7*0.,
BETAIK(1, 5)=7*-.2226,
BETAIK(1, 6)=7*-.2226,
BETAIK(1, 7)=7*0,
SIGIK(1, 1)= 7*163.63,
SIGIK(1, 2)= 7*179.32,
SIGIK(1, 3)= 7*0,
SIGIK(1, 4)= 7*0,
SIGIK(1, 5)= 7*135.3,
SIGIK(1, 6)= 7*135.3,
SIGIK(1, 7)= 7*0,
 IMAX=7,
JMAX=12,
CIMAX=.5,
ELE1(1)=42*64.,
ELE2(1)=42*1.0,
XI=.0625,
ZSTERM=1.145,
DELX=0.06,   TCHECKT=0.3,   HCHECKT=0.01,   PHMAX=65.0,
EVI(1)=20*0.0,
NXPST=15, XPST(1)=.06,.12,.18,.24,.3,.36,.42,.48,.54,.6,.66,.72,.78,.84,10.,
 IPF=5,  TIMER=240.,  IPICKUP=0,
$
       N2           02           N          O          NO          NO+           E-
   02 + M = 20 + M     20 + M = 02 + M   NO + M = N + O + M   N + O + M = NO + M
   N2 + M = 2N + M     2N + M = N2 + M     N + 02 = NO + O       NO + O = N + 02
   N2 + O = NO + N     NO + N = N2 + O     NO+ + E- = N + O      N + O = NO+ + E-
```

Tape Assignments

Tape 5, input, with buffer size 1001

Tape 6, output, with buffer size 1001

Tape 8, to save derivative of pressure at each x for each ψ

Tape 9, to save pressure at each x for each ψ

Tape 10, to save the shock geometry parameters x and corresponding z, r, R_c, $\cos\theta$, and $\sin\theta$

Tape 11, to save quantities behind the shock T_s, e_s, p_s, ρ_s, u_s, ψ_s, h_s, $\left(e_{v,i}\right)_s$(i = 1,IMAX) at each x

Tape 12, to save physical space data

Tape 13, pickup tape

Operational Details

Program D1290 was written in FORTRAN IV language for the Control Data 6000 series digital computer under the Scope 3.0 operating system. The program requires a field length of $110\ 000_8$. The sample case was completed in two passes on the Control Data 6600 computer to illustrate the pickup capability.

Programed STOPS

STOP 1, incorrect input

STOP 6, EOF 10 in main program

STOP 13, in SHOCKG

STOP 30, in CHECK when computing interval less than 1.0E - 15

STOP 50, EOF 9 in FDPDX

STOP 66, in BASIC when no convergence on e iteration

STOP 301, in MAIN for error in XPST array or IZTERM .GT. 500

STOP 321, ITR1 stop in main program

STOP 422, in MAIN after pickup tape written

STOP 663, in MAIN when x is not equal to VARI(IPSI)

STOP 665, in MAIN after an integration attempt

STOP 670, when ac_i is negative

Pickup Tape

Under control of the input value TIMER, the estimated time on the JOB card and a REQUEST card, a pickup tape will be generated if the case does not terminate in the estimated time. A pickup may not be made before the $\psi = 0.0$ streamline integration has started.

Output

When no debug printouts are requested (IBUG array = 1), the printed output will contain:

1 ID information

2 a list of the IMAX species

3 a list of the JMAX reactions

4 a printout of the input quantities and those generated in the initialization section

5 the shock geometry x, z, r, R_c, $\cos\theta$, and $\sin\theta$

6 the free-stream quantities μ_∞, ρ_∞, a_∞, M_∞, $e_{i,\infty}$, e_∞, $(e_{e,i})_\infty$, and $(e_{v,i})_\infty$ (i = 1,IMAX)

7 the quantities behind the shock T_s, e_s, p_s, ρ_s, u_s, ψ_s, h_s, and $(e_{v,i})_s$ (i = 1,IMAX) for each streamline ψ or each x distance along shock

8 IZTERM, the number of x values on the shock or the number of streamlines to be integrated

9 The following values are printed every IPF acceptable integration intervals:

IPSI streamline ID beginning with 2 for ψ at $x = \text{DELX}/5$

IX number of integration steps for streamline beginning with 1 at the shock

$\left.\begin{matrix} x,h,\mu,p \\ \rho,u,T,e \end{matrix}\right\}$ for computing interval $\sum_{i=1}^{IMAX} c_i$

c_i (i=1,IMAX) concentration

$c_{m,i}$ (i=1,IMAX) molecular concentration

$e_{v,i}$ (i=1,IMAX) vibrational energy

(IPSI=6) is used for the stagnation streamline, $\psi = 0.0$, and the streamline beginning at Δx

10 after all the streamlines have been computed, the physical space values r,y,z are printed at the x values given in the XPST array

11 after the initial conditions for a streamline are printed, the statement "——CHECKT= " appears. This number represents the elapsed time, in seconds, from start

12 other comments are printed to help the user follow the flow of the solution or to explain built-in remedial maneuvers to continue a solution which is in trouble

13 the IBUG debug printout options represent areas of difficulty during the development of the program. They may be helpful to the user for a closer examination of selected quantities and so have been left in the program.

Sample Output

A sample output follows:

```
SHOCK SHAPE NEQA    GROSE,12-17-68   7 SPECIES,14 REACTIONS              0000

  SPECIES

  1         N2
  2         O2
  3          N
  4          O
  5         NO
  6        NO+
  7         E-

  REACTIONS

  1       O2 + M = 2O + M
  2       2O + M = O2 + M
  3   NO + M = N + O + M
  4   N + O + M = NO + M
  5       N2 + M = 2N + M
  6       2N + M = N2 + M
  7       N + O2 = NO + O
  8       NO + O = N + O2
  9       N2 + O = NO + N
 10       NO + N = N2 + O
 11     NO+ + E- = N + O
 12     N + O = NO+ + E-

PRINT FREQUENCY=  5
 HCHECKT= 1.00000000E-02  TCHECKT= 3.00000000E-01     PHMAX= 6.50000000E+01
XI= 6.25000000E-02
CIMAX= 5.00000000E-01
ELE1=    6.40000000E+01    6.40000000E+01
   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01
   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01
   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01
   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01
   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01
   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   6.40000000E+01   0.               0.
   0.               0.               0.               0.               0.               0.               0.

ELE2=    1.00000000E+00    1.00000000E+00
   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00
   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00
   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00
   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00
   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00
   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   0.               0.
   0.               0.               0.               0.               0.               0.               0.

NXPST= 15
XPST=
   6.00000000E-02   1.20000000E-01   1.80000000E-01   2.40000000E-01   3.00000000E-01   3.60000000E-01   4.20000000E-01
   4.80000000E-01   5.40000000E-01   6.00000000E-01   6.60000000E-01   7.20000000E-01   7.80000000E-01   8.40000000E-01
```

```
 1.00000000E+01                IIIII
DELX= 6.00000000E-02
ZSTERM= 1.14500000E+00
TIMER= 2.40000000E+02
IPICKUP=0

IMAX= 7   JMAX=12   M=0
R= 8.31469000E+07
GAMMA= 1.40000000E+00
PINF= 1.98000000E+02
TINF= 2.53800000E+02
VINF= 7.02000000E+05
IBUG=1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
```

MUI	THETAI	CGENI	FI	DELHI	DELI	CIINF	EVI	LI
2.801600E+01	3.392140E+03	1.000000E+00	1.000000E+00	0.	1.149810E+05	7.680000E-01	0.	4
3.200000E+01	2.275000E+03	1.000000E+00	1.000000E+00	0.	6.050000E+04	2.320000E-01	0.	6
1.400800E+01	1.000000E+00	1.000000E+00	0.	4.707000E+12	0.	0.	0.	4
1.600000E+01	1.000000E+00	1.000000E+00	0.	2.468100E+12	0.	0.	0.	5
3.000800E+01	2.739000E+03	1.000000E+00	1.000000E+00	9.007300E+11	7.688300E+04	0.	0.	8
3.000800E+01	3.421000E+03	1.000000E+00	1.000000E+00	1.082600E+13	1.276980E+05	0.	0.	3
5.486200E-04	1.000000E+00	1.000000E+00	0.	0.	0.	0.	0.	1

MJ	AJ	BJ	EJ
2	1.20000000E+21	-1.50000000E+00	5.93800000E+04
4	1.00000000E+18	-1.00000000E+00	0.
5	5.20000000E+21	-1.50000000E+00	7.54900000E+04
3	1.30000000E+21	-1.50000000E+00	0.
1	3.00000000E+21	-1.50000000E+00	1.13260000E+05
3	1.67000000E+20	-1.50000000E+00	0.
2	1.00000000E+12	5.00000000E-01	3.12000000E+03
5	2.38000000E+11	5.00000000E-01	1.91300000E+04
1	5.00000000E+13	0.	3.80000000E+04
5	1.11000000E+13	0.	0.
6	1.80000000E+21	-1.50000000E+00	0.
3	2.17000000E+11	1.20000000E-01	3.18580000E+04

```
I=   1  (GIL(L,I),L=1,IMAX+1)
 1.00000000E+00   3.00000000E+00   6.00000000E+00   2.00000000E+00   0.              0.              0.
 0.
I=   1  (EPSIIL(L,I),L=1,IMAX+1)
 0.               7.15920000E+04   8.53430000E+04   9.92120000E+04   0.              0.              0.
 0.
I=   1  (AIJ(I,J),J=1,JMAX)
 1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00  1.00000000E+00  0.
 0.               0.               0.               0.               0.
I=   1  (ALPIK(K,I),K=1,IMAX)
 5.67500000E-04   5.67500000E-04   5.67500000E-04   5.67500000E-04   5.67500000E-04  5.67500000E-04  5.67500000E-04

I=   1  (BETAIK(K,I),K=1,IMAX)
-9.95200000E-02  -9.95200000E-02  -9.95200000E-02  -9.95200000E-02  -9.95200000E-02 -9.95200000E-02 -9.95200000E-02

I=   1  (SIGIK(K,I),K=1,IMAX)
 1.63630000E+02   1.63630000E+02   1.63630000E+02   1.63630000E+02   1.63630000E+02  1.63630000E+02  1.63630000E+02

I=   1  (NUIJ(J,I),J=1,JMAX)
 0.               0.               0.               0.               1.00000000E+00  0.              0.
 0.               1.00000000E+00   0.               0.               0.
I=   1  (NUPIJ(J,I),J=1,JMAX)
 0.               0.               0.               0.               0.              1.00000000E+00  0.
 0.               0.               1.00000000E+00   0.               0.


I=   2  (GIL(L,I),L=1,IMAX+1)
 3.00000000E+00   2.00000000E+00   1.00000000E+00   3.00000000E+00   1.00000000E+00  3.00000000E+00  0.
 0.
I=   2  (EPSIIL(L,I),L=1,IMAX+1)
 0.               1.13420000E+04   1.88790000E+04   5.13850000E+04   5.21040000E+04  7.10260000E+04  0.
 0.
I=   2  (AIJ(I,J),J=1,JMAX)
 1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00  1.00000000E+00  0.
 0.               0.               0.               0.               0.
I=   2  (ALPIK(K,I),K=1,IMAX)
 1.44300000E-07   1.44300000E-07   1.44300000E-07   1.44300000E-07   1.44300000E-07  1.44300000E-07  1.44300000E-07

I=   2  (BETAIK(K,I),K=1,IMAX)
 3.71770000E-01   3.71770000E-01   3.71770000E-01   3.71770000E-01   3.71770000E-01  3.71770000E-01  3.71770000E-01

I=   2  (SIGIK(K,I),K=1,IMAX)
 1.79320000E+02   1.79320000E+02   1.79320000E+02   1.79320000E+02   1.79320000E+02  1.79320000E+02  1.79320000E+02

I=   2  (NUIJ(J,I),J=1,JMAX)
 1.00000000E+00   0.               0.               0.               0.              0.              1.00000000E+00
 0.               0.               0.               0.               0.
I=   2  (NUPIJ(J,I),J=1,JMAX)
 0.               1.00000000E+00   0.               0.               0.              0.              0.
 1.00000000E+00   0.               0.               0.               0.


I=   3  (GIL(L,I),L=1,IMAX+1)
 4.00000000E+00   6.00000000E+00   4.00000000E+00   6.00000000E+00   0.              0.              0.
 0.
I=   3  (EPSIIL(L,I),L=1,IMAX+1)
 0.               2.76590000E+04   2.76700000E+04   4.14960000E+04   0.              0.              0.
 0.
```

```
I=    3  (AIJ(I,J),J=1,JMAX)
  1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   0.
  0.               0.               0.               0.               0.
I=    3  (ALPIK(K,I),K=1,IMAX)
  0.               0.               0.               0.               0.               0.               0.

I=    3  (BETAIK(K,I),K=1,IMAX)
  0.               0.               0.               0.               0.               0.               0.

I=    3  (SIGIK(K,I),K=1,IMAX)
  0.               0.               0.               0.               0.               0.               0.

I=    3  (NUIJ(J,I),J=1,JMAX)
  0.               0.               0.               1.00000000E+00   0.               2.00000000E+00   1.00000000E+00
  0.               0.               1.00000000E+00   0.               1.00000000E+00
I=    3  (NUPIJ(J,I),J=1,JMAX)
  0.               0.               1.00000000E+00   0.               2.00000000E+00   0.               0.
  1.00000000E+00   1.00000000E+00   0.               1.00000000E+00   0.


I=    4  (GIL(L,I),L=1,IMAX+1)
  5.00000000E+00   3.00000000E+00   1.00000000E+00   5.00000000E+00   1.00000000E+00   0.               0.
  0.
I=    4  (EPSIIL(L,I),L=1,IMAX+1)
  0.               2.28000000E+02   3.26000000E+02   2.28310000E+04   4.86220000E+04   0.               0.
  0.
I=    4  (AIJ(I,J),J=1,JMAX)
  1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   0.
  0.               0.               0.               0.               0.
I=    4  (ALPIK(K,I),K=1,IMAX)
  0.               0.               0.               0.               0.               0.               0.

I=    4  (BETAIK(K,I),K=1,IMAX)
  0.               0.               0.               0.               0.               0.               0.

I=    4  (SIGIK(K,I),K=1,IMAX)
  0.               0.               0.               0.               0.               0.               0.

I=    4  (NUIJ(J,I),J=1,JMAX)
  0.               2.00000000E+00   0.               1.00000000E+00   0.               0.               0.

  1.00000000E+00   1.00000000E+00   0.               0.               1.00000000E+00
I=    4  (NUPIJ(J,I),J=1,JMAX)
  2.00000000E+00   0.               1.00000000E+00   0.               0.               0.               1.00000000E+00
  0.               0.               1.00000000E+00   1.00000000E+00   0.


I=    5  (GIL(L,I),L=1,IMAX+1)
  2.00000000E+00   2.00000000E+00   2.00000000E+00   4.00000000E+00   2.00000000E+00   4.00000000E+00   2.00000000E+00
  4.00000000E+00
I=    5  (EPSIIL(L,I),L=1,IMAX+1)
  0.               1.74000000E+02   6.35970000E+04   6.53810000E+04   7.66760000E+04   7.53610000E+04   8.75680000E+04
  8.63590000E+04
I=    5  (AIJ(I,J),J=1,JMAX)
  1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   0.
  0.               0.               0.               0.               0.
I=    5  (ALPIK(K,I),K=1,IMAX)
  1.51300000E-04   1.51300000E-04   1.51300000E-04   1.51300000E-04   1.51300000E-04   1.51300000E-04   1.51300000E-04
```

```
I=    5  (BETAIK(K,I),K=1,IMAX)
 -2.22600000E-01   -2.22600000E-01   -2.22600000E-01   -2.22600000E-01   -2.22600000E-01   -2.22600000E-01   -2.22600000E-01

I=    5  (SIGIK(K,I),K=1,IMAX)
  1.35300000E+02    1.35300000E+02    1.35300000E+02    1.35300000E+02    1.35300000E+02    1.35300000E+02    1.35300000E+02

I=    5  (NUIJ(J,I),J=1,JMAX)
  0.                0.                1.00000000E+00    0.                0.                0.                0.
  1.00000000E+00    0.                1.00000000E+00    0.                0.
I=    5  (NUPIJ(J,I),J=1,JMAX)
  0.                0.                0.                1.00000000E+00    0.                0.                1.00000000E+00
  0.                1.00000000E+00    0.                0.                0.


I=    6  (GIL(L,I),L=1,IMAX+1)
  1.00000000E+00    6.00000000E+00    3.00000000E+00    0.                0.                0.                0.
  0.
I=    6  (EPSIIL(L,I),L=1,IMAX+1)
  0.                5.75280000E+04    8.42050000E+04    0.                0.                0.                0.
  0.
I=    6  (AIJ(I,J),J=1,JMAX)
  1.00000000E+00    1.00000000E+00    1.00000000E+00    1.00000000E+00    1.00000000E+00    1.00000000E+00    0.
  0.                0.                0.                0.                0.
I=    6  (ALPIK(K,I),K=1,IMAX)
  1.51300000E-04    1.51300000E-04    1.51300000E-04    1.51300000E-04    1.51300000E-04    1.51300000E-04    1.51300000E-04

I=    6  (BETAIK(K,I),K=1,IMAX)
 -2.22600000E-01   -2.22600000E-01   -2.22600000E-01   -2.22600000E-01   -2.22600000E-01   -2.22600000E-01   -2.22600000E-01

I=    6  (SIGIK(K,I),K=1,IMAX)
  1.35300000E+02    1.35300000E+02    1.35300000E+02    1.35300000E+02    1.35300000E+02    1.35300000E+02    1.35300000E+02

I=    6  (NUIJ(J,I),J=1,JMAX)
  0.                0.                0.                0.                0.                0.                0.
  0.                0.                0.                1.00000000E+00    0.
I=    6  (NUPIJ(J,I),J=1,JMAX)
  0.                0.                0.                0.                0.                0.                0.
  0.                0.                0.                0.                1.00000000E+00


I=    7  (GIL(L,I),L=1,IMAX+1)
  1.00000000E+00    0.                0.                0.                0.                0.                0.
  0.
I=    7  (EPSIIL(L,I),L=1,IMAX+1)
  0.                0.                0.                0.                0.                0.                0.
  0.
I=    7  (AIJ(I,J),J=1,JMAX)
  0.                0.                0.                0.                0.                0.                0.
  0.                0.                0.                0.                0.
I=    7  (ALPIK(K,I),K=1,IMAX)
  0.                0.                0.                0.                0.                0.                0.

I=    7  (BETAIK(K,I),K=1,IMAX)
  0.                0.                0.                0.                0.                0.                0.

I=    7  (SIGIK(K,I),K=1,IMAX)
  0.                0.                0.                0.                0.                0.                0.
```

```
I=     7   (NUIJ(J,I),J=1,JMAX)
 0.               0.               0.               0.               0.               0.               0.
 0.               0.               0.               1.00000000E+00   0.
I=     7   (NUPIJ(J,I),J=1,JMAX)
 0.               0.               0.               0.               0.               0.               0.
 0.               0.               0.               0.               1.00000000E+00


I=     8   (NUIJ(J,I),J=1,JMAX)
 1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   1.00000000E+00   0.
 0.               0.               0.               0.               0.
END INPUT
```

X	ZS	RS	RC	COST	SINT	
0.	0.	0.	2.10921600E+00	0.	1.00000000E+00	1
1.20000000E-02	4.68747616E-05	1.19998779E-02	2.10930975E+00	5.68914412E-03	9.99977777E-01	2
2.40000000E-02	1.85091743E-04	2.35987784E-02	2.10958622E+00	1.13768982E-02	9.99912266E-01	3
3.60000000E-02	3.77694702E-04	3.59970969E-02	2.10997149E+00	1.70638248E-02	9.99820981E-01	4
4.80000000E-02	5.70297660E-04	4.79554154E-02	2.11035676E+00	2.27507513E-02	9.99729695E-01	5
6.00000000E-02	9.87121805E-04	5.99869210E-02	2.11119117E+00	2.84280000E-02	9.99532435E-01	6
1.20000000E-01	3.48580648E-03	1.19931853E-01	2.11619363E+00	5.67963502E-02	9.98350195E-01	7
1.80000000E-01	8.96227244E-03	1.79662611E-01	2.12720253E+00	8.48621154E-02	9.95780042E-01	8
2.40000000E-01	1.46866721E-02	2.39375523E-01	2.13871192E+00	1.12902667E-01	9.93094237E-01	9
3.00000000E-01	2.26382706E-02	2.98732633E-01	2.15466264E+00	1.40453039E-01	9.89437704E-01	10
3.60000000E-01	3.50371223E-02	3.57379120E-01	2.18028318E+00	1.67024407E-01	9.83842393E-01	11
4.20000000E-01	4.74359740E-02	4.16025607E-01	2.20570372E+00	1.93595775E-01	9.78247083E-01	12
4.80000000E-01	5.98346256E-02	4.74672095E-01	2.23112426E+00	2.20167143E-01	9.72651772E-01	13
5.40000000E-01	7.22336773E-02	5.33318582E-01	2.25654479E+00	2.46738511E-01	9.67056461E-01	14
6.00000000E-01	8.46325290E-02	5.91965069E-01	2.28196533E+00	2.73309879E-01	9.61461150E-01	15
6.60000000E-01	1.07011744E-01	6.47142980E-01	2.33146938E+00	2.95590476E-01	9.52730765E-01	16
7.20000000E-01	1.32327905E-01	7.01300184E-01	2.38806053E+00	3.16608418E-01	9.43077815E-01	17
7.80000000E-01	1.57644066E-01	7.55457388E-01	2.44465169E+00	3.37626360E-01	9.33424864E-01	18
8.40000000E-01	1.82960226E-01	8.09614592E-01	2.50124284E+00	3.58644301E-01	9.23771913E-01	19
9.00000000E-01	2.08276387E-01	8.63771796E-01	2.55783400E+00	3.79662243E-01	9.14118962E-01	20
9.60000000E-01	2.33592548E-01	9.17929000E-01	2.61442515E+00	4.00680185E-01	9.04466011E-01	21
1.02000000E+00	2.58908708E-01	9.72086204E-01	2.67101631E+00	4.21698127E-01	8.94813060E-01	22
1.08000000E+00	2.84224869E-01	1.02624341E+00	2.72760746E+00	4.42716068E-01	8.85160110E-01	23
1.14000000E+00	3.09541030E-01	1.08040061E+00	2.78419861E+00	4.63734010E-01	8.75507159E-01	24
1.20000000E+00	3.34857190E-01	1.13455782E+00	2.84078977E+00	4.84751952E-01	8.65854208E-01	25
1.26000000E+00	3.60173351E-01	1.18871502E+00	2.89738092E+00	5.05769894E-01	8.56201257E-01	26
1.32000000E+00	3.85489512E-01	1.24287222E+00	2.95397208E+00	5.26787835E-01	8.46548306E-01	27
1.38000000E+00	4.12172946E-01	1.29598041E+00	3.01656607E+00	5.46921986E-01	8.36943558E-01	28
1.44000000E+00	4.56750559E-01	1.33535953E+00	3.15772218E+00	5.55489530E-01	8.27969658E-01	29
1.50000000E+00	5.01328171E-01	1.37473866E+00	3.29887828E+00	5.64057074E-01	8.18995758E-01	30
1.56000000E+00	5.45905784E-01	1.41411779E+00	3.44003438E+00	5.72624619E-01	8.10021858E-01	31
1.62000000E+00	5.90483396E-01	1.45349691E+00	3.58119048E+00	5.81192163E-01	8.01047958E-01	32
1.68000000E+00	6.35061009E-01	1.49287604E+00	3.72234658E+00	5.89759707E-01	7.92074058E-01	33
1.74000000E+00	6.79638621E-01	1.53225516E+00	3.86350268E+00	5.98327252E-01	7.83100158E-01	34
1.80000000E+00	7.24216234E-01	1.57163429E+00	4.00465878E+00	6.06894796E-01	7.74126258E-01	35
1.86000000E+00	7.68793846E-01	1.61101342E+00	4.14581488E+00	6.15462340E-01	7.65152358E-01	36
1.92000000E+00	8.13371459E-01	1.65039254E+00	4.28697098E+00	6.24029884E-01	7.56178458E-01	37
1.98000000E+00	8.57949071E-01	1.68977167E+00	4.42812709E+00	6.32597429E-01	7.47204558E-01	38
2.04000000E+00	9.02526684E-01	1.72915080E+00	4.56928319E+00	6.41164973E-01	7.38230658E-01	39
2.10000000E+00	9.47104296E-01	1.76852992E+00	4.71043929E+00	6.49732517E-01	7.29256758E-01	40
2.16000000E+00	9.91681909E-01	1.80790905E+00	4.85159539E+00	6.58300061E-01	7.20282858E-01	41

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 2.22000000E+00   1.03625952E+00   1.84728817E+00   4.99275149E+00   6.66867606E-01   7.11308958E-01   42
 2.28000000E+00   1.08083713E+00   1.88666730E+00   5.13390759E+00   6.75435150E-01   7.02335058E-01   43
 2.34000000E+00   1.12541475E+00   1.92604643E+00   5.27506369E+00   6.84002694E-01   6.93361158E-01   44
 2.40000000E+00   1.16999236E+00   1.96542555E+00   5.41621979E+00   6.92570238E-01   6.84387258E-01   45
+++ FREESTREAM QUANTITIES +++
MUINF= 2.88492827E+01   RHOINF= 2.70683965E-07   AINF= 3.20011325E+04   MINF= 2.19367236E+01   EIINF= 5.76975408E+13
EINF= 1.82888850E+09
EEIINF=
  0.
EVIINF=
  1.57903727E+04   7.56528812E+05   0.               0.               1.56070331E+05   1.32695556E+04
  0.

+++ QUANTITIES BEHIND SHOCK +++
    TS               ES               PS               RHOS             US               PSIS             HS

  1.76101270E+04   1.94871992E+11   1.18070770E+05   2.32631684E-06   0.               0.               2.45626372E+11
IX=  1  EVIS=
  4.73918161E+10   4.28651161E+10   0.               0.               4.50982537E+10   4.42084304E+10   0.

  1.76095021E+04   1.94862921E+11   1.18065372E+05   2.32629304E-06   3.99377917E+03   1.36811720E-05   2.45615501E+11
IX=  2  EVIS=
  4.73899672E+10   4.28634946E+10   0.               0.               4.50965257E+10   4.42067044E+10   0.

  1.76076600E+04   1.94836184E+11   1.18049461E+05   2.32622288E-06   7.98658257E+03   5.47202304E-05   2.45583454E+11
IX=  3  EVIS=
  4.73845170E+10   4.28587149E+10   0.               0.               4.50914318E+10   4.42016162E+10   0.

  1.76050932E+04   1.94798931E+11   1.18027292E+05   2.32612512E-06   1.19788050E+04   1.23113195E-04   2.45538803E+11
IX=  4  EVIS=
  4.73769228E+10   4.28520547E+10   0.               0.               4.50843340E+10   4.41945264E+10   0.

  1.76025265E+04   1.94761681E+11   1.18005125E+05   2.32602736E-06   1.59710274E+04   2.18861391E-04   2.45494156E+11
IX=  5  EVIS=
  4.73693287E+10   4.28453949E+10   0.               0.               4.50772365E+10   4.41874369E+10   0.

  1.75969803E+04   1.94681202E+11   1.17957231E+05   2.32581613E-06   1.99564560E+04   3.41887158E-04   2.45397692E+11
IX=  6  EVIS=
  4.73529195E+10   4.28310041E+10   0.               0.               4.50619000E+10   4.41721177E+10   0.

  1.75637484E+04   1.94199245E+11   1.17670402E+05   2.32455051E-06   3.98710378E+04   1.36659155E-03   2.44819957E+11
IX=  7  EVIS=
  4.72545978E+10   4.27447765E+10   0.               0.               4.49700060E+10   4.40803277E+10   0.

  1.74915493E+04   1.93153742E+11   1.17048101E+05   2.32180132E-06   5.95732050E+04   3.06679722E-03   2.43566368E+11
IX=  8  EVIS=
  4.70409903E+10   4.25574418E+10   0.               0.               4.47703616E+10   4.38809106E+10   0.

  1.74161678E+04   1.92064499E+11   1.16399640E+05   2.31893191E-06   7.92576721E+04   5.44413801E-03   2.42259867E+11
IX=  9  EVIS=
  4.68179732E+10   4.23618520E+10   0.               0.               4.45619208E+10   4.36727091E+10   0.
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1.73136478E+04	1.90587014E+11	1.15519835E+05	2.31503169E-06	9.85980337E+04	8.47881147E-03	2.40486907E+11
IX= 10 EVIS=						
4.65146763E+10	4.20956508E+10	0.	0.	4.42784441E+10	4.33895611E+10	0.
1.71569597E+04	1.88338302E+11	1.14180306E+05	2.30907914E-06	1.17251134E+05	1.21346707E-02	2.37786719E+11
IX= 11 EVIS=						
4.60512682E+10	4.16894161E+10	0.	0.	4.38453121E+10	4.29569390E+10	0.
1.70006191E+04	1.86104350E+11	1.12848976E+05	2.30314798E-06	1.35904234E+05	1.64440873E-02	2.35102060E+11
IX= 12 EVIS=						
4.55886791E+10	4.12836865E+10	0.	0.	4.34129366E+10	4.25250818E+10	0.
1.68444941E+04	1.83685200E+11	1.11525859E+05	2.29724101E-06	1.54557334E+05	2.14070611E-02	2.32432939E+11
IX= 13 EVIS=						
4.51268741E+10	4.08786311E+10	0.	0.	4.29812848E+10	4.20939572E+10	0.
1.66886132E+04	1.81680890E+11	1.10210966E+05	2.29136100E-06	1.73210435E+05	2.70235921E-02	2.29779363E+11
IX= 14 EVIS=						
4.46658199E+10	4.04742202E+10	0.	0.	4.25503254E+10	4.16635339E+10	0.
1.65329654E+04	1.79491459E+11	1.08904310E+05	2.28551075E-06	1.91863535E+05	3.32936805E-02	2.27141337E+11
IX= 15 EVIS=						
4.42054847E+10	4.00704257E+10	0.	0.	4.21200285E+10	4.12337823E+10	0.
1.62905487E+04	1.76105087E+11	1.06882010E+05	2.27644864E-06	2.07504514E+05	3.97896514E-02	2.23056293E+11
IX= 16 EVIS=						
4.34885878E+10	3.94415524E+10	0.	0.	4.14498915E+10	4.05645153E+10	0.
1.60231030E+04	1.72403293E+11	1.04669434E+05	2.26653385E-06	2.22259109E+05	4.67280386E-02	2.18583690E+11
IX= 17 EVIS=						
4.26977620E+10	3.87477844E+10	0.	0.	4.07106186E+10	3.98262327E+10	0.
1.57562326E+04	1.68746203E+11	1.02481509E+05	2.25674289E-06	2.37013704E+05	5.42237553E-02	2.14157450E+11
IX= 18 EVIS=						
4.19087358E+10	3.80555477E+10	0.	0.	3.99729961E+10	3.90896316E+10	0.
1.54899007E+04	1.65133952E+11	1.00318277E+05	2.24708959E-06	2.51768300E+05	6.22768016E-02	2.09777600E+11
IX= 19 EVIS=						
4.11214044E+10	3.73647482E+10	0.	0.	3.92369245E+10	3.83546144E+10	0.
1.52240773E+04	1.61566652E+11	9.81797769E+04	2.23758745E-06	2.66522895E+05	7.08871775E-02	2.05444167E+11
IX= 20 EVIS=						
4.03356843E+10	3.66753105E+10	0.	0.	3.85023242E+10	3.76211031E+10	0.
1.49587404E+04	1.58044390E+11	9.60660374E+04	2.22824946E-06	2.81277490E+05	8.00548830E-02	2.01157174E+11
IX= 21 EVIS=						
3.95515149E+10	3.59871788E+10	0.	0.	3.77691370E+10	3.68890414E+10	0.

1.46938758E+04	1.54567225E+11	9.39770798E+04	2.21908807E-06	2.96032085E+05	8.97799182E-02	1.96916639E+11
IX= 22 EVIS=						
3.87688606E+10	3.53003194E+10	0.	0.	3.70373276E+10	3.61583959E+10	0.
1.44294786E+04	1.51135187E+11	9.19129162E+04	2.21011497E-06	3.10786680E+05	1.00062283E-01	1.92722578E+11
IX= 23 EVIS=						
3.79877120E+10	3.46147210E+10	0.	0.	3.63068855E+10	3.54291580E+10	0.
1.41655528E+04	1.47748276E+11	8.98735494E+04	2.20134101E-06	3.25541275E+05	1.10901977E-01	1.88575003E+11
IX= 24 EVIS=						
3.72080878E+10	3.39303971E+10	0.	0.	3.55778262E+10	3.47013453E+10	0.
1.39021126E+04	1.44406458E+11	8.78589721E+04	2.19277603E-06	3.40295870E+05	1.22299001E-01	1.84473921E+11
IX= 25 EVIS=						
3.64300362E+10	3.32473869E+10	0.	0.	3.48501925E+10	3.39750029E+10	0.
1.36391822E+04	1.41109665E+11	8.58691662E+04	2.18442868E-06	3.55050465E+05	1.34253355E-01	1.80419333E+11
IX= 26 EVIS=						
3.56536363E+10	3.25657563E+10	0.	0.	3.41240560E+10	3.32502048E+10	0.
1.33767968E+04	1.37857794E+11	8.39041025E+04	2.17630632E-06	3.69805060E+05	1.46765038E-01	1.76411238E+11
IX= 27 EVIS=						
3.48785991E+10	3.18855989E+10	0.	0.	3.33995182E+10	3.25270547E+10	0.
1.31163079E+04	1.34666607E+11	8.19733686E+04	2.16845362E-06	3.83939234E+05	1.59575612E-01	1.72469292E+11
IX= 28 EVIS=						
3.41101217E+10	3.12104212E+10	0.	0.	3.26803153E+10	3.18092842E+10	0.
1.28735059E+04	1.31724929E+11	8.01915008E+04	2.16132692E-06	3.89953650E+05	1.69420543E-01	1.68827831E+11
IX= 29 EVIS=						
3.33936034E+10	3.05611480E+10	0.	0.	3.20100390E+10	3.11403948E+10	0.
1.26313174E+04	1.28821627E+11	7.84308859E+04	2.15440541E-06	3.95968066E+05	1.79560141E-01	1.65226514E+11
IX= 30 EVIS=						
3.26790512E+10	2.99535262E+10	0.	0.	3.13415512E+10	3.04733434E+10	0.
1.23898046E+04	1.25556503E+11	7.66914644E+04	2.14768968E-06	4.01982482E+05	1.89994406E-01	1.61665323E+11
IX= 31 EVIS=						
3.19666564E+10	2.93277203E+10	0.	0.	3.06750286E+10	2.98083085E+10	0.
1.21490376E+04	1.23129331E+11	7.49731683E+04	2.14117885E-06	4.07996898E+05	2.00723339E-01	1.58144233E+11
IX= 32 EVIS=						
3.12566340E+10	2.87039152E+10	0.	0.	3.00106694E+10	2.91454911E+10	0.
1.19090940E+04	1.20339858E+11	7.32759216E+04	2.13487045E-06	4.14011314E+05	2.11746939E-01	1.54663215E+11
IX= 33 EVIS=						
3.05492213E+10	2.80823150E+10	0.	0.	2.93486930E+10	2.84851128E+10	0.
1.16700581E+04	1.17587807E+11	7.15996405E+04	2.12876039E-06	4.20025731E+05	2.23065206E-01	1.51222236E+11
IX= 34 EVIS=						
2.98446765E+10	2.74631423E+10	0.	0.	2.86893380E+10	2.78274147E+10	0.

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 1.14320209E+04   1.14872880E+11   6.99442345E+04   2.12284296E-06   4.26040147E+05   2.34678140E-01   1.47821260E+11
IX= 35  EVIS=
 2.91432769E+10   2.68466364E+10   0.               0.               2.80328608E+10   2.71726559E+10   0.

 1.11950789E+04   1.12194760E+11   6.83096066E+04   2.11711077E-06   4.32054563E+05   2.46585742E-01   1.44460246E+11
IX= 36  EVIS=
 2.84453168E+10   2.62330509E+10   0.               0.               2.73795337E+10   2.65211113E+10   0.

 1.09593333E+04   1.09553112E+11   6.66956546E+04   2.11155483E-06   4.38068979E+05   2.58788010E-01   1.41139151E+11
IX= 37  EVIS=
 2.77511049E+10   2.56226521E+10   0.               0.               2.67296422E+10   2.58730692E+10   0.

 1.07248890E+04   1.06547586E+11   6.51022721E+04   2.10616454E-06   4.44083395E+05   2.71284946E-01   1.37857931E+11
IX= 38  EVIS=
 2.70609614E+10   2.50157165E+10   0.               0.               2.60834826E+10   2.52288287E+10   0.

 1.04918540E+04   1.04377824E+11   6.35293490E+04   2.10092779E-06   4.50097811E+05   2.84076549E-01   1.34616536E+11
IX= 39  EVIS=
 2.63752152E+10   2.44125277E+10   0.               0.               2.54413590E+10   2.45886970E+10   0.

 1.02605550E+04   1.01845833E+11   6.19775081E+04   2.09581147E-06   4.56112227E+05   2.97162820E-01   1.31417915E+11
IX= 40  EVIS=
 2.56948397E+10   2.38139363E+10   0.               0.               2.48041791E+10   2.39535829E+10   0.

 1.00306336E+04   9.93461194E+10   6.04450483E+04   2.09084250E-06   4.62126643E+05   3.10543757E-01   1.28255541E+11
IX= 41  EVIS=
 2.50187927E+10   2.32190194E+10   0.               0.               2.41709630E+10   2.33225137E+10   0.

 9.80245541E+03   9.68811281E+10   5.89327281E+04   2.08598234E-06   4.68141059E+05   3.24219362E-01   1.25132915E+11
IX= 42  EVIS=
 2.43481628E+10   2.26287286E+10   0.               0.               2.35427259E+10   2.26965059E+10   0.

 9.57612792E+03   9.44504916E+10   5.74404342E+04   2.08121397E-06   4.74155475E+05   3.38189633E-01   1.22049977E+11
IX= 43  EVIS=
 2.36832795E+10   2.20433472E+10   0.               0.               2.29197721E+10   2.20758672E+10   0.

 9.35175595E+03   9.20538501E+10   5.59680556E+04   2.07651949E-06   4.80169891E+05   3.52454573E-01   1.19006670E+11
IX= 44  EVIS=
 2.30244647E+10   2.14631521E+10   0.               0.               2.23023988E+10   2.14608984E+10   0.

 9.12944068E+03   8.96908562E+10   5.45154852E+04   2.07188033E-06   4.86184307E+05   3.67014179E-01   1.16002938E+11
IX= 45  EVIS=
 2.23720301E+10   2.08884107E+10   0.               0.               2.16908931E+10   2.08518905E+10   0.

XXXXX ITK= 13  NXPST= 15  XXXXX

IZTERM= 45
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XXXXXXXXXXXXXXXXX

2   1        X= 1.20000000D-02        H= 2.45615501D+11       MU= 2.88492827E+01         P= 1.18065372E+05      RHO= 2.32629304E-06
             U= 3.99377917E+03        T= 1.76095021E+04        E= 1.94862921E+11        CI= 6.25000000E-02 SUM(CI)= 1.00000000E+00
       CI( 1)= 7.68000000D-01  CI( 2)= 2.32000000D-01  CI( 3)= 0.              CI( 4)= 0.              CI( 5)= 0.
       CI( 6)= 0.              CI( 7)= 0.              CI( 8)=
       CM( 1)= 7.90842701E-01  CM( 2)= 2.09157299E-01  CM( 3)= 0.              CM( 4)= 0.              CM( 5)= 0.
       CM( 6)= 0.              CM( 7)= 0.              CM( 8)=
      EVI( 1)= 4.73899672D+10 EVI( 2)= 4.28634946D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 4.50965257D+10
      EVI( 6)= 4.42067044D+10 EVI( 7)= 0.             EVI( 8)=

-----------CHECKT= 4.80250000E+01
2   6        X= 3.15312500D-02        H= 2.45612335D+11       MU= 2.07502764E+01         P= 1.18022305E+05      RHO= 2.81818299E-06
             U= 5.29848106E+03        T= 1.04513581E+04        E= 2.03733470E+11        CI= 3.90625000E-03 SUM(CI)= 9.99810714E-01
       CI( 1)= 5.55273186D-01  CI( 2)= 1.79584524D-03  CI( 3)= 1.92089449D-01  CI( 4)= 2.12853184D-01  CI( 5)= 3.65880631D-02
       CI( 6)= 1.21096398D-03  CI( 7)= 2.21393982D-08  CI( 8)=
       CM( 1)= 4.11267565E-01  CM( 2)= 1.16450891E-03  CM( 3)= 2.84545199E-01  CM( 4)= 2.76047650E-01  CM( 5)= 2.53003340E-02
       CM( 6)= 8.37371279E-04  CM( 7)= 8.37371279E-04  CM( 8)=
      EVI( 1)= 2.62560755D+10 EVI( 2)= 2.43077184D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.53297894D+10
      EVI( 6)= 2.44774826D+10 EVI( 7)= 0.             EVI( 8)=

2  11        X= 6.27812500D-02        H= 2.45594265D+11       MU= 1.98840345E+01         P= 1.17884762E+05      RHO= 3.08842635E-06
             U= 8.01337358E+03        T= 9.12806804E+03        E= 2.07424418E+11        CI= 7.81250000E-03 SUM(CI)= 9.99888171E-01
       CI( 1)= 5.09826645D-01  CI( 2)= 7.71561894D-04  CI( 3)= 2.43596931D-01  CI( 4)= 2.20834285D-01  CI( 5)= 2.33738066D-02
       CI( 6)= 1.48251385D-03  CI( 7)= 2.71039971D-08  CI( 8)=
       CM( 1)= 3.61845030E-01  CM( 2)= 4.79678654E-04  CM( 3)= 3.45780252E-01  CM( 4)= 2.74442284E-01  CM( 5)= 1.54880557E-02
       CM( 6)= 9.82349921E-04  CM( 7)= 9.82349921E-04  CM( 8)=
      EVI( 1)= 2.23680029D+10 EVI( 2)= 2.08848625D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.16871182D+10
      EVI( 6)= 2.08481313D+10 EVI( 7)= 0.             EVI( 8)=


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3   1        X= 2.40000000D-02        H= 2.45583454D+11       MU= 2.88492827E+01         P= 1.18049461E+05      RHO= 2.32622288E-06
             U= 7.98658257E+03        T= 1.76076600E+04        E= 1.94836184E+11        CI= 6.25000000E-02 SUM(CI)= 1.00000000E+00
       CI( 1)= 7.68000000D-01  CI( 2)= 2.32000000D-01  CI( 3)= 0.              CI( 4)= 0.              CI( 5)= 0.
       CI( 6)= 0.              CI( 7)= 0.              CI( 8)=
       CM( 1)= 7.90842701E-01  CM( 2)= 2.09157299E-01  CM( 3)= 0.              CM( 4)= 0.              CM( 5)= 0.
       CM( 6)= 0.              CM( 7)= 0.              CM( 8)=
      EVI( 1)= 4.73845170D+10 EVI( 2)= 4.28587149D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 4.50914318D+10
      EVI( 6)= 4.42016162D+10 EVI( 7)= 0.             EVI( 8)=

-----------CHECKT= 5.42410000E+01
3   6        X= 6.30625000D-02        H= 2.45561095D+11       MU= 2.07531671E+01         P= 1.17889130E+05      RHO= 2.81578504E-06
             U= 1.14260046E+04        T= 1.04499108E+04        E= 2.03693862E+11        CI= 7.81250000E-03 SUM(CI)= 9.99639924E-01
       CI( 1)= 5.55128647D-01  CI( 2)= 1.79530601D-03  CI( 3)= 1.92057323D-01  CI( 4)= 2.12871375D-01  CI( 5)= 3.65759165D-02
       CI( 6)= 1.21133447D-03  CI( 7)= 2.21461715D-08  CI( 8)=
       CM( 1)= 4.11217788E-01  CM( 2)= 1.16432143E-03  CM( 3)= 2.84537244E-01  CM( 4)= 2.76109701E-01  CM( 5)= 2.52954580E-02
       CM( 6)= 8.37744153E-04  CM( 7)= 8.37744153E-04  CM( 8)=
      EVI( 1)= 2.62516178D+10 EVI( 2)= 2.43039728D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.53258023D+10
      EVI( 6)= 2.44735082D+10 EVI( 7)= 0.             EVI( 8)=
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XXXXXXXXXXXXXXXXX

 4    1        X= 3.60000000D-02       H= 2.45538803D+11      MU= 2.88492827E+01        P= 1.18027292E+05     RHO= 2.32612512E-06
               U= 1.19788050E+04       T= 1.76050932E+04       E= 1.94798931E+11       CI= 6.25000000E-02 SUM(CI)= 1.00000000E+00
         CI( 1)= 7.68000000D-01  CI( 2)= 2.32000000D-01  CI( 3)= 0.              CI( 4)= 0.              CI( 5)= 0.
         CI( 6)= 0.              CI( 7)= 0.              CI( 8)=
         CM( 1)= 7.90842701E-01  CM( 2)= 2.09157299E-01  CM( 3)= 0.              CM( 4)= 0.              CM( 5)= 0.
         CM( 6)= 0.              CM( 7)= 0.              CM( 8)=
        EVI( 1)= 4.73769228D+10 EVI( 2)= 4.28520547D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 4.50843340D+10
        EVI( 6)= 4.41945264D+10 EVI( 7)= 0.             EVI( 8)=

------------CHECKT= 5.74630000E+01
 4    5        X= 6.72500000D-02       H= 2.45510405D+11      MU= 2.15266421E+01        P= 1.17868660E+05     RHO= 2.63390585E-06
               U= 1.52294001E+04       T= 1.15858613E+04       E= 2.00759884E+11       CI= 7.81250000E-03 SUM(CI)= 1.00181248E+00
         CI( 1)= 5.96556664D-01  CI( 2)= 4.15504760D-03  CI( 3)= 1.49273533D-01  CI( 4)= 2.04325822D-01  CI( 5)= 4.68663401D-02
         CI( 6)= 6.35061524D-04  CI( 7)= 1.16104857D-08  CI( 8)=
         CM( 1)= 4.58375993E-01  CM( 2)= 2.79513196E-03  CM( 3)= 2.29394483E-01  CM( 4)= 2.74903053E-01  CM( 5)= 3.36201990E-02
         CM( 6)= 4.55569920E-04  CM( 7)= 4.55569920E-04  CM( 8)=
        EVI( 1)= 2.95965589D+10 EVI( 2)= 2.72450670D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.84571192D+10
        EVI( 6)= 2.75957957D+10 EVI( 7)= 0.             EVI( 8)=

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 5    1        X= 4.80000000D-02       H= 2.45494156D+11      MU= 2.88492827E+01        P= 1.18005125E+05     RHO= 2.32602736E-06
               U= 1.59710274E+04       T= 1.76025265E+04       E= 1.94761681E+11       CI= 6.25000000E-02 SUM(CI)= 1.00000000E+00
         CI( 1)= 7.68000000D-01  CI( 2)= 2.32000000D-01  CI( 3)= 0.              CI( 4)= 0.              CI( 5)= 0.
         CI( 6)= 0.              CI( 7)= 0.              CI( 8)=
         CM( 1)= 7.90842701E-01  CM( 2)= 2.09157299E-01  CM( 3)= 0.              CM( 4)= 0.              CM( 5)= 0.
         CM( 6)= 0.              CM( 7)= 0.              CM( 8)=
        EVI( 1)= 4.73693287D+10 EVI( 2)= 4.28453949D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 4.50772365D+10
        EVI( 6)= 4.41874369D+10 EVI( 7)= 0.             EVI( 8)=

------------CHECKT= 6.02130000E+01
 5    2        X= 6.36250000D-02       H= 2.45482369D+11      MU= 2.32749724E+01        P= 1.17910793E+05     RHO= 2.38810443E-06
               U= 1.69707198E+04       T= 1.38211239E+04       E= 1.96108149E+11       CI= 1.56250000E-02 SUM(CI)= 1.00549289E+00
         CI( 1)= 6.67960109D-01  CI( 2)= 4.27871955D-02  CI( 3)= 7.96368928D-02  CI( 4)= 1.68885192D-01  CI( 5)= 4.60850595D-02
         CI( 6)= 1.38436690D-04  CI( 7)= 2.53096298D-09  CI( 8)=
         CM( 1)= 5.54924084E-01  CM( 2)= 3.11209624E-02  CM( 3)= 1.32320566E-01  CM( 4)= 2.45674887E-01  CM( 5)= 3.57447511E-02
         CM( 6)= 1.07375038E-04  CM( 7)= 1.07375038E-04  CM( 8)=
        EVI( 1)= 3.61908711D+10 EVI( 2)= 3.30374226D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 3.46265159D+10
        EVI( 6)= 3.37517332D+10 EVI( 7)= 0.             EVI( 8)=

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PSI=0.000 STREAMLINE--
----- CHECKT= 6.09430000E+01 -----

 6    6        X= 6.00000000D-02       H= 2.45605323D+11      MU= 2.88492827E+01        P= 1.17903357E+05     RHO= 3.19199053E-06
               U= 6.48834434E+03       T= 8.68740592E+03       E= 2.08668071E+11       CI= 6.25000000E-02 SUM(CI)= 9.99970928E-01
         CI( 1)= 4.94727004D-01  CI( 2)= 4.30810137D-04  CI( 3)= 2.60778666D-01  CI( 4)= 2.23488877D-01  CI( 5)= 1.89726254D-02
         CI( 6)= 1.57291679D-03  CI( 7)= 2.87567852D-08  CI( 8)=
         CM( 1)= 5.09441719E-01  CM( 2)= 3.88392607E-04  CM( 3)= 5.37070064E-01  CM( 4)= 4.02968362E-01  CM( 5)= 1.82400237E-02
         CM( 6)= 1.51218079E-03  CM( 7)= 1.51218079E-03  CM( 8)=
        EVI( 1)= 2.10758897D+10 EVI( 2)= 1.97460794D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.04757015D+10
        EVI( 6)= 1.96420403D+10 EVI( 7)= 0.             EVI( 8)=
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6   11        X= 9.90625000D-02         H= 2.45555467D+11        MU= 1.94240633E+01         P= 1.17611923E+05      RHO= 3.27099871E-06
              U= 1.19083982E+04         T= 8.39972372E+03         E= 2.09599500E+11        CI= 7.81250000E-03  SUM(CI)= 1.00012786E+00
         CI( 1)= 4.84290629D-01   CI( 2)= 4.14102220D-04   CI( 3)= 2.72962201D-01   CI( 4)= 2.25350646D-01   CI( 5)= 1.58317063D-02
         CI( 6)= 1.27854899D-03   CI( 7)= 2.33750183D-08   CI( 8)=
         CM( 1)= 3.35768555E-01   CM( 2)= 2.51360867E-04   CM( 3)= 3.78500505E-01   CM( 4)= 2.73576576E-01   CM( 5)= 1.02478028E-02
         CM( 6)= 8.27599859E-04   CM( 7)= 8.27599859E-04   CM( 8)=
        EVI( 1)= 2.02332274D+10  EVI( 2)= 1.90029855D+10  EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.96853788D+10
        EVI( 6)= 1.88554919D+10  EVI( 7)= 0.              EVI( 8)=

6   16        X= 1.38125000D-01         H= 2.45503623D+11        MU= 1.93342063E+01         P= 1.17188172E+05      RHO= 3.30284181E-06
              U= 1.56683972E+04         T= 8.25042446E+03         E= 2.10022610E+11        CI= 7.81250000E-03  SUM(CI)= 1.00012611E+00
         CI( 1)= 4.78940501D-01   CI( 2)= 3.59356092D-04   CI( 3)= 2.78994707D-01   CI( 4)= 2.26182453D-01   CI( 5)= 1.44304052D-02
         CI( 6)= 1.21866311D-03   CI( 7)= 2.22801572D-08   CI( 8)=
         CM( 1)= 3.30523074E-01   CM( 2)= 2.17120776E-04   CM( 3)= 3.85075758E-01   CM( 4)= 2.73316138E-01   CM( 5)= 9.29753503E-03
         CM( 6)= 7.85186753E-04   CM( 7)= 7.85186753E-04   CM( 8)=
        EVI( 1)= 1.97962120D+10  EVI( 2)= 1.86174605D+10  EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.92754086D+10
        EVI( 6)= 1.84475828D+10  EVI( 7)= 0.              EVI( 8)=

6   21        X= 1.77187500D-01         H= 2.45404624D+11        MU= 1.92780735E+01         P= 1.16611571E+05      RHO= 3.31649502E-06
              U= 2.10593335E+04         T= 8.15229459E+03         E= 2.10243537E+11        CI= 7.81250000E-03  SUM(CI)= 1.00012521E+00
         CI( 1)= 4.75556586D-01   CI( 2)= 3.27042781D-04   CI( 3)= 2.82798393D-01   CI( 4)= 2.26693411D-01   CI( 5)= 1.35643055D-02
         CI( 6)= 1.18544942D-03   CI( 7)= 2.16729292D-08   CI( 8)=
         CM( 1)= 3.27234965E-01   CM( 2)= 1.97023586E-04   CM( 3)= 3.89192475E-01   CM( 4)= 2.73138265E-01   CM( 5)= 8.71413216E-03
         CM( 6)= 7.61569612E-04   CM( 7)= 7.61569612E-04   CM( 8)=
        EVI( 1)= 1.95090952D+10  EVI( 2)= 1.83641145D+10  EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.90060212D+10
        EVI( 6)= 1.81795906D+10  EVI( 7)= 0.              EVI( 8)=

6   26        X= 2.70937500D-01         H= 2.44995362D+11        MU= 1.92055140E+01         P= 1.14868117E+05      RHO= 3.31350611E-06
              U= 3.55249305E+04         T= 8.00740135E+03         E= 2.10328724E+11        CI= 3.12500000E-02  SUM(CI)= 1.00012049E+00
         CI( 1)= 4.71185972D-01   CI( 2)= 2.85315759D-04   CI( 3)= 2.87736760D-01   CI( 4)= 2.27378385D-01   CI( 5)= 1.23951467D-02
         CI( 6)= 1.13888724D-03   CI( 7)= 2.08216582D-08   CI( 8)=
         CM( 1)= 3.23007166E-01   CM( 2)= 1.71238618E-04   CM( 3)= 3.94498312E-01   CM( 4)= 2.72932421E-01   CM( 5)= 7.93305662E-03
         CM( 6)= 7.28902788E-04   CM( 7)= 7.28902788E-04   CM( 8)=
        EVI( 1)= 1.90853371D+10  EVI( 2)= 1.79901101D+10  EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.86083704D+10
        EVI( 6)= 1.77840616D+10  EVI( 7)= 0.              EVI( 8)=

6   31        X= 4.27187500D-01         H= 2.43801304D+11        MU= 1.91497794E+01         P= 1.10172548E+05      RHO= 3.23609277E-06
              U= 6.04163638E+04         T= 7.84097636E+03         E= 2.09756375E+11        CI= 3.12500000E-02  SUM(CI)= 1.00011897E+00
         CI( 1)= 4.67974259D-01   CI( 2)= 2.48885641D-04   CI( 3)= 2.91473911D-01   CI( 4)= 2.28013057D-01   CI( 5)= 1.13191095D-02
         CI( 6)= 1.08973328D-03   CI( 7)= 1.99230030D-08   CI( 8)=
         CM( 1)= 3.19874495E-01   CM( 2)= 1.48940785E-04   CM( 3)= 3.98462386E-01   CM( 4)= 2.72899984E-01   CM( 5)= 7.22335545E-03
         CM( 6)= 6.95419621E-04   CM( 7)= 6.95419621E-04   CM( 8)=
        EVI( 1)= 1.85888897D+10  EVI( 2)= 1.75606396D+10  EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.81518003D+10
        EVI( 6)= 1.73300238D+10  EVI( 7)= 0.              EVI( 8)=

6   36        X= 5.83437500D-01         H= 2.42161803D+11        MU= 1.91224627E+01         P= 1.04767916E+05      RHO= 3.13163581E-06
              U= 8.32414472E+04         T= 7.69404665E+03         E= 2.08707109E+11        CI= 3.12500000E-02  SUM(CI)= 1.00011849E+00
         CI( 1)= 4.66648780D-01   CI( 2)= 2.23180344D-04   CI( 3)= 2.93190414D-01   CI( 4)= 2.28485128D-01   CI( 5)= 1.05234916D-02
         CI( 6)= 1.04747302D-03   CI( 7)= 1.91503816D-08   CI( 8)=
         CM( 1)= 3.18513489E-01   CM( 2)= 1.33367432E-04   CM( 3)= 4.00237205E-01   CM( 4)= 2.73074896E-01   CM( 5)= 6.70604756E-03
         CM( 6)= 6.67497463E-04   CM( 7)= 6.67497463E-04   CM( 8)=
        EVI( 1)= 1.81696917D+10  EVI( 2)= 1.71815839D+10  EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.77488766D+10
        EVI( 6)= 1.69294254D+10  EVI( 7)= 0.              EVI( 8)=
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 6   41        X= 7.39687500D-01       H= 2.40044148D+11       MU= 1.91066884E+01        P= 9.75016084E+04      RHO= 2.97307966E-06
               U= 1.05661956E+05       T= 7.53606424E+03        E= 2.07249329E+11       CI= 3.12500000E-02  SUM(CI)= 1.00011761E+00
         CI( 1)= 4.66119556D-01  CI( 2)= 2.01022771D-04  CI( 3)= 2.94069684D-01  CI( 4)= 2.28907018D-01  CI( 5)= 9.81382156D-03
         CI( 6)= 1.00649252D-03  CI( 7)= 1.84011573D-08  CI( 8)=
         CM( 1)= 3.17889816E-01  CM( 2)= 1.20027482E-04  CM( 3)= 4.01106354E-01  CM( 4)= 2.73353440E-01  CM( 5)= 6.24865469E-03
         CM( 6)= 6.40853737E-04  CM( 7)= 6.40853737E-04  CM( 8)=
        EVI( 1)= 1.77085032D+10 EVI( 2)= 1.67741316D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.73158245D+10
        EVI( 6)= 1.64989729D+10 EVI( 7)= 0.             EVI( 8)=

 6   46        X= 8.95937500D-01       H= 2.37396301D+11       MU= 1.90976430E+01        P= 8.98280434E+04      RHO= 2.80498781E-06
               U= 1.28297085E+05       T= 7.35554186E+03        E= 2.05371904E+11       CI= 3.12500000E-02  SUM(CI)= 1.00011662E+00
         CI( 1)= 4.66121034D-01  CI( 2)= 1.79056581D-04  CI( 3)= 2.94427539D-01  CI( 4)= 2.29339353D-01  CI( 5)= 9.08699018D-03
         CI( 6)= 9.62628309D-04  CI( 7)= 1.75992116D-08  CI( 8)=
         CM( 1)= 3.17740331E-01  CM( 2)= 1.06861208E-04  CM( 3)= 4.01404343E-01  CM( 4)= 2.73740068E-01  CM( 5)= 5.78312765E-03
         CM( 6)= 6.12634358E-04  CM( 7)= 6.12634358E-04  CM( 8)=
        EVI( 1)= 1.71819148D+10 EVI( 2)= 1.63087056D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.68212320D+10
        EVI( 6)= 1.60074854D+10 EVI( 7)= 0.             EVI( 8)=

 6   51        X= 1.05218750D+00       H= 2.34574548D+11       MU= 1.90923825E+01        P= 8.21649929E+04      RHO= 2.63148167E-06
               U= 1.48672957E+05       T= 7.16969265E+03        E= 2.03350697E+11       CI= 3.12500000E-02  SUM(CI)= 1.00011573E+00
         CI( 1)= 4.66406783D-01  CI( 2)= 1.58253446D-04  CI( 3)= 2.94499028D-01  CI( 4)= 2.29768144D-01  CI( 5)= 8.36573719D-03
         CI( 6)= 9.17772528D-04  CI( 7)= 1.67791377D-08  CI( 8)=
         CM( 1)= 3.17847542E-01  CM( 2)= 9.44198538E-05  CM( 3)= 4.01391212E-01  CM( 4)= 2.74176331E-01  CM( 5)= 5.32264246E-03
         CM( 6)= 5.83926426E-04  CM( 7)= 5.83926426E-04  CM( 8)=
        EVI( 1)= 1.66402651D+10 EVI( 2)= 1.58297361D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.63123379D+10
        EVI( 6)= 1.55019483D+10 EVI( 7)= 0.             EVI( 8)=

 6   56        X= 1.20843750D+00       H= 2.31567803D+11       MU= 1.90893191E+01        P= 7.45361547E+04      RHO= 2.45350937E-06
               U= 1.67681656E+05       T= 6.97466961E+03        E= 2.01188398E+11       CI= 3.12500000E-02  SUM(CI)= 1.00011511E+00
         CI( 1)= 4.66845327D-01  CI( 2)= 1.38760385D-04  CI( 3)= 2.94410136D-01  CI( 4)= 2.30186969D-01  CI( 5)= 7.66083040D-03
         CI( 6)= 8.73075213D-04  CI( 7)= 1.59619609D-08  CI( 8)=
         CM( 1)= 3.18095354E-01  CM( 2)= 8.27762899E-05  CM( 3)= 4.01205672E-01  CM( 4)= 2.74632032E-01  CM( 5)= 4.87336832E-03
         CM( 6)= 5.55398939E-04  CM( 7)= 5.55398939E-04  CM( 8)=
        EVI( 1)= 1.60724407D+10 EVI( 2)= 1.53273478D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.57786687D+10
        EVI( 6)= 1.49719903D+10 EVI( 7)= 0.             EVI( 8)=

 6   61        X= 1.36468750D+00       H= 2.28357015D+11       MU= 1.90875734E+01        P= 6.70211678E+04      RHO= 2.27350516E-06
               U= 1.85845941E+05       T= 6.76738218E+03        E= 1.98877791E+11       CI= 3.12500000E-02  SUM(CI)= 1.00011507E+00
         CI( 1)= 4.67367106D-01  CI( 2)= 1.20563349D-04  CI( 3)= 2.94229007D-01  CI( 4)= 2.30594218D-01  CI( 5)= 6.97516501D-03
         CI( 6)= 8.28998908D-04  CI( 7)= 1.51561377D-08  CI( 8)=
         CM( 1)= 3.18421756E-01  CM( 2)= 7.19144303E-05  CM( 3)= 4.00922170E-01  CM( 4)= 2.75092753E-01  CM( 5)= 4.43678265E-03
         CM( 6)= 5.27311966E-04  CM( 7)= 5.27311966E-04  CM( 8)=
        EVI( 1)= 1.54695925D+10 EVI( 2)= 1.47936392D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.52118590D+10
        EVI( 6)= 1.44093551D+10 EVI( 7)= 0.             EVI( 8)=

 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 6.25000000E-02  IPSI,IX=     6   66  T,TPREV,H,HPREV=    6.2345190E+03    6.4767085E+03    2.2030123E+11    2.2393482E+11
 IEXP,ITNEG=   0  0
 6   66        X= 1.70843750D+00       H= 2.23045873D+11       MU= 1.90858695E+01        P= 5.66814721E+04      RHO= 2.02498915E-06
               U= 2.12511171E+05       T= 6.42516536E+03        E= 1.95054873E+11       CI= 6.25000000E-02  SUM(CI)= 1.00011454E+00
         CI( 1)= 4.68501330D-01  CI( 2)= 8.86116956D-05  CI( 3)= 2.93754933D-01  CI( 4)= 2.31380260D-01  CI( 5)= 5.64883609D-03
         CI( 6)= 7.40553177D-04  CI( 7)= 1.35391324D-08  CI( 8)=
         CM( 1)= 3.19166022E-01  CM( 2)= 5.28509769E-05  CM( 3)= 4.00240457E-01  CM( 4)= 2.76005841E-01  CM( 5)= 3.59280687E-03
         CM( 6)= 4.71011108E-04  CM( 7)= 4.71011108E-04  CM( 8)=
        EVI( 1)= 1.44760531D+10 EVI( 2)= 1.39132112D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.42771529D+10
        EVI( 6)= 1.34821171D+10 EVI( 7)= 0.             EVI( 8)=
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 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 6.25000000E-02  IPSI,IX=    6   69  T,TPREV,H,HPREV=    5.9795305E+03   6.2402299E+03   2.1642890E+11   2.2029817E+11
 IEXP,ITNEG=  0  0
  6   71         X= 2.14593750D+00        H= 2.16425465D+11       MU= 1.90851824E+01        P= 4.44641349E+04     RHO= 1.70297964E-06
                 U= 2.41664672E+05        T= 5.99308787E+03        E= 1.90315855E+11       CI= 1.25000000E-01 SUM(CI)= 1.00011574E+00
          CI( 1)= 4.69675836D-01  CI( 2)= 6.06623928D-05  CI( 3)= 2.93223849D-01  CI( 4)= 2.32143172D-01  CI( 5)= 4.36283422D-03
          CI( 6)= 6.49375350D-04  CI( 7)= 1.18722507D-08  CI( 8)=
          CM( 1)= 3.19954633E-01  CM( 2)= 3.61797759E-05  CM( 3)= 3.99502473E-01  CM( 4)= 2.76905924E-01  CM( 5)= 2.77477629E-03
          CM( 6)= 4.13007309E-04  CM( 7)= 4.13007309E-04  CM( 8)=
         EVI( 1)= 1.32251782D+10 EVI( 2)= 1.28030174D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.30991912D+10
         EVI( 6)= 1.23147724D+10 EVI( 7)= 0.             EVI( 8)=


 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 6.25000000E-02  IPSI,IX=    6   72  T,TPREV,H,HPREV=    5.7033703E+03   5.9856968E+03   2.1228651E+11   2.1642547E+11
 IEXP,ITNEG=  0  0
 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 6.25000000E-02  IPSI,IX=    6   75  T,TPREV,H,HPREV=    5.4007319E+03   5.7100513E+03   2.0780591E+11   2.1228221E+11
 IEXP,ITNEG=  0  0
  6   75         X= 2.45843750D+00        H= 2.11196095D+11       MU= 1.90850612E+01        P= 3.62363458E+04     RHO= 1.47341756E-06
                 U= 2.62412947E+05        T= 5.64502732E+03        E= 1.86602696E+11       CI= 6.25000000E-02 SUM(CI)= 1.00011737E+00
          CI( 1)= 4.70384385D-01  CI( 2)= 4.56979778D-05  CI( 3)= 2.92892966D-01  CI( 4)= 2.32589561D-01  CI( 5)= 3.61119871D-03
          CI( 6)= 5.93550550D-04  CI( 7)= 1.08515630D-08  CI( 8)=
          CM( 1)= 3.20435278E-01  CM( 2)= 2.72546470E-05  CM( 3)= 3.99049127E-01  CM( 4)= 2.77436625E-01  CM( 5)= 2.29671916E-03
          CM( 6)= 3.77497620E-04  CM( 7)= 3.77497620E-04  CM( 8)=
         EVI( 1)= 1.22205778D+10 EVI( 2)= 1.19100794D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.21524022D+10
         EVI( 6)= 1.13776846D+10 EVI( 7)= 0.             EVI( 8)=


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  6    1         X= 6.00000000D-02        H= 2.45397692D+11       MU= 2.88492827E+01        P= 1.17957231E+05     RHO= 2.32581613E-06
                 U= 1.99564560E+04        T= 1.75969803E+04        E= 1.94681202E+11       CI= 6.25000000E-02 SUM(CI)= 1.00000000E+00
          CI( 1)= 7.68000000D-01  CI( 2)= 2.32000000D-01  CI( 3)= 0.             CI( 4)= 0.             CI( 5)= 0.
          CI( 6)= 0.              CI( 7)= 0.              CI( 8)=
          CM( 1)= 7.90842701E-01  CM( 2)= 2.09157299E-01  CM( 3)= 0.             CM( 4)= 0.             CM( 5)= 0.
          CM( 6)= 0.              CM( 7)= 0.              CM( 8)=
         EVI( 1)= 4.73529195D+10 EVI( 2)= 4.28310041D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 4.50619000D+10
         EVI( 6)= 4.41721177D+10 EVI( 7)= 0.             EVI( 8)=


------------CHECKT= 1.04575000E+02
  6    6         X= 1.38125000D-01        H= 2.45139219D+11       MU= 2.10884979E+01        P= 1.17241755E+05     RHO= 2.71857690E-06
                 U= 3.12138764E+04        T= 1.09380593E+04        E= 2.02013069E+11       CI= 1.56250000E-02 SUM(CI)= 1.00110249E+00
          CI( 1)= 5.74472092D-01  CI( 2)= 2.46577901D-03  CI( 3)= 1.72095317D-01  CI( 4)= 2.09782081D-01  CI( 5)= 4.13588891D-02
          CI( 6)= 9.28312177D-04  CI( 7)= 1.69718284D-08  CI( 8)=
          CM( 1)= 4.32422669E-01  CM( 2)= 1.62498673E-03  CM( 3)= 2.59082791E-01  CM( 4)= 2.76499310E-01  CM( 5)= 2.90654774E-02
          CM( 6)= 6.52383011E-04  CM( 7)= 6.52383011E-04  CM( 8)=
         EVI( 1)= 2.76884699D+10 EVI( 2)= 2.55675736D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.66710023D+10
         EVI( 6)= 2.58146001D+10 EVI( 7)= 0.             EVI( 8)=


  6    7         X= 1.53750000D-01        H= 2.45064364D+11       MU= 2.08832587E+01        P= 1.17011006E+05     RHO= 2.76444688E-06
                 U= 3.35263367E+04        T= 1.06309157E+04        E= 2.02737269E+11       CI= 1.56250000E-02 SUM(CI)= 1.00110797E+00
          CI( 1)= 5.64268901D-01  CI( 2)= 2.04233466D-03  CI( 3)= 1.83463532D-01  CI( 4)= 2.11538758D-01  CI( 5)= 3.87105716D-02
          CI( 6)= 1.08385310D-03  CI( 7)= 1.98154987D-08  CI( 8)=
          CM( 1)= 4.20608704E-01  CM( 2)= 1.33283134E-03  CM( 3)= 2.73509166E-01  CM( 4)= 2.76101163E-01  CM( 5)= 2.69395788E-02
          CM( 6)= 7.54278346E-04  CM( 7)= 7.54278346E-04  CM( 8)=
         EVI( 1)= 2.67843977D+10 EVI( 2)= 2.47724633D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.58245220D+10
         EVI( 6)= 2.49706609D+10 EVI( 7)= 0.             EVI( 8)=
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6   12          X= 3.56875000D-01       H= 2.43514928D+11       MU= 2.00300180E+01        P= 1.12503024E+05       RHO= 2.93176231E-06
                U= 6.49837530E+04       T= 9.24422946E+03        E= 2.05141072E+11       CI= 6.25000000E-02 SUM(CI)= 1.00113904E+00
           CI( 1)= 5.20407496D-01  CI( 2)= 8.97088217D-04  CI( 3)= 2.33266741D-01  CI( 4)= 2.19467984D-01  CI( 5)= 2.56161218D-02
           CI( 6)= 1.48358605D-03  CI( 7)= 2.71235997D-08  CI( 8)=
           CM( 1)= 3.72064946E-01  CM( 2)= 5.61521662E-04  CM( 3)= 3.33547760E-01  CM( 4)= 2.74746730E-01  CM( 5)= 1.70984865E-02
           CM( 6)= 9.90277773E-04  CM( 7)= 9.90277773E-04  CM( 8)=
          EVI( 1)= 2.27088599D+10 EVI( 2)= 2.11851514D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.20066070D+10
          EVI( 6)= 2.11662998D+10 EVI( 7)= 0.             EVI( 8)=

6   17          X= 6.69375000D-01       H= 2.39511788D+11       MU= 1.97718071E+01        P= 1.00996863E+05       RHO= 2.79372024E-06
                U= 1.10585573E+05       T= 8.59657137E+03        E= 2.03360400E+11       CI= 6.25000000E-02 SUM(CI)= 1.00113928E+00
           CI( 1)= 5.07544079D-01  CI( 2)= 5.99201180D-04  CI( 3)= 2.48770940D-01  CI( 4)= 2.22777069D-01  CI( 5)= 2.01094296D-02
           CI( 6)= 1.33853777D-03  CI( 7)= 2.44717605D-08  CI( 8)=
           CM( 1)= 3.58190449E-01  CM( 2)= 3.70227817E-04  CM( 3)= 3.51131571E-01  CM( 4)= 2.75294077E-01  CM( 5)= 1.32497921E-02
           CM( 6)= 8.81941831E-04  CM( 7)= 8.81941831E-04  CM( 8)=
          EVI( 1)= 2.08097425D+10 EVI( 2)= 1.95114186D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.02261112D+10
          EVI( 6)= 1.93936148D+10 EVI( 7)= 0.             EVI( 8)=

6   22          X= 9.81875000D-01       H= 2.33729500D+11       MU= 1.96937302E+01        P= 8.56501250E+04       RHO= 2.49957486E-06
                U= 1.54252209E+05       T= 8.11603247E+03        E= 1.99463623E+11       CI= 6.25000000E-02 SUM(CI)= 1.00113656E+00
           CI( 1)= 5.04796961D-01  CI( 2)= 4.66015440D-04  CI( 3)= 2.52959038D-01  CI( 4)= 2.24552197D-01  CI( 5)= 1.71547612D-02
           CI( 6)= 1.20757074D-03  CI( 7)= 2.20773613D-08  CI( 8)=
           CM( 1)= 3.54844916E-01  CM( 2)= 2.86799449E-04  CM( 3)= 3.55632998E-01  CM( 4)= 2.76391899E-01  CM( 5)= 1.12583724E-02
           CM( 6)= 7.92507741E-04  CM( 7)= 7.92507741E-04  CM( 8)=
          EVI( 1)= 1.94030214D+10 EVI( 2)= 1.82705049D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.89064892D+10
          EVI( 6)= 1.80805827D+10 EVI( 7)= 0.             EVI( 8)=

6   27          X= 1.29437500D+00       H= 2.27201311D+11       MU= 1.96652413E+01        P= 7.03979266E+04       RHO= 2.17265353E-06
                U= 1.91963857E+05       T= 7.66341968E+03        E= 1.94799492E+11       CI= 6.25000000E-02 SUM(CI)= 1.00113554E+00
           CI( 1)= 5.04970688D-01  CI( 2)= 3.71836018D-04  CI( 3)= 2.53915555D-01  CI( 4)= 2.25936693D-01  CI( 5)= 1.48476139D-02
           CI( 6)= 1.09313592D-03  CI( 7)= 1.99852115D-08  CI( 8)=
           CM( 1)= 3.54453542E-01  CM( 2)= 2.28507657E-04  CM( 3)= 3.56461354E-01  CM( 4)= 2.77693724E-01  CM( 5)= 9.73013566E-03
           CM( 6)= 7.16368355E-04  CM( 7)= 7.16368355E-04  CM( 8)=
          EVI( 1)= 1.80802598D+10 EVI( 2)= 1.71025841D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.76649088D+10
          EVI( 6)= 1.68459533D+10 EVI( 7)= 0.             EVI( 8)=

CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 6.25000000E-02  IPSI,IX=    6   31  T,TPREV,H,HPREV=   7.1125002E+03   7.3719752E+03   2.1903267E+11   2.2287013E+11
IEXP,ITNEG=  0  0
6   32          X= 1.66937500D+00       H= 2.20978519D+11       MU= 1.96526627E+01        P= 5.78340282E+04       RHO= 1.88458232E-06
                U= 2.22026365E+05       T= 7.25343407E+03        E= 1.90290537E+11       CI= 6.25000000E-02 SUM(CI)= 1.00113714E+00
           CI( 1)= 5.06269763D-01  CI( 2)= 2.88697733D-04  CI( 3)= 2.53738963D-01  CI( 4)= 2.27302629D-01  CI( 5)= 1.25605724D-02
           CI( 6)= 9.76496048D-04  CI( 7)= 1.78527480D-08  CI( 8)=
           CM( 1)= 3.55138095E-01  CM( 2)= 1.77302474E-04  CM( 3)= 3.55985597E-01  CM( 4)= 2.79193868E-01  CM( 5)= 8.22609615E-03
           CM( 6)= 6.39521042E-04  CM( 7)= 6.39521042E-04  CM( 8)=
          EVI( 1)= 1.68842637D+10 EVI( 2)= 1.60455292D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.65416013D+10
          EVI( 6)= 1.57296782D+10 EVI( 7)= 0.             EVI( 8)=
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 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 6.25000000E-02  IPSI,IX=    6   34  T,TPREV,H,HPREV=   6.8461061E+03   7.1190266E+03   2.1494755E+11   2.1902952E+11
 IEXP,ITNEG=  0  0
 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 6.25000000E-02  IPSI,IX=    6   37  T,TPREV,H,HPREV=   6.5604525E+03   6.8530523E+03   2.1058484E+11   2.1494386E+11
 IEXP,ITNEG=  0  0
  6   37         X= 2.10687500D+00        H= 2.13879677D+11        MU= 1.96470686E+01         P= 4.55399098E+04      RHO= 1.58437232E-06
                 U= 2.51978949E+05        T= 6.79182707E+03         E= 1.85136490E+11        CI= 6.25000000E-02 SUM(CI)= 1.00114099E+00
         CI( 1)= 5.07907028D-01  CI( 2)= 2.18596431D-04  CI( 3)= 2.53141411D-01  CI( 4)= 2.28560537D-01  CI( 5)= 1.04455632D-02
         CI( 6)= 8.67843931D-04  CI( 7)= 1.58663202D-08  CI( 8)=
         CM( 1)= 3.56185188E-01  CM( 2)= 1.34211846E-04  CM( 3)= 3.55046164E-01  CM( 4)= 2.80659034E-01  CM( 5)= 6.83899950E-03
         CM( 6)= 5.68201455E-04  CM( 7)= 5.68201455E-04  CM( 8)=
        EVI( 1)= 1.55406462D+10 EVI( 2)= 1.48565627D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.52786777D+10
        EVI( 6)= 1.44756686D+10 EVI( 7)= 0.             EVI( 8)=

 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=    6   39  T,TPREV,H,HPREV=   6.5679443E+03   6.7172012E+03   2.1058064E+11   2.1279894E+11
 IEXP,ITNEG=  0  0
 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=    6   42  T,TPREV,H,HPREV=   6.4165746E+03   6.5721089E+03   2.0827823E+11   2.1057945E+11
 IEXP,ITNEG=  0  0
  6   42         X= 2.32562500D+00        H= 2.10011570D+11        MU= 1.96459598E+01         P= 3.97042701E+04      RHO= 1.43463647E-06
                 U= 2.66888748E+05        T= 6.53916866E+03         E= 1.82336078E+11        CI= 3.12500000E-02 SUM(CI)= 1.00114171E+00
         CI( 1)= 5.08724349D-01  CI( 2)= 1.89110692D-04  CI( 3)= 2.52782115D-01  CI( 4)= 2.29113219D-01  CI( 5)= 9.51299515D-03
         CI( 6)= 8.19901194D-04  CI( 7)= 1.49898092D-08  CI( 8)=
         CM( 1)= 3.56738225E-01  CM( 2)= 1.16101908E-04  CM( 3)= 3.54522221E-01  CM( 4)= 2.81321818E-01  CM( 5)= 6.22806986E-03
         CM( 6)= 5.36781722E-04  CM( 7)= 5.36781722E-04  CM( 8)=
        EVI( 1)= 1.48067779D+10 EVI( 2)= 1.42064084D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.45883774D+10
        EVI( 6)= 1.37907689D+10 EVI( 7)= 0.             EVI( 8)=

  6   44         X= 2.41937500D+00        H= 2.08276928D+11        MU= 1.96456718E+01         P= 3.72657849E+04      RHO= 1.37029682E-06
                 U= 2.73310972E+05        T= 6.42564084E+03         E= 1.81081517E+11        CI= 6.25000000E-02 SUM(CI)= 1.00114171E+00
         CI( 1)= 5.09066752D-01  CI( 2)= 1.77423419D-04  CI( 3)= 2.52625360D-01  CI( 4)= 2.29336953D-01  CI( 5)= 9.13481642D-03
         CI( 6)= 8.00385886D-04  CI( 7)= 1.46330213D-08  CI( 8)=
         CM( 1)= 3.56973099E-01  CM( 2)= 1.08925071E-04  CM( 3)= 3.54297181E-01  CM( 4)= 2.81592408E-01  CM( 5)= 5.98039208E-03
         CM( 6)= 5.23997549E-04  CM( 7)= 5.23997549E-04  CM( 8)=
        EVI( 1)= 1.44774320D+10 EVI( 2)= 1.39144338D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.42784506D+10
        EVI( 6)= 1.34834039D+10 EVI( 7)= 0.             EVI( 8)=

 XXXXXXXXXXXXXXXXXX

  7    1         X= 1.20000000D-01        H= 2.44819957D+11        MU= 2.88492827E+01         P= 1.17670402E+05      RHO= 2.32455051E-06
                 U= 3.98710378E+04        T= 1.75637484E+04         E= 1.94199245E+11        CI= 6.25000000E-02 SUM(CI)= 1.00000000E+00
         CI( 1)= 7.68000000D-01  CI( 2)= 2.32000000D-01  CI( 3)= 0.             CI( 4)= 0.             CI( 5)= 0.
         CI( 6)= 0.              CI( 7)= 0.              CI( 8)=
         CM( 1)= 7.90842701E-01  CM( 2)= 2.09157299E-01  CM( 3)= 0.             CM( 4)= 0.             CM( 5)= 0.
         CM( 6)= 0.              CM( 7)= 0.              CM( 8)=
        EVI( 1)= 4.72545978D+10 EVI( 2)= 4.27447765D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 4.49700060D+10
        EVI( 6)= 4.40803277D+10 EVI( 7)= 0.             EVI( 8)=

------------CHECKT= 1.32771000E+02
  7    6         X= 2.76250000D-01        H= 2.43734420D+11        MU= 2.11102459E+01         P= 1.14960063E+05      RHO= 2.68217629E-06
                 U= 6.15134412E+04        T= 1.08819545E+04         E= 2.00873679E+11        CI= 3.12500000E-02 SUM(CI)= 1.00113490E+00
         CI( 1)= 5.75639622D-01  CI( 2)= 2.48462473D-03  CI( 3)= 1.70724296D-01  CI( 4)= 2.09775614D-01  CI( 5)= 4.15909755D-02
         CI( 6)= 9.19753629D-04  CI( 7)= 1.68153571D-08  CI( 8)=
         CM( 1)= 4.33748358E-01  CM( 2)= 1.63909498E-03  CM( 3)= 2.57283830E-01  CM( 4)= 2.76775926E-01  CM( 5)= 2.92587217E-02
         CM( 6)= 6.47034968E-04  CM( 7)= 6.47034968E-04  CM( 8)=
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       EVI( 1)= 2.75232950D+10 EVI( 2)= 2.54223213D+10 EVI( 3)= 0.               EVI( 4)= 0.              EVI( 5)= 2.65163597D+10
       EVI( 6)= 2.56604111D+10 EVI( 7)= 0.             EVI( 8)=
        CM( 6)= 8.65021331E-04  CM( 7)= 8.65021331E-04  CM( 8)=
       EVI( 1)= 2.14505032D+10 EVI( 2)= 2.00763167D+10 EVI( 3)= 0.               EVI( 4)= 0.              EVI( 5)= 2.08269715D+10
       EVI( 6)= 1.99917114D+10 EVI( 7)= 0.             EVI( 8)=

 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=     9    24   T,TPREV,H,HPREV=    8.4250562E+03    8.6309996E+03    2.2011161E+11    2.2270955E+11
 IEXP,ITNEG=  0  0
PICKUP TAPE WRITTEN -- TIMER= 2.40000000E+02    CHECKT= 2.10177000E+02

 9   25           X= 1.36500000D+00         H= 2.21273066D+11        MU= 2.04746711E+01          P= 6.75445715E+04      RHO= 1.95011368E-06
                  U= 2.20695744E+05         T= 8.52906442E+03         E= 1.86636844E+11         CI= 3.12500000E-02  SUM(CI)= 1.00147351E+00
        CI( 1)= 5.49211921D-01  CI( 2)= 1.01769129D-03  CI( 3)= 2.03797815D-01  CI( 4)= 2.18320198D-01  CI( 5)= 2.78907317D-02
        CI( 6)= 1.23621240D-03  CI( 7)= 2.26010013D-08  CI( 8)=
        CM( 1)= 4.02743578E-01  CM( 2)= 7.24541482E-04  CM( 3)= 2.96010412E-01  CM( 4)= 2.78588150E-01  CM( 5)= 2.02032756E-02
        CM( 6)= 8.65021331E-04  CM( 7)= 8.65021331E-04  CM( 8)=
       EVI( 1)= 2.06119926D+10 EVI( 2)= 1.93370408D+10 EVI( 3)= 0.               EVI( 4)= 0.              EVI( 5)= 2.00406481D+10
       EVI( 6)= 1.92090332D+10 EVI( 7)= 0.             EVI( 8)=

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 9   26           X= 1.42750000D+00         H= 2.20093924D+11        MU= 2.04636961E+01          P= 6.54040949E+04      RHO= 1.90737910E-06
                  U= 2.25975433E+05         T= 8.43929048E+03         E= 1.85803890E+11         CI= 6.25000000E-02  SUM(CI)= 1.00147480E+00
        CI( 1)= 5.49086838D-01  CI( 2)= 9.78267630D-04  CI( 3)= 2.04219964D-01  CI( 4)= 2.18691253D-01  CI( 5)= 2.72819916D-02
        CI( 6)= 1.22190221D-03  CI( 7)= 2.23393758D-08  CI( 8)=
        CM( 1)= 4.01064514E-01  CM( 2)= 6.25950420E-04  CM( 3)= 2.98336327E-01  CM( 4)= 2.79701959E-01  CM( 5)= 1.86047182E-02
        CM( 6)= 8.33265644E-04  CM( 7)= 8.33265644E-04  CM( 8)=
       EVI( 1)= 2.03490794D+10 EVI( 2)= 1.91051702D+10 EVI( 3)= 0.               EVI( 4)= 0.              EVI( 5)= 1.97940496D+10
       EVI( 6)= 1.89636285D+10 EVI( 7)= 0.             EVI( 8)=

 9   27           X= 1.49000000D+00         H= 2.19091349D+11        MU= 2.04541416E+01          P= 6.35282650E+04      RHO= 1.86880552E-06
                  U= 2.30365368E+05         T= 8.36253755E+03         E= 1.85097301E+11         CI= 6.25000000E-02  SUM(CI)= 1.00147464E+00
        CI( 1)= 5.49011915D-01  CI( 2)= 9.43552823D-04  CI( 3)= 2.04565624D-01  CI( 4)= 2.19042778D-01  CI( 5)= 2.67035695D-02
        CI( 6)= 1.20717589D-03  CI( 7)= 2.20701425D-08  CI( 8)=
        CM( 1)= 4.00826936E-01  CM( 2)= 6.03111344E-04  CM( 3)= 2.98701759E-01  CM( 4)= 2.80020750E-01  CM( 5)= 1.82017659E-02
        CM( 6)= 8.22838795E-04  CM( 7)= 8.22838795E-04  CM( 8)=
       EVI( 1)= 2.01243592D+10 EVI( 2)= 1.89069543D+10 EVI( 3)= 0.               EVI( 4)= 0.              EVI( 5)= 1.95832546D+10
       EVI( 6)= 1.87538743D+10 EVI( 7)= 0.             EVI( 8)=

 9   28           X= 1.55250000D+00         H= 2.18084152D+11        MU= 2.04457630E+01          P= 6.16647304E+04      RHO= 1.82969610E-06
                  U= 2.34700744E+05         T= 8.28733961E+03         E= 1.84381982E+11         CI= 6.25000000E-02  SUM(CI)= 1.00147456E+00
        CI( 1)= 5.48952357D-01  CI( 2)= 9.11209704D-04  CI( 3)= 2.04848853D-01  CI( 4)= 2.19376358D-01  CI( 5)= 2.61534849D-02
        CI( 6)= 1.19227882D-03  CI( 7)= 2.17977874D-08  CI( 8)=
        CM( 1)= 4.00648473E-01  CM( 2)= 5.82199302E-04  CM( 3)= 2.98992797E-01  CM( 4)= 2.80332314E-01  CM( 5)= 1.78195133E-02
        CM( 6)= 8.12351710E-04  CM( 7)= 8.12351710E-04  CM( 8)=
       EVI( 1)= 1.99042465D+10 EVI( 2)= 1.87127759D+10 EVI( 3)= 0.               EVI( 4)= 0.              EVI( 5)= 1.93767638D+10
       EVI( 6)= 1.85484216D+10 EVI( 7)= 0.             EVI( 8)=
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9   29      X= 1.61500000D+00       H= 2.17062595D+11      MU= 2.04384204E+01       P= 5.98147054E+04     RHO= 1.79033029E-06
            U= 2.39013713E+05       T= 8.21251309E+03       E= 1.83652723E+11      CI= 6.25000000E-02 SUM(CI)= 1.00147449E+00
        CI( 1)= 5.49016818D-01  CI( 2)= 8.81120626D-04  CI( 3)= 2.05076594D-01  CI( 4)= 2.19694582D-01  CI( 5)= 2.56289761D-02
        CI( 6)= 1.17727836D-03  CI( 7)= 2.15235421D-08  CI( 8)=
        CM( 1)= 4.00522436E-01  CM( 2)= 5.62772307E-04  CM( 3)= 2.99217708E-01  CM( 4)= 2.80638139E-01  CM( 5)= 1.74552584E-02
        CM( 6)= 8.01843177E-04  CM( 7)= 8.01843177E-04  CM( 8)=
       EVI( 1)= 1.96852761D+10 EVI( 2)= 1.85195785D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.91713267D+10
       EVI( 6)= 1.83440361D+10 EVI( 7)= 0.             EVI( 8)=

9   30      X= 1.67750000D+00       H= 2.16026465D+11      MU= 2.04319908E+01       P= 5.79791940E+04     RHO= 1.75074139E-06
            U= 2.43310119E+05       T= 8.13794587E+03       E= 1.82909527E+11      CI= 6.25000000E-02 SUM(CI)= 1.00147442E+00
        CI( 1)= 5.49080535D-01  CI( 2)= 8.52840768D-04  CI( 3)= 2.05255063D-01  CI( 4)= 2.19999552D-01  CI( 5)= 2.51241755D-02
        CI( 6)= 1.16223271D-03  CI( 7)= 2.12484708D-08  CI( 8)=
        CM( 1)= 4.00442906E-01  CM( 2)= 5.44538585E-04  CM( 3)= 2.99383892E-01  CM( 4)= 2.80939301E-01  CM( 5)= 1.71066689E-02
        CM( 6)= 7.91346577E-04  CM( 7)= 7.91346577E-04  CM( 8)=
       EVI( 1)= 1.94671208D+10 EVI( 2)= 1.83270730D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.89666359D+10
       EVI( 6)= 1.81404122D+10 EVI( 7)= 0.             EVI( 8)=

9   31      X= 1.74000000D+00       H= 2.14975461D+11      MU= 2.04263667E+01       P= 5.61590281E+04     RHO= 1.71097279E-06
            U= 2.47592048E+05       T= 8.06346199E+03       E= 1.82152596E+11      CI= 6.25000000E-02 SUM(CI)= 1.00147435E+00
        CI( 1)= 5.49175178D-01  CI( 2)= 8.26061782D-04  CI( 3)= 2.05389817D-01  CI( 4)= 2.20292977D-01  CI( 5)= 2.46391095D-02
        CI( 6)= 1.14718907D-03  CI( 7)= 2.09734360D-08  CI( 8)=
        CM( 1)= 4.00404599E-01  CM( 2)= 5.27295026E-04  CM( 3)= 2.99497981E-01  CM( 4)= 2.81236571E-01  CM( 5)= 1.67717770E-02
        CM( 6)= 7.80888584E-04  CM( 7)= 7.80888584E-04  CM( 8)=
       EVI( 1)= 1.92492669D+10 EVI( 2)= 1.81348056D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.87622092D+10
       EVI( 6)= 1.79370706D+10 EVI( 7)= 0.             EVI( 8)=

9   32      X= 1.80250000D+00       H= 2.13909197D+11      MU= 2.04214540E+01       P= 5.43555370E+04     RHO= 1.67108120E-06
            U= 2.51861769E+05       T= 7.98889727E+03       E= 1.81382030E+11      CI= 6.25000000E-02 SUM(CI)= 1.00147429E+00
        CI( 1)= 5.49308812D-01  CI( 2)= 8.00558475D-04  CI( 3)= 2.05485821D-01  CI( 4)= 2.20576262D-01  CI( 5)= 2.41706292D-02
        CI( 6)= 1.13218558D-03  CI( 7)= 2.06991353D-08  CI( 8)=
        CM( 1)= 4.00402792E-01  CM( 2)= 5.10892752E-04  CM( 3)= 2.99565908E-01  CM( 4)= 2.81530499E-01  CM( 5)= 1.64489267E-02
        CM( 6)= 7.70490394E-04  CM( 7)= 7.70490394E-04  CM( 8)=
       EVI( 1)= 1.90312359D+10 EVI( 2)= 1.79423530D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.85575970D+10
       EVI( 6)= 1.77335646D+10 EVI( 7)= 0.             EVI( 8)=

9   33      X= 1.86500000D+00       H= 2.12827207D+11      MU= 2.04171682E+01       P= 5.25686899E+04     RHO= 1.63107927E-06
            U= 2.56121711E+05       T= 7.91409998E+03       E= 1.80597817E+11      CI= 6.25000000E-02 SUM(CI)= 1.00147429E+00
        CI( 1)= 5.49465860D-01  CI( 2)= 7.76159116D-04  CI( 3)= 2.05547567D-01  CI( 4)= 2.20850568D-01  CI( 5)= 2.37168464D-02
        CI( 6)= 1.11726814D-03  CI( 7)= 2.04264078D-08  CI( 8)=
        CM( 1)= 4.00433213E-01  CM( 2)= 4.95217852E-04  CM( 3)= 2.99593036E-01  CM( 4)= 2.81821459E-01  CM( 5)= 1.61367250E-02
        CM( 6)= 7.60179004E-04  CM( 7)= 7.60179004E-04  CM( 8)=
       EVI( 1)= 1.88125860D+10 EVI( 2)= 1.77493246D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 1.83523840D+10
       EVI( 6)= 1.75294820D+10 EVI( 7)= 0.             EVI( 8)=
------------------------------------------------------------------------------------------------------------------------------
        CI( 6)= 4.74193166D-04  CI( 7)= 8.66941664D-09  CI( 8)=
        CM( 1)= 4.81604662E-01  CM( 2)= 4.37711114E-03  CM( 3)= 2.01365292E-01  CM( 4)= 2.74574484E-01  CM( 5)= 3.73848535E-02
        CM( 6)= 3.46798629E-04  CM( 7)= 3.46798629E-04  CM( 8)=
       EVI( 1)= 2.96645530D+10 EVI( 2)= 2.73048295D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.85207572D+10
       EVI( 6)= 2.76592685D+10 EVI( 7)= 0.             EVI( 8)=
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10    6          X= 6.12500000D-01        H= 2.35955685D+11        MU= 2.16402572E+01         P= 1.04795636E+05       RHO= 2.45028403E-06
                 U= 1.39073266E+05        T= 1.11312292E+04         E= 1.93186915E+11        CI= 6.25000000E-02  SUM(CI)= 1.00137716E+00
          CI( 1)= 6.01575540D-01  CI( 2)= 4.05333121D-03  CI( 3)= 1.43122966D-01  CI( 4)= 2.04985395D-01  CI( 5)= 4.79157327D-02
          CI( 6)= 6.24187013D-04  CI( 7)= 1.14116728D-08  CI( 8)=
          CM( 1)= 4.64671951E-01  CM( 2)= 2.74109781E-03  CM( 3)= 2.21103498E-01  CM( 4)= 2.76028777E-01  CM( 5)= 3.45544114E-02
          CM( 6)= 4.50132214E-04  CM( 7)= 4.50132214E-04  CM( 8)=
         EVI( 1)= 2.82572726D+10 EVI( 2)= 2.60677205D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.72035022D+10
         EVI( 6)= 2.63455730D+10 EVI( 7)= 0.             EVI( 8)=

10    7          X= 6.75000000D-01        H= 2.34778207D+11        MU= 2.14254379E+01         P= 1.01830197E+05       RHO= 2.43927415E-06
                 U= 1.47296742E+05        T= 1.07572092E+04         E= 1.93032101E+11        CI= 6.25000000E-02  SUM(CI)= 1.00138869E+00
          CI( 1)= 5.91968594D-01  CI( 2)= 3.07129244D-03  CI( 3)= 1.53918609D-01  CI( 4)= 2.06430456D-01  CI( 5)= 4.52457444D-02
          CI( 6)= 7.53982282D-04  CI( 7)= 1.37846494D-08  CI( 8)=
          CM( 1)= 4.52712248E-01  CM( 2)= 2.05636829E-03  CM( 3)= 2.35420731E-01  CM( 4)= 2.76428932E-01  CM( 5)= 3.23050482E-02
          CM( 6)= 5.38336461E-04  CM( 7)= 5.38336461E-04  CM( 8)=
         EVI( 1)= 2.71560892D+10 EVI( 2)= 2.50993822D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.61725525D+10
         EVI( 6)= 2.53176291D+10 EVI( 7)= 0.             EVI( 8)=

IMAXL= 16
XPST=    6.00000000E-02    1.20000000E-01    1.80000000E-01    2.40000000E-01    3.00000000E-01
  3.60000000E-01    4.20000000E-01    4.80000000E-01    5.40000000E-01    6.00000000E-01

ELE2=    1.00000000E+00    1.00000000E+00    1.00000000E+00    1.00000000E+00    1.00000000E+00
KSTAG= 70

 --- DATA ON TAPE 13 ---
----- PICKUP CASE -----

IMAXL= 16
XPST=    6.00000000E-02    1.20000000E-01    1.80000000E-01    2.40000000E-01    3.00000000E-01
  3.60000000E-01    4.20000000E-01    4.80000000E-01    5.40000000E-01    6.00000000E-01

ELE2=    1.00000000E+00    1.00000000E+00    1.00000000E+00    1.00000000E+00    1.00000000E+00
KSTAG=
 9   25          X= 1.36500000D+00        H= 2.21273066D+11        MU= 2.04746711E+01         P= 6.75445715E+04       RHO= 1.95011368E-06
                 U= 2.20695744E+05        T= 8.52906442E+03         E= 1.86636844E+11        CI= 3.12500000E-02  SUM(CI)=           IIIII
          CI( 1)= 5.49211921D-01  CI( 2)= 1.01769129D-03  CI( 3)= 2.03797815D-01  CI( 4)= 2.18320198D-01  CI( 5)= 2.78907317D-02
          CI( 6)= 1.23621240D-03  CI( 7)=
          CM( 1)=           IIIII  CM( 2)=           IIIII  CM( 3)=           IIIII  CM( 4)=           IIIII  CM( 5)=           IIIII
          CM( 6)=           IIIII  CM( 7)=           IIIII  CM( 8)=
         EVI( 1)= 2.06119926D+10 EVI( 2)= 1.93370408D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.00406481D+10
         EVI( 6)= 1.92090332D+10 EVI( 7)= 0.             EVI( 8)=
     IPF= 5      CIMAX= 5.00000000E-01     TIMER= 4.80000000E+02    HCHECKT= 1.00000000E-02   TCHECKT= 3.00000000E-01
  IZTERM=45      KSTAG= 64

 9   25          X= 1.36500000D+00        H= 2.21273066D+11        MU= 2.04746711E+01         P= 6.75445715E+04       RHO= 1.95011368E-06
                 U= 2.20695744E+05        T= 8.52906442E+03         E= 1.86636844E+11        CI= 6.25000000E-02  SUM(CI)= 1.00147459E+00
          CI( 1)= 5.49211921D-01  CI( 2)= 1.01769129D-03  CI( 3)= 2.03797815D-01  CI( 4)= 2.18320198D-01  CI( 5)= 2.78907317D-02
          CI( 6)= 1.23621240D-03  CI( 7)= 2.26010013D-08  CI( 8)=
          CM( 1)= 4.01375409E-01  CM( 2)= 6.51152953E-04  CM( 3)= 2.97879300E-01  CM( 4)= 2.79377141E-01  CM( 5)= 1.90300439E-02
          CM( 6)= 8.43476485E-04  CM( 7)= 8.43476485E-04  CM( 8)=
         EVI( 1)= 2.06119926D+10 EVI( 2)= 1.93370408D+10 EVI( 3)= 0.             EVI( 4)= 0.             EVI( 5)= 2.00406481D+10
         EVI( 6)= 1.92090332D+10 EVI( 7)= 0.             EVI( 8)=

 9   30          X= 1.67750000D+00        H= 2.16026465D+11        MU= 2.04319908E+01         P= 5.79791940E+04       RHO= 1.75074139E-06
                 U= 2.43310119E+05        T= 8.13794587E+03         E= 1.82909527E+11        CI= 6.25000000E-02  SUM(CI)= 1.00147442E+00
          CI( 1)= 5.49080535D-01  CI( 2)= 8.52840768D-04  CI( 3)= 2.05255063D-01  CI( 4)= 2.19999552D-01  CI( 5)= 2.51241755D-02
          CI( 6)= 1.16223271D-03  CI( 7)= 2.12484708D-08  CI( 8)=
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           CM( 1)= 4.00442906E-01  CM( 2)= 5.44538585E-04  CM( 3)= 2.99383892E-01  CM( 4)= 2.80939301E-01  CM( 5)= 1.71066689E-02
           CM( 6)= 7.91346577E-04  CM( 7)= 7.91346577E-04  CM( 8)=
          EVI( 1)= 1.94671208D+10 EVI( 2)= 1.83270730D+10 EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.89666359D+10
          EVI( 6)= 1.81404122D+10 EVI( 7)= 0.              EVI( 8)=

 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=     9   34  T,TPREV,H,HPREV=   7.7530198E+03   7.9088102E+03   2.1061436E+11   2.1282721E+11
 IEXP,ITNEG=  0  0
  9   35         X= 1.92750000D+00         H= 2.11728386D+11        MU= 2.04134152E+01        P= 5.07989532E+04      RHO= 1.59107015E-06
                 U= 2.60376595E+05         T= 7.83853754E+03         E= 1.79800848E+11       CI= 3.12500000E-02 SUM(CI)= 1.00147488E+00
           CI( 1)= 5.49644025D-01  CI( 2)= 7.52970571D-04  CI( 3)= 2.05581032D-01  CI( 4)= 2.21115546D-01  CI( 5)= 2.32787274D-02
           CI( 6)= 1.10256334D-03  CI( 7)= 2.01575680D-08  CI( 8)=
           CM( 1)= 4.00489424E-01  CM( 2)= 4.80334403E-04  CM( 3)= 2.99586734E-01  CM( 4)= 2.82107715E-01  CM( 5)= 1.58357214E-02
           CM( 6)= 7.50036098E-04  CM( 7)= 7.50036098E-04  CM( 8)=
          EVI( 1)= 1.65917636D+10 EVI( 2)= 1.75543470D+10 EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.81451111D+10
          EVI( 6)= 1.73233725D+10 EVI( 7)= 0.              EVI( 8)=

 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=     9   37  T,TPREV,H,HPREV=   7.5992688E+03   7.7577726E+03   2.0833031E+11   2.1061323E+11
 IEXP,ITNEG=  0  0
 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=     9   40  T,TPREV,H,HPREV=   7.4415937E+03   7.6040731E+03   2.0596852E+11   2.0832907E+11
 IEXP,ITNEG=  0  0
  9   40         X= 2.14625000D+00         H= 2.07745787D+11        MU= 2.04038315E+01        P= 4.47450873E+04      RHO= 1.45045777E-06
                 U= 2.75247469E+05         T= 7.57017531E+03         E= 1.76896846E+11       CI= 3.12500000E-02 SUM(CI)= 1.00147599E+00
           CI( 1)= 5.50423249D-01  CI( 2)= 6.77463993D-04  CI( 3)= 2.05503778D-01  CI( 4)= 2.21992953D-01  CI( 5)= 2.18256438D-02
           CI( 6)= 1.05188641D-03  CI( 7)= 1.92310691D-08  CI( 8)=
           CM( 1)= 4.00868904E-01  CM( 2)= 4.31964411E-04  CM( 3)= 2.99333556E-01  CM( 4)= 2.83094176E-01  CM( 5)= 1.48409478E-02
           CM( 6)= 7.15226374E-04  CM( 7)= 7.15226374E-04  CM( 8)=
          EVI( 1)= 1.78080548D+10 EVI( 2)= 1.68620967D+10 EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.74093113D+10
          EVI( 6)= 1.65918894D+10 EVI( 7)= 0.              EVI( 8)=

 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=     9   43  T,TPREV,H,HPREV=   7.2790446E+03   7.4465641E+03   2.0352114E+11   2.0596715E+11
 IEXP,ITNEG=  0  0
  9   45         X= 2.36500000D+00         H= 2.03519626D+11        MU= 2.03981991E+01        P= 3.89155233E+04      RHO= 1.30961012E-06
                 U= 2.90195609E+05         T= 7.28998474E+03         E= 1.73804276E+11       CI= 6.25000000E-02 SUM(CI)= 1.00147650E+00
           CI( 1)= 5.51359847D-01  CI( 2)= 6.09421406D-04  CI( 3)= 2.05217759D-01  CI( 4)= 2.22804137D-01  CI( 5)= 2.04821723D-02
           CI( 6)= 1.00314447D-03  CI( 7)= 1.83399467D-08  CI( 8)=
           CM( 1)= 4.01440174E-01  CM( 2)= 3.88471849E-04  CM( 3)= 2.98834430E-01  CM( 4)= 2.84050196E-01  CM( 5)= 1.39229348E-02
           CM( 6)= 6.81896183E-04  CM( 7)= 6.81896183E-04  CM( 8)=
          EVI( 1)= 1.69907942D+10 EVI( 2)= 1.61397294D+10 EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.66416879D+10
          EVI( 6)= 1.58291062D+10 EVI( 7)= 0.              EVI( 8)=

 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=     9   46  T,TPREV,H,HPREV=   7.1103954E+03   7.2840460E+03   2.0097722E+11   2.0351963E+11
 IEXP,ITNEG=  0  0
  9   47         X= 2.42750000D+00         H= 2.02260227D+11        MU= 2.03970875E+01        P= 3.72841125E+04      RHO= 1.26920372E-06
                 U= 2.94503464E+05         T= 7.20633707E+03         E= 1.72884239E+11       CI= 3.12500000E-02 SUM(CI)= 1.00147697E+00
           CI( 1)= 5.51642549D-01  CI( 2)= 5.91295586D-04  CI( 3)= 2.05111930D-01  CI( 4)= 2.23024331D-01  CI( 5)= 2.01171272D-02
           CI( 6)= 9.89715308D-04  CI( 7)= 1.80944286D-08  CI( 8)=
           CM( 1)= 4.01624120E-01  CM( 2)= 3.76897119E-04  CM( 3)= 2.98664049E-01  CM( 4)= 2.84315425E-01  CM( 5)= 1.36740471E-02
           CM( 6)= 6.72730930E-04  CM( 7)= 6.72730930E-04  CM( 8)=
          EVI( 1)= 1.67470237D+10 EVI( 2)= 1.59241599D+10 EVI( 3)= 0.              EVI( 4)= 0.              EVI( 5)= 1.64126535D+10
          EVI( 6)= 1.56015885D+10 EVI( 7)= 0.              EVI( 8)=
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10    1          X= 3.00000000D-01      H= 2.40486907D+11      MU= 2.88492827E+01      P= 1.15519835E+05     RHO= 2.31503169E-06
                 U= 5.85980337E+04      T= 1.73136478E+04       E= 1.90587014E+11     CI= 6.25000000E-02 SUM(CI)= 1.00000000E+00
            CI( 1)= 7.68000000D-01  CI( 2)= 2.32000000D-01  CI( 3)= 0.              CI( 4)= 0.             CI( 5)= 0.
            CI( 6)= 0.              CI( 7)= 0.              CI( 8)=
------------CHECKT= 2.60585000E+02
 CHECK,ABS((HPREV-H)/H).GT.HCHECKT
REDUCED SPEC= 3.12500000E-02  IPSI,IX=    43    3  T,TPREV,H,HPREV=    9.1125061E+03    9.4064075E+03    1.1877390E+11    1.2096168E+11
 IEXP,ITNEG=  0  0
43    4          X= 2.40500000D+00      H= 1.19867536D+11      MU= 2.85908929E+01      P= 5.30244443E+04     RHO= 1.96285869E-06
                 U= 5.01515375E+05      T= 9.28899537E+03       E= 9.28536487E+10     CI= 3.12500000E-02 SUM(CI)= 1.00000144E+00
            CI( 1)= 7.67622127D-01  CI( 2)= 2.22206662D-01  CI( 3)= 2.90116480D-04  CI( 4)= 9.69147933D-03  CI( 5)= 1.91055390D-04
            CI( 6)= 1.44313649D-09  CI( 7)= 2.63840822D-14  CI( 8)=
            CM( 1)= 7.83373857E-01  CM( 2)= 1.98533965E-01  CM( 3)= 5.92139435E-04  CM( 4)= 1.73180030E-02  CM( 5)= 1.82032930E-04
            CM( 6)= 1.37498536E-09  CM( 7)= 1.37498536E-09  CM( 8)=
           EVI( 1)= 2.28402441D+10 EVI( 2)= 2.13008860D+10 EVI( 3)= 0.             EVI( 4)= 0.            EVI( 5)= 2.21297464D+10
           EVI( 6)= 2.12889391D+10 EVI( 7)= 0.             EVI( 8)=


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44    1          X= 2.34000000D+00      H= 1.19006670D+11      MU= 2.88492827E+01      P= 5.59680556E+04     RHO= 2.07651949E-06
                 U= 4.80169891E+05      T= 9.35175595E+03       E= 9.20538501E+10     CI= 6.25000000E-02 SUM(CI)= 1.00000000E+00
            CI( 1)= 7.68000000D-01  CI( 2)= 2.32000000D-01  CI( 3)= 0.              CI( 4)= 0.             CI( 5)= 0.
            CI( 6)= 0.              CI( 7)= 0.              CI( 8)=
            CM( 1)= 7.90842701E-01  CM( 2)= 2.09157299E-01  CM( 3)= 0.              CM( 4)= 0.             CM( 5)= 0.
            CM( 6)= 0.              CM( 7)= 0.              CM( 8)=
           EVI( 1)= 2.30244647D+10 EVI( 2)= 2.14631521D+10 EVI( 3)= 0.             EVI( 4)= 0.            EVI( 5)= 2.23023988D+10
           EVI( 6)= 2.14608984D+10 EVI( 7)= 0.             EVI( 8)=

------------CHECKT= 2.61445000E+02
44    2          X= 2.40250000D+00      H= 1.24235779D+11      MU= 2.87044863E+01      P= 5.37622913E+04     RHO= 1.92366587E-06
                 U= 4.92728308E+05      T= 9.64832328E+03       E= 9.62879467E+10     CI= 6.25000000E-02 SUM(CI)= 1.00000673E+00
            CI( 1)= 7.67798941D-01  CI( 2)= 2.26587886D-01  CI( 3)= 1.76680344D-04  CI( 4)= 5.38645261D-03  CI( 5)= 5.67742969D-05
            CI( 6)= 2.53988286D-10  CI( 7)= 4.64353018D-15  CI( 8)=
            CM( 1)= 7.86667410E-01  CM( 2)= 2.03252777E-01  CM( 3)= 3.62044439E-04  CM( 4)= 9.66345969E-03  CM( 5)= 5.43080854E-05
            CM( 6)= 2.42955321E-10  CM( 7)= 2.42955321E-10  CM( 8)=
           EVI( 1)= 2.38953336D+10 EVI( 2)= 2.22300621D+10 EVI( 3)= 0.             EVI( 4)= 0.            EVI( 5)= 2.31184647D+10
           EVI( 6)= 2.22738097D+10 EVI( 7)= 0.             EVI( 8)=
AAAAAAAAAAAAAAAAA

----- CHECKT= 2.61679000E+02 -----

 BEGIN PHYSICAL SPACE CALCULATIONS  KSTAG=  119

X= 6.00000000E-02   R= 5.40347303E-02   Y= 2.09377752E-01   Z= 2.10266976E-01   PSI= 0.
X= 6.00000000E-02   R= 5.99869210E-02   Y= 0.               Z= 9.87121805E-04   PSI= 3.41887158E-04


X= 1.20000000E-01   R= 1.11148742E-01   Y= 1.54642164E-01   Z= 1.57872841E-01   PSI= 0.
X= 1.20000000E-01   R= 1.14179899E-01   Y= 1.01273290E-01   Z= 1.04592015E-01   PSI= 3.41887158E-04
X= 1.20000000E-01   R= 1.20144291E-01   Y=-3.74036088E-03   Z=-2.48383530E-04   PSI= 1.36659155E-03


X= 1.80000000E-01   R= 1.66786066E-01   Y= 1.51734903E-01   Z= 1.60056861E-01   PSI= 0.
X= 1.80000000E-01   R= 1.68817364E-01   Y= 1.27798455E-01   Z= 1.36221423E-01   PSI= 3.41887158E-04
X= 1.80000000E-01   R= 1.73346952E-01   Y= 7.44225959E-02   Z= 8.30708081E-02   PSI= 1.36659155E-03
X= 1.80000000E-01   R= 1.79714188E-01   Y=-6.07767611E-04   Z= 8.35706958E-03   PSI= 3.06679722E-03
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X= 2.40000000E-01   R= 2.22480425E-01   Y= 1.49643037E-01   Z= 1.63296510E-01   PSI= 0.
X= 2.40000000E-01   R= 2.23970108E-01   Y= 1.36448637E-01   Z= 1.50193227E-01   PSI= 3.41887158E-04
X= 2.40000000E-01   R= 2.27608269E-01   Y= 1.04224765E-01   Z= 1.18191886E-01   PSI= 1.36659155E-03
X= 2.40000000E-01   R= 2.32926057E-01   Y= 5.71241233E-02   Z= 7.14165097E-02   PSI= 3.06679722E-03
X= 2.40000000E-01   R= 2.39431829E-01   Y=-4.98711476E-04   Z= 1.41916046E-02   PSI= 5.44413801E-03

X= 3.00000000E-01   R= 2.77602697E-01   Y= 1.50441287E-01   Z= 1.71490552E-01   PSI= 0.
X= 3.00000000E-01   R= 2.78787173E-01   Y= 1.42008033E-01   Z= 1.63146372E-01   PSI= 3.41887158E-04
X= 3.00000000E-01   R= 2.81819609E-01   Y= 1.20417639E-01   Z= 1.41784023E-01   PSI= 1.36659155E-03
X= 3.00000000E-01   R= 2.86348461E-01   Y= 8.81730372E-02   Z= 1.09879998E-01   PSI= 3.06679722E-03
X= 3.00000000E-01   R= 2.92095416E-01   Y= 4.72557704E-02   Z= 6.93949115E-02   PSI= 5.44413801E-03
X= 3.00000000E-01   R= 2.98757757E-01   Y=-1.78878533E-04   Z= 2.24612814E-02   PSI= 8.47881147E-03

X= 3.60000000E-01   R= 3.32123713E-01   Y= 1.51207882E-01   Z= 1.83801846E-01   PSI= 0.
X= 3.60000000E-01   R= 3.33102284E-01   Y= 1.45349029E-01   Z= 1.78037659E-01   PSI= 3.41887158E-04
X= 3.60000000E-01   R= 3.35692176E-01   Y= 1.29842963E-01   Z= 1.62782133E-01   PSI= 1.36659155E-03
X= 3.60000000E-01   R= 3.39649716E-01   Y= 1.06148582E-01   Z= 1.39470597E-01   PSI= 3.06679722E-03
X= 3.60000000E-01   R= 3.44741025E-01   Y= 7.56661570E-02   Z= 1.09480695E-01   PSI= 5.44413801E-03
X= 3.60000000E-01   R= 3.50769186E-01   Y= 3.95746556E-02   Z= 7.39723462E-02   PSI= 8.47881147E-03
X= 3.60000000E-01   R= 3.57401364E-01   Y=-1.33177702E-04   Z= 3.49060964E-02   PSI= 1.21346707E-02

X= 4.20000000E-01   R= 3.86611222E-01   Y= 1.51937124E-01   Z= 1.96068022E-01   PSI= 0.
X= 4.20000000E-01   R= 3.87447433E-01   Y= 1.47617759E-01   Z= 1.91842616E-01   PSI= 3.41887158E-04
X= 4.20000000E-01   R= 3.89726689E-01   Y= 1.35844483E-01   Z= 1.80325444E-01   PSI= 1.36659155E-03
X= 4.20000000E-01   R= 3.93262522E-01   Y= 1.17580483E-01   Z= 1.62458739E-01   PSI= 3.06679722E-03
X= 4.20000000E-01   R= 3.97863847E-01   Y= 9.38127901E-02   Z= 1.39208062E-01   PSI= 5.44413801E-03
X= 4.20000000E-01   R= 4.03366396E-01   Y= 6.53899148E-02   Z= 1.11403467E-01   PSI= 8.47881147E-03
X= 4.20000000E-01   R= 4.09441686E-01   Y= 3.40086019E-02   Z= 8.07047896E-02   PSI= 1.21346707E-02
X= 4.20000000E-01   R= 4.16037782E-01   Y=-6.28852922E-05   Z= 4.73744566E-02   PSI= 1.64440873E-02

X= 4.80000000E-01   R= 4.40806623E-01   Y= 1.53817099E-01   Z= 2.09445300E-01   PSI= 0.
X= 4.80000000E-01   R= 4.41546091E-01   Y= 1.50458433E-01   Z= 2.05178487E-01   PSI= 3.41887158E-04
X= 4.80000000E-01   R= 4.43606901E-01   Y= 1.41098227E-01   Z= 1.97074267E-01   PSI= 1.36659155E-03
X= 4.80000000E-01   R= 4.46836298E-01   Y= 1.26430295E-01   Z= 1.82807477E-01   PSI= 3.06679722E-03
X= 4.80000000E-01   R= 4.51070322E-01   Y= 1.07199342E-01   Z= 1.64102456E-01   PSI= 5.44413801E-03
X= 4.80000000E-01   R= 4.56162928E-01   Y= 8.40687062E-02   Z= 1.41604402E-01   PSI= 8.47881147E-03

X= 4.80000000E-01   R= 4.61857596E-01   Y= 5.82035024E-02   Z= 1.16446565E-01   PSI= 1.21346707E-02
X= 4.80000000E-01   R= 4.68030382E-01   Y= 3.01666853E-02   Z= 8.91765056E-02   PSI= 1.64440873E-02
X= 4.80000000E-01   R= 4.74681182E-01   Y=-4.12746433E-05   Z= 5.97946798E-02   PSI= 2.14070611E-02

X= 5.40000000E-01   R= 4.94677229E-01   Y= 1.56608521E-01   Z= 2.23682959E-01   PSI= 0.
X= 5.40000000E-01   R= 4.95348279E-01   Y= 1.53888841E-01   Z= 2.21052875E-01   PSI= 3.41887158E-04
X= 5.40000000E-01   R= 4.97243699E-01   Y= 1.46206942E-01   Z= 2.13624046E-01   PSI= 1.36659155E-03
X= 5.40000000E-01   R= 5.00235748E-01   Y= 1.34080545E-01   Z= 2.01897134E-01   PSI= 3.06679722E-03
X= 5.40000000E-01   R= 5.04189352E-01   Y= 1.18057086E-01   Z= 1.86401545E-01   PSI= 5.44413801E-03
X= 5.40000000E-01   R= 5.08964975E-01   Y= 9.87020918E-02   Z= 1.67684173E-01   PSI= 8.47881147E-03
X= 5.40000000E-01   R= 5.14338386E-01   Y= 7.69243343E-02   Z= 1.46623852E-01   PSI= 1.21346707E-02
X= 5.40000000E-01   R= 5.20233939E-01   Y= 5.30304041E-02   Z= 1.23517072E-01   PSI= 1.64440873E-02
X= 5.40000000E-01   R= 5.26582662E-01   Y= 2.72998330E-02   Z= 9.86341572E-02   PSI= 2.14070611E-02
X= 5.40000000E-01   R= 5.33325361E-01   Y=-2.74762121E-05   Z= 7.22071063E-02   PSI= 2.70235921E-02

X= 6.00000000E-01   R= 5.48373279E-01   Y= 1.59495847E-01   Z= 2.37981589E-01   PSI= 0.
X= 6.00000000E-01   R= 5.48991529E-01   Y= 1.57233760E-01   Z= 2.35806681E-01   PSI= 3.41887158E-04
X= 6.00000000E-01   R= 5.50743328E-01   Y= 1.50824190E-01   Z= 2.29644128E-01   PSI= 1.36659155E-03
X= 6.00000000E-01   R= 5.53528572E-01   Y= 1.40633399E-01   Z= 2.19846079E-01   PSI= 3.06679722E-03
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X= 6.00000000E-01   R= 5.57248692E-01   Y= 1.27022037E-01   Z= 2.06759283E-01   PSI= 5.44413801E-03
X= 6.00000000E-01   R= 5.61755717E-01   Y= 1.10531504E-01   Z= 1.90904276E-01   PSI= 8.47881147E-03
X= 6.00000000E-01   R= 5.66849804E-01   Y= 9.18930028E-02   Z= 1.72984081E-01   PSI= 1.21346707E-02
X= 6.00000000E-01   R= 5.72460801E-01   Y= 7.13632015E-02   Z= 1.53245475E-01   PSI= 1.64440873E-02
X= 6.00000000E-01   R= 5.78566507E-01   Y= 4.90233357E-02   Z= 1.31766562E-01   PSI= 2.14070611E-02
X= 6.00000000E-01   R= 5.85118240E-01   Y= 2.50515239E-02   Z= 1.08718596E-01   PSI= 2.70235921E-02
X= 6.00000000E-01   R= 5.91970299E-01   Y=-1.91354987E-05   Z= 8.46141310E-02   PSI= 3.32936805E-02

X= 6.60000000E-01   R= 5.99096533E-01   Y= 1.62543959E-01   Z= 2.61872375E-01   PSI= 0.
X= 6.60000000E-01   R= 5.99666289E-01   Y= 1.60616444E-01   Z= 2.60035972E-01   PSI= 3.41887158E-04
X= 6.60000000E-01   R= 6.01289080E-01   Y= 1.55126443E-01   Z= 2.54805480E-01   PSI= 1.36659155E-03
X= 6.60000000E-01   R= 6.03884343E-01   Y= 1.46346516E-01   Z= 2.46440572E-01   PSI= 3.06679722E-03
X= 6.60000000E-01   R= 6.07367644E-01   Y= 1.34562306E-01   Z= 2.35213393E-01   PSI= 5.44413801E-03
X= 6.60000000E-01   R= 6.11608163E-01   Y= 1.20216380E-01   Z= 2.21545588E-01   PSI= 8.47881147E-03
X= 6.60000000E-01   R= 6.16422309E-01   Y= 1.03929839E-01   Z= 2.06028900E-01   PSI= 1.21346707E-02
X= 6.60000000E-01   R= 6.21761643E-01   Y= 8.58665563E-02   Z= 1.88819454E-01   PSI= 1.64440873E-02
X= 6.60000000E-01   R= 6.27603902E-01   Y= 6.61018513E-02   Z= 1.69989012E-01   PSI= 2.14070611E-02
X= 6.60000000E-01   R= 6.33918719E-01   Y= 4.47384543E-02   Z= 1.49635446E-01   PSI= 2.70235921E-02
X= 6.60000000E-01   R= 6.40627903E-01   Y= 2.20408888E-02   Z= 1.28010777E-01   PSI= 3.32936805E-02
X= 6.60000000E-01   R= 6.47147507E-01   Y=-1.53163277E-05   Z= 1.06997152E-01   PSI= 3.97896514E-02

X= 7.20000000E-01   R= 6.49008872E-01   Y= 1.65160838E-01   Z= 2.88087427E-01   PSI= 0.
X= 7.20000000E-01   R= 6.49536208E-01   Y= 1.63495261E-01   Z= 2.86516659E-01   PSI= 3.41887158E-04
X= 7.20000000E-01   R= 6.51050279E-01   Y= 1.58713102E-01   Z= 2.82006711E-01   PSI= 1.36659155E-03
X= 7.20000000E-01   R= 6.53485474E-01   Y= 1.51021600E-01   Z= 2.74753026E-01   PSI= 3.06679722E-03
X= 7.20000000E-01   R= 6.56765790E-01   Y= 1.40660800E-01   Z= 2.64981985E-01   PSI= 5.44413801E-03
X= 7.20000000E-01   R= 6.60775811E-01   Y= 1.27995247E-01   Z= 2.53037383E-01   PSI= 8.47881147E-03
X= 7.20000000E-01   R= 6.65346111E-01   Y= 1.13560067E-01   Z= 2.39423885E-01   PSI= 1.21346707E-02
X= 7.20000000E-01   R= 6.70435765E-01   Y= 9.74845162E-02   Z= 2.24263389E-01   PSI= 1.64440873E-02
X= 7.20000000E-01   R= 6.76028175E-01   Y= 7.98210244E-02   Z= 2.07605342E-01   PSI= 2.14070611E-02
X= 7.20000000E-01   R= 6.82097234E-01   Y= 6.06520513E-02   Z= 1.89527509E-01   PSI= 2.70235921E-02
X= 7.20000000E-01   R= 6.88596804E-01   Y= 4.01233148E-02   Z= 1.70167313E-01   PSI= 3.32936805E-02
X= 7.20000000E-01   R= 6.94939135E-01   Y= 2.00912163E-02   Z= 1.51275485E-01   PSI= 3.97896514E-02
X= 7.20000000E-01   R= 7.01304083E-01   Y=-1.23167902E-05   Z= 1.32316289E-01   PSI= 4.67280386E-02

X= 7.80000000E-01   R= 6.98778666E-01   Y= 1.67874101E-01   Z= 3.14341925E-01   PSI= 0.
X= 7.80000000E-01   R= 6.99271594E-01   Y= 1.66414119E-01   Z= 3.12979142E-01   PSI= 3.41887158E-04
X= 7.80000000E-01   R= 7.00698582E-01   Y= 1.62187590E-01   Z= 3.09033995E-01   PSI= 1.36659155E-03
X= 7.80000000E-01   R= 7.03004416E-01   Y= 1.55358048E-01   Z= 3.02659130E-01   PSI= 3.06679722E-03
X= 7.80000000E-01   R= 7.06123488E-01   Y= 1.46119810E-01   Z= 2.94035929E-01   PSI= 5.44413801E-03
X= 7.80000000E-01   R= 7.09947955E-01   Y= 1.34792296E-01   Z= 2.83462546E-01   PSI= 8.47881147E-03
X= 7.80000000E-01   R= 7.14322554E-01   Y= 1.21835374E-01   Z= 2.71368233E-01   PSI= 1.21346707E-02
X= 7.80000000E-01   R= 7.19210973E-01   Y= 1.07356591E-01   Z= 2.57853377E-01   PSI= 1.64440873E-02
X= 7.80000000E-01   R= 7.24591602E-01   Y= 9.14199524E-02   Z= 2.42977722E-01   PSI= 2.14070611E-02
X= 7.80000000E-01   R= 7.30449774E-01   Y= 7.40689029E-02   Z= 2.26781821E-01   PSI= 2.70235921E-02
X= 7.80000000E-01   R= 7.36751932E-01   Y= 5.54028294E-02   Z= 2.09358444E-01   PSI= 3.32936805E-02
X= 7.80000000E-01   R= 7.42949722E-01   Y= 3.70458796E-02   Z= 1.92223611E-01   PSI= 3.97896514E-02
X= 7.80000000E-01   R= 7.49120716E-01   Y= 1.87682977E-02   Z= 1.75162861E-01   PSI= 4.67280386E-02
X= 7.80000000E-01   R= 7.55460289E-01   Y=-8.59365627E-06   Z= 1.57636044E-01   PSI= 5.42237553E-02

X= 8.40000000E-01   R= 7.48308629E-01   Y= 1.70938064E-01   Z= 3.40868009E-01   PSI= 0.
X= 8.40000000E-01   R= 7.48774593E-01   Y= 1.69638828E-01   Z= 3.39667811E-01   PSI= 3.41887158E-04
X= 8.40000000E-01   R= 7.50132917E-01   Y= 1.65851442E-01   Z= 3.36169130E-01   PSI= 1.36659155E-03
X= 8.40000000E-01   R= 7.52334650E-01   Y= 1.59712399E-01   Z= 3.30498055E-01   PSI= 3.06679722E-03
X= 8.40000000E-01   R= 7.55321601E-01   Y= 1.51383950E-01   Z= 3.22804468E-01   PSI= 5.44413801E-03
X= 8.40000000E-01   R= 7.58997210E-01   Y= 1.41135329E-01   Z= 3.13337079E-01   PSI= 8.47881147E-03
X= 8.40000000E-01   R= 7.63217648E-01   Y= 1.29367575E-01   Z= 3.02466359E-01   PSI= 1.21346707E-02
X= 8.40000000E-01   R= 7.67945558E-01   Y= 1.16184848E-01   Z= 2.90288526E-01   PSI= 1.64440873E-02
X= 8.40000000E-01   R= 7.73159275E-01   Y= 1.01647557E-01   Z= 2.76859384E-01   PSI= 2.14070611E-02
X= 8.40000000E-01   R= 7.78843993E-01   Y= 8.57969824E-02   Z= 2.62217069E-01   PSI= 2.70235921E-02
X= 8.40000000E-01   R= 7.84976411E-01   Y= 6.86980963E-02   Z= 2.46421598E-01   PSI= 3.32936805E-02
X= 8.40000000E-01   R= 7.91041936E-01   Y= 5.17857271E-02   Z= 2.30798427E-01   PSI= 3.97896514E-02
X= 8.40000000E-01   R= 7.97127448E-01   Y= 3.48176263E-02   Z= 2.15123772E-01   PSI= 4.67280386E-02
X= 8.40000000E-01   R= 8.03274085E-01   Y= 1.76790947E-02   Z= 1.99291677E-01   PSI= 5.42237553E-02
X= 8.40000000E-01   R= 8.09616659E-01   Y=-5.76366770E-06   Z= 1.82954902E-01   PSI= 6.22768016E-02

END THIS CASE, HALLELUJAH
```

Complete Program

The complete program including comments for the sample case, the flow diagram, and the deck setup is reproduced herein.

```
      PROGRAM D1290 (INPUT=1001,OUTPUT=1001,TAPE5=INPUT,TAPE6=OUTPUT,
     1 TAPE8,TAPE9,TAPE10,TAPE11,TAPE12,TAPE13)
C
C     TAPE8  TO SAVE DERIVATIVE OF PRESSURE AT EACH X FOR EACH PSI
C     TAPE9  TO SAVE PRESSURE AT EACH X FOR EACH PSI
C     TAPE10 TO SAVE X AND CORRESPONDING ZS,RS,RC,COST,SINT
C     TAPE11 TO SAVE TS,ES,PS,RHOS,US,PSIS,HS,(EVIS(I),I=1,IMAX)
C     TAPE12 TO SAVE PHYSICAL SPACE DATA
C     TAPE13 TO SAVE COMMON FOR PICKUP TAPE
C
C     BL WEIGEL FOR WILLIAM L GROSE,APD,GAS PHYSICS SECTION
C        INVERSE TECHNIQUE FOR DETERMINING THE FLOW FIELD IN A SHOCK
C        LAYER ABOUT A SMOOTH SYMMETRIC BODY TRAVELING AT HYPERSONIC
C        SPEEDS
C        PHASE 3, A DIRECT NON-EQUILIBRIUM CALCULATION
C
C        CALINTH,INTEGRATION ROUTINE
C        THE NUMERICAL INTEGRATION ALGORITHM USED IS FOUND IN -A METHOD
C        FOR THE NUMERICAL INTEGRATION OF COUPLED FIRST ORDER
C        DIFFERENTIAL EQUATIONS WITH GREATLY DIFFERENT TIME CONSTANTS-
C        BY CHARLES E. TREANOR,CONTRACT NO.NASR-119,CAL REPORT NO.
C        AG-1729-A-4,JANUARY 1964. CORNELL AERONAUTICAL LABORATORY,INC.
C        CORNELL UNIVERSITY, BUFFALO,N.Y.
C
C        ITR1 - NEWTON-RAPHSON ITERATION METHOD
C        FTLUP - INTERPOLATION ROUTINE
C
C                                   R        .SHOCK
C                                           .
C                                   1     .
C     B SHOCK GEOMETRY              1          .
C                                   1 X.    .     BODY
C                                   1 /   .
C                                   1.
C                                   1  .
C                                   .  . . .   .   .  . .   Z
C                                   1  .
C                                   1.
C                                   1 .   .
C                                   1  .    .
C                                   1          .
C                                   1     .
C          INPUT
C     READ IN 1 CARD, 80 COLUMNS, BY FORMAT(8A10) FOR CASE ID
C          INPUT DEFINITIONS --- NAMELIST INPUT
C
C     $NAM1
C     DELX   = INCREMENT ALONG SHOCK
C     ZSTERM= LENGTH OF SYMMETRY AXIS ,Z
C     IMAX   = MAXIMUM NUMBER OF I-S,SPECIES,  LESS THAN OR = 25
C     JMAX   = MAXIMUM NUMBER OF J-S,REACTIONS,LESS THAN OR = 50
C     IBUG   = 0  DEBUG PRINT OUTS
C            = 1,NO DEBUG PRINT OUTS, 1 UNLESS INPUT OTHERWISE
C     MJ     = CODE INDICATING WHICH SPECIES, I, TO USE TO CALCULATE
C              COUPLING FACTOR, PHI SUB J, FOR REACTION J
C     M      = 1 FOR VIBRATIONAL NON-EQUILIBRIUM.
C          = 0 FOR VIBRATIONAL EQUILIBRIUM
C     R      = UNIVERSAL GAS CONSTANT, ERG/MOLE DEG K
C     GAMMA = RATIO OF SPECIFIC HEATS
C     CIINF = FREE STREAM MASS FRACTION FOR EACH SPECIES
```

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C      PINF   = FREE STREAM PRESSURE, DYNES/ CM**2
C      TINF   = FREE STREAM TEMPERATURE, DEG.K
C      VINF   = FREE STREAM VELOCITY, CM/SEC
C      MUI    = MOLECULAR WEIGHT FOR EACH SPECIES, GM/MOLE
C      THETAI= CHARACTERISTIC VIBRATIONAL TEMPERATURE,DEG.K
C      DGENI = FUDGE FACTOR TO PERMIT APPROXIMATING POLYATOMIC MOLECULE
C               BY DIATOMIC MOLECULE
C      FI     = 0 FOR MONATOMIC SPECIES
C             = 1 FOR ALL OTHERS
C      DELHI = HEAT OF FORMATION,ERGS/MOLE
C      DELI   = DISSOCIATION ENERGY OF SPECIES
C      EVI    = VIBRATIONAL  ENERGY OF SPECIES
C      LI     = NUMBER OF ELECTRONIC LEVELS FOR EACH SPECIES     LI.LE.20
C      GIL    = DEGENERACY OF L-TH ELECTRONIC LEVEL FOR I-TH SPECIES
C      EPSIIL= L-TH ELECTRONIC ENERGY LEVEL FOR I-TH SPECIES
C      AJ     = FREQUENCY FACTOR IN ARRHENIUS TYPE RATE EQ.
C      BJ     = TEMPERATURE EXPONENT IN ARRHENIUS TYPE RATE EQ.
C      EJ     =                          IN ARRHENIUS TYPE RATE EQ.
C      AIJ    = FACTOR TO ALLOW USE OF GENERAL SPECIES IN REACTION EQS IF
C               DESIRED, =1.0 OR =0.0
C      NUIJ   = STOICHIOMETRIC COEFFICIENTS OF I-IH REACTANT IN J-TH
C               REACTION
C      NUPIJ = STOICHIOMETRIC COEFFICIENT  FOR I-TH PRODUCT IN J-TH
C               REACTION
C      ALPIK = FACTORS IN EQ. FOR VIBRATIONAL RELAXATION TIME
C      BETAIK= FACTORS IN EQ. FOR VIBRATIONAL RELAXATION TIME
C      SIGIK = FACTORS IN EQ. FOR VIBRATIONAL RELAXATION TIME
C      XI     = INITIAL COMPUTING INTERVAL,    .0001220703125 UNLESS INPUT
C      ELE1   = (2*IMAX+1) VALUES USED BY INTEGRATION SCHEME
C                NORMALLY .1,.5 OR .05
C      ELE2   = (2*IMAX+1) VALUES USED BY INTEGRATION SCHEME
C                NORMALLY .05,.1 OR .01  AND.LT.ELE1
C      XPST    = 99 OR LESS X-S AT WHICH PHYSICAL SPACE CALCULATIONS ARE
C                DESIRED. THEY MUST BE MULTIPLES OF DELX IN ORDER TO
C                HAVE RS,COST,ZS AND SINT VALUES
C                AND LAST MUST BE .GT.X AT ZSTERM
C                THEREFORE, XPST(NXPST) SET = X AT ZSTERM + 100.0 IN
C                PROGRAM
C               XPST(1) MAY NOT BE 0.0
C                THEREFORE, XPST(1) SET = DELX IN PROGRAM
C      NXPST   = NUMBER OF X-S AT WHICH PHYSICAL SPACE CALCULATIONS ARE
C                DESIRED
C      IPF     = PRINT FREQUENCY, 5 UNLESS INPUT OTHERWISE
C               IPF NOT IN COMMON THEREFORE IT MAY BE VARIED ON PICKUP RUN
C      CIMAX = MAXIMUM CJ OR COMPUTING INTERVAL
C               0.0625 UNLESS INPUT OTHERWISE
C               CIMAX NOT IN COMMON THEREFORE IT MAY BE VARIED ON PICKUP
C               RUNS
C      TIMER =  TIME,IN DECIMAL SECONDS, REQUESTED ON JOB CARD
C                IF THE JOB DOES NOT TERMINATE IN THE TIME ESTIMATED ON
C                THE JOB CARD, DATA FOR PICKUP WILL BE STORED ON TAPE 13.
C               IT IS = 3600.0 OR 1 HOUR UNLESS INPUT OTHERWISE
C                TIMER NOT IN COMMON THEREFORE IT MAY BE VARIED ON PICKUP
C                RUNS
C      IPICKUP = 0 UNLESS INPUT
C              = 1 TO PICKUP CASE FROM TAPE 13
C      HCHECKT = CONTROL ON SIZE OF COMPUTING INTERVAL IN CHECK
C                IF(ABS(HPREV-H)/H.GT.HCHECK) REDUCE INTERVAL
C      TCHECKT = CONTROL ON SIZE OF COMPUTING INTERVAL IN CHECK
C                IF(ABS(TPREV-T)/T.GE.TCHECK) REDUCE INTERVAL
C      PHMAX   = CONTROL ON COMPUTING INTERVAL .LE.65.0
C      $
C
C         AFTER READING IN NAM1, READ IN THE IMAX SPECIES BY FORMAT(8A10)
C         10 SPACES PER SPECIES
C         THEN READ IN THE JMAX REACTIONS BY THE SAME FORMAT USING 20
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```
C         SPACES PER REACTION
C         IF THE SPECIES AND REACTIONS ARE NOT READ IN,
C         IMAX/8 PLUS JMAX/4  BLANK CARDS MUST BE PUT IN THE DECK
C
C                   STOPS
C      STOP 1 INCORRECT INPUT
C      STOP 6  EOF 10 IN MAIN
C      STOP 13  IN SHOCKG
C      STOP 30 IN CHECK WHEN COMPUTING INTERVAL.LT.1.0E-15
C      STOP 50 EOF 9 IN FDPDX
C      STOP 66  IN BASIC WHEN NO CONVERGENCE ON E ITERATION
C      STOP 301 IN MAIN FOR ERROR IN XPST ARRAY  OR  IZTERM.GT.500
C      STOP 321 ITR1 STOP IN MAIN
C      STOP 422 IN MAIN AFTER PICKUP TAPE WRITTEN
C      STOP 563 IN MAIN WHEN X.NE.VARI(IPSI)
C      STOP 665 IN MAIN AFTER AN INTEGRATION ATTEMPT
C      STOP 670  IN MAIN WHEN A CI NEGATIVE
C
       COMMON M,IX,IMAX,IPSI,IBUG(15)
       COMMON P( 500),DPDX( 500),VARI( 500)
C         FOLLOWING 7 VARIABLES DIMENSIONED BY IMAX
       COMMON EVIINF(25),THETAI(25),MUI(25),FI(25),DELHI(25),CIINF(25),
      1       LI(25)
       COMMON R,MUINF,DELTA,LAMSQ,OMEGSQ,OMEGA,MU,T,U
C         FOLLOWING 2 VARIABLES DIMENSIONED BY (LMAX IN LI,IMAX)
       COMMON EPSIIL(20,25),GIL(20,25)
       COMMON VAR(52),CUVAR(52),DER(51)
C
       COMMON ZS,RS,RC,SINT,COST,PS,US,PSIS
C         FOLLOWING 4 VARIABLES DIMENSIONED BY JMAX
       COMMON MJ(50),EJ(50),AJ(50),BJ(50)
C         FOLLOWING 3 VARIABLES DIMENSIONED BY IMAX
       COMMON TVI(25),NI(25),DGENI(25)
C         FOLLOWING 3 VARIABLES DIMENSIONED BY (IMAX+1,JMAX) OR
C                                              (IMAX  ,JMAX)
       COMMON NUIJ(26,50),AIJ(25,50),NUPIJ(25,50)
C         FOLLOWING 3 VARIABLES DIMENSIONED BY (IMAX,IMAX)
       COMMON SIGIK(25,25),ALPIK(25,25),BETAIK(25,25)
       COMMON KSTAG,IMAXP2,IMAXL,N,IG,ISTAG,LPS2,LPS1,IMAXP1
       COMMON X,TS,ES,RHOS,HS,RHOURT,PHMAX,AAAAA,PREPSIS,PREX,PRERU
C             EVIS(IMAX)
       COMMON EVIS(25),XPST(100)
C
       COMMON /LAB2/ DELX,ZSTERM,IZTERM
       COMMON /LAB3/ EINF,PINF,RHOINF,VINF,E,JMAX,KEYINT,RHO,HSTAG
       COMMON /LAB4/ PFTL,KITR1,EITR1
       COMMON /LAB5/ IUNEG
       COMMON /LAB6/ ELB,SPEC,CJ,TPREV,HPREV,HCHECK,TCHECK
       COMMON /LAB7/ ITNEG,IEXP
       COMMON /LAB8/ ELE1(51),ELE2(51),NERR
C                 SPECIE(IMAX),REACT(JMAX),DELI(IMAX)
       DIMENSION SPECIE(25),REACT(50),IN(8),DELI(25)
C
       DOUBLE PRECISION VAR,XVAR,H,CI,EVI
C
       DIMENSION  RUT(200),PSISTG(200)
       DIMENSION ENG(11),ENGI(11)
       DIMENSION CIG(25,6),EIG(25,6)
       DIMENSION PSIG(6),TG(6),HG(6),CIT(6),EIT(6),EG(6)
C                 CM(IMAX),CI(IMAX),EVI(IMAX)
       DIMENSION CM(25  ),CI(25  ),EVI(25  )
       DIMENSION XX(3),XXX(3)
C         XX AND XXX ARE TOKEN DIMENSIONS WHICH WILL CHANGE AS THE
C         DIMENSION STATEMENTS ARE CHANGED...THEY ARE USED FOR PICKUP RUN
C
```

```
      EQUIVALENCE (VAR(1),XVAR),(VAR(2),H),(VAR(3),CI(1))
C                    VAR(2+IMAX+1)=EVI(1)
      EQUIVALENCE(M,XX(1)),(DELX,XXX(1))
C
      REAL MUI,LAMSQ,MUINF,MU
      REAL NI
      REAL MINF,MINFSQ,LAMBDA
      REAL NUIJ,NUPIJ
C
C     INPUT
C
      NAME LIST/NAM1/ DELX,ZSTERM,IMAX,JMAX,IBUG,MJ,M,R,GAMMA,
     1 CIINF,PINF,TINF,VINF,MUI,THETAI,DGENI,FI,DELHI,DELI,EVI,LI,
     2 GIL,EPSIIL,AJ,BJ,EJ,AIJ,NUIJ,NUPIJ,ALPIK,BETAIK,SIGIK,XI,CIMAX,
     3 ELE1,ELE2,XPST,NXPST,IPF,TIMER,IPICKUP,HCHECKT,TCHECKT,PHMAX
C
      EXTERNAL FOFTS
C                    INITIALIZE
      REWIND 8
      REWIND 9
      REWIND 10
      REWIND 11
      REWIND 12
      REWIND 13
      NERR=0
C                                         TIMER= ONE HOUR
      TIMER=3600.0
      DO 5 I=1,15
5     IBUG(I)=1
      NXPST=2
      IPICKUP=0
      ICHEK=0
      ITNEG=0
      IEXP=0
      NEG=0
      IGK=0
      IUNEG=0
      DELZS=.001953125
      DELX=.015625
      XI=.0001220703125
      CIMAX=.0625
      IPF=5
      DO 10 I=1,52
      VAR(I)=0.
      CUVAR(I)=0.
      IF (I.EQ.52) GO TO 10
      DER(I)=0.
      ELE1(I)=0.
      ELE2(I)=0.
10    CONTINUE
C                    READ INPUT
      READ (5,15) (IN(I),I=1,8)
15    FORMAT (8A10)
      READ (5,NAM1)
      IF (IPICKUP.EQ.0) GO TO 60
      PRINT 15, (IN(I),I=1,8)
C     READ PICKUP FROM TAPE13
C                    THIS SHOULD PICKUP ALL COMMON AND LABELED COMMON
C                    PLEASE CHECK DIMENSIONS IF THERE ARE PICKUP PROBLEMS
C
      READ (13) (XX(I),I=1,8961),(XXX(I),I=1,128)
      DO 20 I=1,IZTERM
      READ (13) X,ZS,RS,RC,COST,SINT
      CALL RECOUT (10,1,0,X,ZS,RS,RC,COST,SINT)
      READ (13) (DPDX(J),J=I,IZTERM)
```

```
      CALL RECOUT (8,2,0,DPDX,I,IZTERM,1)
      READ (13) IX,TS,ES,PS,RHOS,US,PSIS,HS
      READ (13) (EVIS(J),J=1,IMAX)
      CALL RECOUT (11,1,0,IX,TS,ES,PS,RHOS,US,PSIS,HS)
      CALL RECOUT (11,2,0,EVIS,1,IMAX,1)
      READ (13) X
      READ (13) (P(J),J=I,IZTERM)
      CALL RECOUT (9,1,0,X)
      CALL RECOUT (9,2,0,P,I,IZTERM,1)
20    CONTINUE
      IF (KSTAG.EQ.0) GO TO 30
      DO 25 I=1,KSTAG
      READ (13) K,RHOURT,VAR(1),PSIS
      CALL RECOUT (12,1,0,K,RHOURT,VAR(1),PSIS)
25    CONTINUE
30    REWIND 8
      REWIND 9
      REWIND 10
      REWIND 11
      REWIND 13
      IREAD=IPSI
      IF (IPSI.EQ.6.AND.ISTAG.EQ.1) IREAD=IPSI-1
      DO 35 I=1,IREAD
      CALL RECIN (11,1,IRECIN,IX,TS,ES,PS,RHOS,US,PSIS,HS)
      CALL RECIN (11,2,IRECIN,EVIS,1,IMAX,1)
35    CONTINUE
      DO 40 I=1,IREAD
      CALL RECIN (9,1,IRECIN,X)
      CALL RECIN (9,2,IRECIN,P,I,IZTERM,1)
      CALL RECIN (8,2,IRECIN,DPDX,I,IZTERM,1)
40    CONTINUE
      READ (13) (XX(I),I=1,8961),(XXX(I),I=1,128)
      REWIND 13
      PRINT 45
45    FORMAT (24H1----- PICKUP CASE -----/)
      PRINT 50, IMAXL,(XPST(I),I=1,10),(ELE2(I),I=1,5)
50    FORMAT (1X,6HIMAXL=,I3,/1X,5HXPST=,2(5E17.8/)/1X,5HELE2=,5E17.8/1X
     1,6HKSTAG=,I3/)
      PRINT 600, IPSI,IX,XVAR,H,MU,PFTL,RHO,U,T,E,SPEC,SUMCI
      IMAXP1=IMAX+1
      PRINT 605, (VAR(I),I=3,IMAXP1)
      PRINT 610, (CM(I),I=1,IMAX)
      IMAXP3=2+IMAX+1
      PRINT 615, (VAR(I),I=IMAXP3,IMAXL)
      SPEC=0
      IX=IX-1
      IBUG(11)=0
      KEYINT=0
      KIPF=IPF-1
      HCHECK=HCHECKT
      TCHECK=TCHECKT
      PRINT 55, IPF,CIMAX,TIMER,HCHECKT,TCHECKT,IZTERM,KSTAG
55    FORMAT (10H       IPF=I2,10H    CIMAX=E15.8,10H    TIMER=E15.8,10H
     1 HCHECKT=E15.8,10H  TCHECKT=E15.8/10H   IZTERM=I2,10H    KSTAG=I3/
     2)
      GO TO 560
60    CONTINUE
C
      IF (IBUG(1).EQ.1) GO TO 65
      WRITE (6,NAM1)
65    PRINT 70
70    FORMAT (1H1)
      PRINT 15, (IN(I),I=1,8)
C
C        SUM OF CIINF SHOULD BE 1.0
      SUM=0.
```

```
      DO 75 I=1,IMAX
75    SUM=SUM+CIINF(I)
      IF (SUM.EQ.1.0) GO TO 85
      PRINT 80, SUM,(CIINF(I),I=1,IMAX)
80    FORMAT (34H SUM OF CIINF SHOULD BE 1.0. IT IS,E17.8,8H  CIINF=/5(5
     1E17.8))
      STOP 1
C                                                                   STOP 1
85    CONTINUE
      HCHECK=HCHECKT
      TCHECK=TCHECKT
C        READ IN SPECIES AND REACTIONS
      READ (5,90) (SPECIE(I),I=1,IMAX)
90    FORMAT (8A10)
      PRINT 95
95    FORMAT (//)
      PRINT 100
100   FORMAT (12H     SPECIES/)
      DO 110 I=1,IMAX
105   FORMAT (I5,A10)
110   PRINT 105, I,SPECIE(I)
      PRINT 95
      JMAX2=2*JMAX
      READ (5,90) (REACT(I),I=1,JMAX2)
      PRINT 115
115   FORMAT (14H     REACTIONS/)
      J=0
      DO 120 I=1,JMAX2,2
      J=J+1
120   PRINT 125, J,REACT(I),REACT(I+1)
125   FORMAT (I5,2A10)
      PRINT 95
C                    PRINT INPUT
      PRINT 130, IPF
130   FORMAT (17H PRINT FREQUENCY=I3)
      PRINT 135, HCHECKT,TCHECKT,PHMAX
135   FORMAT (10H  HCHECKT=E15.8,10H  TCHECKT=E15.8,10H     PHMAX=E15.8)
      NXPSTP1=NXPST+1
      PRINT 140, XI,CIMAX,ELE1,ELE2,NXPST,(XPST(I),I=1,NXPSTP1)
140   FORMAT (4H XI=E15.8/7H CIMAX=E15.8/6H ELE1=2E17.8/7(7E17.8/)/6H EL
     1E2=2E17.8/7(7E17.8/)/7H NXPST=I3/6H XPST=/15(7E17.8/)/)
      PRINT 145, DELX,ZSTERM,TIMER,IPICKUP
145   FORMAT (6H DELX=E15.8/8H ZSTERM=E15.8/7H TIMER=E15.8/9H IPICKUP=I1
     1//)
      PRINT 150, IMAX,JMAX,M,R,GAMMA,PINF,TINF,VINF,IBUG
150   FORMAT (6H IMAX=I2,8H   JMAX=I2,5H   M=I1/3H R=E15.8/7H GAMMA=E15.
     18/6H PINF=E15.8/6H TINF=E15.8/6H VINF=E15.8/6H IBUG=I1,14I5/)
      PRINT 155
155   FORMAT (5X,3HMUI12X,6HTHETAI9X,5HDGENI10X,2HFI13X,5HDELHI10X,4HDEL
     1I11X,5HCIINF10X,3HEVI12X,2HLI/)
      DO 165 I=1,IMAX
160   FORMAT (7E15.5,D15.6,I5)
165   PRINT 160, MUI(I),THETAI(I),DGENI(I),FI(I),DELHI(I),DELI(I),CIINF(
     1I),EVI(I),LI(I)
      PRINT 170
170   FORMAT (/6X,2HMJ6X,2HAJ16X,2HBJ16X,2HEJ/)
      DO 180 J=1,JMAX
175   FORMAT (I8,3E18.8)
180   PRINT 175, MJ(J),AJ(J),BJ(J),EJ(J)
      PRINT 95
      IMAXP1=IMAX+1
      DO 225 I=1,IMAX
      PRINT 185, I,(GIL(L,I),L=1,IMAXP1)
185   FORMAT (4H  I=I5,23H  (GIL(L,I),L=1,IMAX+1)/(3(7E18.8/)))
```

```
      PRINT 190, I,(EPSIIL(L,I),L=1,IMAXP1)
 190  FORMAT (4H  I=I5,26H  (EPSIIL(L,I),L=1,IMAX+1)/3(7E18.8/))
      PRINT 195, I,(AIJ(I,J),J=1,JMAX)
 195  FORMAT (4H  I=I5,21H  (AIJ(I,J),J=1,JMAX)/5(7E18.8/))
      PRINT 200, I,(ALPIK(K,I),K=1,IMAX)
 200  FORMAT (4H  I=I5,23H  (ALPIK(K,I),K=1,IMAX)/3(7E18.8/))
      PRINT 205, I,(BETAIK(K,I),K=1,IMAX)
 205  FORMAT (4H  I=I5,24H  (BETAIK(K,I),K=1,IMAX)/3(7E18.8/))
      PRINT 210, I,(SIGIK(K,I),K=1,IMAX)
 210  FORMAT (4H  I=I5,23H  (SIGIK(K,I),K=1,IMAX)/3(7E18.8/))
      PRINT 215, I,(NUIJ(I,J),J=1,JMAX)
 215  FORMAT (4H  I=I5,22H  (NUIJ(J,I),J=1,JMAX)/5(7E18.8/))
      PRINT 220, I,(NUPIJ(I,J),J=1,JMAX)
 220  FORMAT (4H  I=I5,23H  (NUPIJ(J,I),J=1,JMAX)/5(7E18.8/))
      PRINT 95
 225  CONTINUE
      IM=IMAX+1
      PRINT 215, IM,(NUIJ(IM,J),J=1,JMAX)
      PRINT 230
 230  FORMAT (2X,9HEND INPUT//)
      PRINT 95
C
C          DEFINE SHOCK GEOMETRY
C          AT EACH X FIND ZS,RS,RC,COST,SINT AND STORE ON TAPE 10
C
      CALL SHOCKG (DELX,ZSTERM,IZTERM)
C
C          IZTERM=NUMBER OF DELTA X INCREMENTS AS GENERATED IN SHOCKG
      IF (NXPST-1.GT.IZTERM) PRINT 235
 235  FORMAT (84H NXPST-1.GT.IZTERM,IT MUST BE .LE. FOR PHYSICAL SPACE C
     1ALCULATIONS - SEE DO 700 LOOP/)
      IF (NXPST-1.GT.IZTERM) STOP 301
      PRINT 415, IZTERM
      IF (IZTERM.GT.500) PRINT 240
 240  FORMAT (1X,50HIZTERM.GT.500 CHANGE DIMENSION OF P,DPDX AND VARI )
      IF(IZTERM.GT.500) STOP 301
C                                                                STOP 301
C              FREESTREAM QUANTITIES
      SUM=0
      DO 245 I=1,IMAX
 245  SUM=SUM+CIINF(I)/MUI(I)
      MUINF=1./SUM
      RHOINF=MUINF*PINF/(R*TINF)
      AINF=SQRT(GAMMA*R*TINF/MUINF)
      MINF=VINF/AINF
C              FOR EACH I, SPECIE
      EINF=0
      DO 275 I=1,IMAX
      TEM=EXP(THETAI(I)/TINF)
      EVIINF(I)=(R*THETAI(I))/(MUI(I)*(TEM-1.))*FI(I)
C              FOR EACH L, REACTION LEVEL
      GSUM=0
      GESUM=0
      LII=LI(I)
      IF (LII.LE.20) GO TO 255
      PRINT 250, LII
 250  FORMAT (1X,4HLII=,I3,2X,28HA LEVEL IN LI ARRAY IS GT 20/2X,43HNEED
     1 TO CHANGE DIMENSION OF EPSIIL AND GIL )
 255  CONTINUE
      DO 265 L=1,LII
      TEM1=EXP(-EPSIIL(L,I)/TINF)
      GSUM=GSUM+GIL(L,I)*TEM1
      GESUM=GESUM+GIL(L,I)*EPSIIL(L,I)*TEM1
      IF (IBUG(1).NE.0) GO TO 265
      PRINT 260, I,L,GSUM,GESUM,TEM1,EPSIIL(L,I),TINF,GIL(L,I)
 260  FORMAT (36H I,L,GSUM,GESUM,TEM1,EPSIIL,TINF,GIL/2I5,6E18.8/)
```

```
265   CONTINUE
      EEIINF=R/MUI(I)*(GESUM/GSUM)
      EIINF=1.5*R*TINF/MUI(I)+FI(I)*R*TINF/MUI(I)+EVIINF(I)+EEIINF+DELHI
     1(I)/MUI(I)
      EINF=EINF+EIINF*CIINF(I)
      IF (IBUG(2).NE.0) GO TO 275
      PRINT 270, I,EINF,TEM,THETAI(I),TINF,MUI(I),EVIINF(I),GSUM,GESUM,E
     1EIINF,EIINF,FI(I),DELHI(I)
270   FORMAT (34H I,EINF,TEM,THETAI,TINF,MUI,EVIINF/I5,6E18.8/33H GSUM,G
     1ESUM,EEIINF,EIINF,FI,DELHI/6E18.8/)
275   CONTINUE
      PRINT 280, MUINF,RHOINF,AINF,MINF,EIINF,EINF,EEIINF
280   FORMAT (31H   +++ FREESTREAM QUANTITIES +++/8H   MUINF=E15.8,10H    R
     1HOINF=E15.8,8H    AINF=E15.8,8H    MINF=E15.8,9H    EIINF=E15.8/7H    E
     2INF=E15.8/9H   EEIINF=/(8E18.8/))
      PRINT 285, (EVIINF(I),I=1,IMAX)
285   FORMAT (9H  EVIINF=/(6E18.8))
C                                     END FREESTREAM QUANTITIES
C                                     BEGIN QUANTITIES BEHIND SHOCK
C                                     FOR RANGE OF X
      PRINT 290
290   FORMAT (//33H  +++ QUANTITIES BEHIND SHOCK +++/6X,2HTS15X,2HES16X,
     12HPS16X,4HRHOS14X,2HUS16X,4HPSIS14X,2HHS)
      IEOF=10
      IF (NXPST.EQ.2) PRINT 310
      IF (NXPST.EQ.2) STOP 2
      NXPSTM1=NXPST-1
      ITK=0
      DO 385 IX=1,IZTERM
C
C      USE RECOUT  TO  WRITE
C      USE RECIN   TO  READ
C
      CALL RECIN (10,1,IRECIN,X,ZS,RS,RC,COST,SINT)
      IF (ENDFILE 10) 295,305
295   PRINT 300, IEOF
300   FORMAT (14H  IN MAIN EOF I3)
      STOP 6
C                                                                  STOP 6
305   CONTINUE
310   FORMAT (78H NXPST=2 - SURELY SOME PHYSICAL SPACE VALUES ARE DESIRE
     1D -- MAKE IT 3 AT LEAST)
      DO 315 IT=2,NXPSTM1
      IF (ABS(XPST(IT)-X).GT.0.000001) GO TO 315
      ITK=ITK+1
315   CONTINUE
      TEM=SINT**2
      LAMBDA=RHOINF*VINF*SINT
      OMEGA=PINF+RHOINF*VINF**2*TEM
      DELTA=EINF+PINF/RHOINF+(VINF**2*TEM)/2.
      LAMSQ=LAMBDA**2
      OMEGSQ=OMEGA**2
      MINFSQ=MINF**2
      TEM=TEM*MINFSQ
      TG=(TINF*(2.*GAMMA*TEM-(GAMMA-1.0))*((GAMMA-1.0)*TEM+2.))/((GAMMA+
     11.)**2*TEM)
      IF (IBUG(5).NE.0) GO TO 325
      PRINT 320, X,SINT,LAMBDA,OMEGA,DELTA,TEM,TG
320   FORMAT (39H X, SINT, LAMBDA, OMEGA, DELTA, TEM, TG/7E17.8/)
C
C                                     C5.002 LF-ITR1
325   CONTINUE
      DELTTS=10.
```

```
      E1=.0001
      E2=.001
      MAXI=50
      CALL ITR1 (TG,DELTTS,FOFTS,E1,E2,MAXI,ICODE)
      IF (ICODE.EQ.1) PRINT 330
330   FORMAT (34H  MAXIMUM ITERATION EXCEEDED *****//)
      IF (ICODE.EQ.2) PRINT 335
335   FORMAT (30H  DERIVATIVE =0. IN ITR1 *****//)
      IF (ICODE.EQ.1.OR.ICODE.EQ.2) STOP 321
C                                                                STOP 321
      TS=TG
      ES=0.
      DO 360 I=1,IMAX
      IF (M.EQ.1) EVIS(I)=EVIINF(I)
      IF (M.EQ.1) GO TO 345
      TEM=EXP(THETAI(I)/TS)
      EVIS(I)=(R*THETAI(I))/(MUI(I)*(TEM-1.))*FI(I)
      IF (IBUG(5).NE.0) GO TO 345
      PRINT 340, IX,I,TEM,EVIS(I)
340   FORMAT (19H  IX,I,TEM,EVIS(I)=2I5,2E18.8)
345   SUMG=0.
      SUMGE=0.
      LII=LI(I)
      DO 350 L=1,LII
      TEM1=EXP(-EPSIIL(L,I)/TS)
      SUMG=SUMG+TEM1*GIL(L,I)
350   SUMGE=SUMGE+TEM1*GIL(L,I)*EPSIIL(L,I)
      EEIS=(R/MUI(I))*(SUMGE/SUMG)
      EIS=(1.5*R*TS)/MUI(I)+(FI(I)*R*TS)/MUI(I)+1.0*EVIS(I)+EEIS+DELHI(I
     1)/MUI(I)
      IF (IBUG(5).NE.0) GO TO 360
      PRINT 355, EEIS,EIS,SUMG,SUMGE
355   FORMAT (22H  EEIS,EIS,SUMG,SUMGE=4E18.8)
360   ES=ES+EIS*CIINF(I)
      PS=SQRT(OMEGSQ-2.*LAMSQ*(DELTA-ES))
      RHOS=(MUINF*PS)/(R*TS)
      US=VINF*COST
      PSIS=(RHOINF*VINF*RS**2)/2.
      HS=PS/RHOS+ES
C
C          WRITE ON TAPE 11 AT EACH X
      CALL RECOUT (11,1,0,IX,TS,ES,PS,RHOS,US,PSIS,HS)
      CALL RECOUT (11,2,0,EVIS,1,IMAX,1)
C
      PRINT 365, TS,ES,PS,RHOS,US,PSIS,HS
365   FORMAT (/7E18.8)
      PRINT 370, IX,(EVIS(I),I=1,IMAX)
370   FORMAT (5H  IX=I3,7H  EVIS=/4(7E18.8/)/)
      IF (IBUG(5).NE.0) GO TO 385
      PRINT 375
375   FORMAT (50H  ////////////////////////////////////////////////)
      PRINT 380, IX,TS,PS,RHOS,US,PSIS,HS,ES
380   FORMAT (29H  IX,TS,PS,RHOS,US,PSIS,HS,ES/I4,7E18.8/)
385   CONTINUE
      REWIND 10
      END FILE 11
      REWIND 11
      PRINT 390, ITK,NXPST
390   FORMAT (//2X,10HXXXXX ITK=I3,2X,6HNXPST=I3,2X,5HXXXXX//)
      IF (ITK.GE.3*NXPST/4) GO TO 400
      PRINT 395
395   FORMAT (89H  NUMBER OF X-S IN XPST ARRAY,ITK,IS .LT. 3*NXPST/4 - R
     1EEXAMINE DELX,NXPST AND XPST ARRAY)
C                                                   SECOND    STOP 301
      STOP 301
400   CONTINUE
```

```
C                      END COMPUTATION OF QUANTITIES BEHIND SHOCK
C
      CALL FOPDX
C                FIND PRESSURE,P,AT EACH X FOR EACH STREAMLINE AND
C                STORE ON TAPE 9
C                FIND P DOT, DPDX, AT EACH X FOR EACH STREAMLINE AND
C                STORE ON TAPE 8
C
C                    INTEGRATE ALONG EACH STREAMLINE PSI
C
C         VAR(1) = XVAR
C         VAR(2)= H,ENTHALPY       VAR(2) MUST BE H,WHICH MAY BE + OR -
C                               CONCENTRATION OF SPECIE
C         VAR(3) = CI(1)
C       -        -
C         VAR(2+IMAX)=CI(IMAX)
C                          EQUILIBRIUM VIBRATIONAL ENERGY
C         VAR(2+IMAX+1)=EVI(1)
C       -        -
C         VAR(2+IMAX+IMAX)=EVI(IMAX)
C
      DO 410 I=1,IMAX
C        TRUNCATE
      Y=FI(I)*(DELI(I)/THETAI(I)+1.0)
      NI(I)=AINT(Y)
C
      IF (IBUG(5).NE.0) GO TO 410
      PRINT 405, I,Y,NI(I)
405   FORMAT (12H  I,Y,NI(I)=I5,2E18.8/)
410   CONTINUE
C
      MU=0.
      N=1+2*IMAX
      IF (M.EQ.0) N=N-IMAX
C                                  INITIALIZE
      PRINT 415, IZTERM
415   FORMAT (9H  IZTERM=I3)
      KSTAG=0
      ISTAG=0
      XPST(1)=DELX
      XPST(NXPST)=VARI(IZTERM)+100.0
      SUMCI=0.
      PRINT 95
      IZTM1=IZTERM-1
      LPS1=1
C
      IPSI=0
C                   BEGIN EACH STREAMLINE COMPUTATION HERE
420   IPSI=IPSI+1
      IF (IPSI.EQ.IZTERM) GO TO 735
425   CONTINUE
      KIPF=0
      IEOF=11
C     ISTAG = 2 FOR STREAMLINE  DELX
      IF (ISTAG.EQ.1) ISTAG=2
      CALL RECIN (11,1,IRECIN,IX,TS,ES,PS,RHOS,US,PSIS,HS)
      CALL RECIN (11,2,IRECIN,EVIS,1,IMAX,1)
      IF (ENDFILE 11) 430,440
430   PRINT 435, IEOF,IPSI
435   FORMAT (5H  EOFI4,57H  IN MAIN, TRY TO COMPUTE PHYSICAL SPACE VALU
     1ES --- IPSI=I3//)
      GO TO 735
440   CONTINUE
```

```
C
      IF (IPSI.EQ.1) HSTAG=HS
C
      CJ=XI
      SPEC=0.0
C          EVALUATE DERIVATIVES WHEN SPEC=0.0
      II=0
C        USE SHOCK VALUES FOR INITIAL COMPUTATION ON EACH STREAMLINE
      KEYINT=0
      IX=0
      T=TS
      IF (M.EQ.0) GO TO 450
      DO 445 I=1,IMAX
445   TVI(I)=TINF
      GO TO 460
450   DO 455 I=1,IMAX
455   TVI(I)=TS
460   RHO=RHOS
      MU=MUINF
      U=US
      DO 465 I=1,IMAX
      MM=2+I
      K=IMAX+MM
      VAR(MM)=0.
      VAR(MM)=CIINF(I)
      VAR(K)=0.
      IF (M.EQ.0) VAR(K)=EVIS(I)
      IF (M.EQ.1) VAR(K)=EVIINF(I)
      EVI(I)=VAR(K)
465   CONTINUE
      E=ES
      H=HS
      IF (IPSI.EQ.6.AND.ISTAG.EQ.0) GO TO 635
C
      IEOF=9
      CALL RECIN (9,1,IRECIN,X)
      CALL RECIN (9,2,IRECIN,P,IPSI,IZTERM,1)
      IF (ENDFILE 9) 430,470
C
470   IEOF=8
      CALL RECIN (8,2,IRECIN,DPDX,IPSI,IZTERM,1)
      IF (ENDFILE 8) 430,475
475   IF (IBUG(3).NE.0) GO TO 485
      PRINT 480, (VARI(IT),DPDX(IT),P(IT),IT=IPSI,IZTERM)
480   FORMAT (33H  (DPDX(IT),P(IT),IT=IPSI,IZTERM)/(6E17.8))
485   CONTINUE
      VAR(1)=X
C      OMIT PSI=0.0 STREAMLINE FOR NOW --- PICK IT UP LATER
      IF (X.NE.0.) GO TO 490
      IG=0
      PRINT 725
      GO TO 730
C
490   CONTINUE
      IF (X.EQ.VARI(IPSI)) GO TO 500
C
      PRINT 495, IPSI,X,VARI(IPSI)
495   FORMAT (6H IPSI=I4,4H  X=E15.8,13H  VARI(IPSI)=E15.8,34H  X AND VA
     1RI(IPSI) SHOULD BE EQUAL/63H  EXAMINE GENERATION OF X,ON TAPE 9,AN
     2DVARI IN FDPDX SUBROUTINE)
      STOP 663
C                                                               STOP 663
500   CONTINUE
C           INITIALIZE
C
```

```
      ELB=0
      SPEC=0
      IF (VAR(1).GT.XPST(LPS1)) LPS1=LPS1+1
      LPS2=LPS1
505   CONTINUE
C                                                         CHECK ON PICKUP
      CALL SECOND (CHECKT)
      IF (IX.NE.1) GO TO 515
      PRINT 510, CHECKT
510   FORMAT (20H ------------CHECKT=E15.8)
515   IF (ICHEK.EQ.1) GO TO 540
      IF ((TIMER-CHECKT).GT.30.) GO TO 560
      IF (IPSI.GT.5) GO TO 525
      PRINT 520
520   FORMAT (1X,/10X,10H$$$$$$$$$$/67H     MUST BE ON OR BEYOND PSI=0.,
     1 IPSI=6, BEFORE PICKUP IS POSSIBLE/10X,10H$$$$$$$$$$/)
525   CONTINUE
      KIPF=0
      IPF=1
C                                                         WRITE PICKUP TAPE
      WRITE (13) (XX(I),I=1,8961),(XXX(I),I=1,128)
      PRINT 530, TIMER,CHECKT
530   FORMAT (30H PICKUP TAPE WRITTEN -- TIMER=E15.8,10H   CHECKT=E15.8/
     1)
      ICHEK=1
      PRINT 600, IPSI,IX,XVAR,H,MU,PFTL,RHO,U,T,E,SPEC,SUMCI
      PRINT 605, (VAR(I),I=3,IMAXP2)
      PRINT 610, (CM(I),I=1,IMAX)
      IMAXP3=2+IMAX+1
      PRINT 615, (VAR(I),I=IMAXP3,IMAXL)
      PRINT 620
      PRINT 535
535   FORMAT (/93H -----------     -----     -----     -----     -----
     1    -----     -----     -----     -----//)
      ITEST=0
540   IF (TIMER-CHECKT.GT.10.) GO TO 560
      REWIND 8
      REWIND 9
      REWIND 10
      REWIND 11
      REWIND 12
      DO 545 I=1,IZTERM
C                                 READ
C                                 WRITE ON 13 TO SAVE FOR PICKUP
      CALL RECIN (10,1,IRECIN,X,ZS,RS,RC,COST,SINT)
      WRITE (13) X,ZS,RS,RC,COST,SINT
      CALL RECIN (8,2,IRECIN,DPDX,I,IZTERM,1)
      WRITE (13) (DPDX(J),J=I,IZTERM)
      CALL RECIN (11,1,IRECIN,IX,TS,ES,PS,RHOS,US,PSIS,HS)
      CALL RECIN (11,2,IRECIN,EVIS,1,IMAX,1)
      WRITE (13) IX,TS,ES,PS,RHOS,US,PSIS,HS
      WRITE (13) (EVIS(J),J=1,IMAX)
      CALL RECIN (9,1,IRECIN,X)
      CALL RECIN (9,2,IRECIN,P,I,IZTERM,1)
      WRITE (13) X
      WRITE (13) (P(J),J=I,IZTERM)
545   CONTINUE
      DO 550 I=1,KSTAG
      CALL RECIN (12,1,IRECIN,IPSI,RHOURT,VAR(1),PSIS)
      WRITE (13) IPSI,RHOURT,VAR(1),PSIS
550   CONTINUE
      PRINT 50, IMAXL,(XPST(I),I=1,10),(ELE2(I),I=1,5),KSTAG
      PRINT 555
555   FORMAT (25H  --- DATA ON TAPE 13 ---/)
```

```
      STOP 422
C                              PICKUP DATA ON TAPE 13                   STOP 422
560   CONTINUE
      IX=IX+1
C
C        CALINTH,  MODIFIED RUNGE-KUTTA
      CALL CALINTH (VAR,DER,ELE1,ELE2,CJ,SPEC,N,CUVAR,ELB,CIMAX,NERR,PHM
     1AX)
C
      IF (NERR.EQ.0) GO TO 575
      IF (NERR.EQ.1) PRINT 565, CJ,N
565   FORMAT (16H BAD INPUT,CJ,N=E17.8,I5)
      IF (NERR.EQ.2) PRINT 570, ELE1,ELE2
570   FORMAT (1X,21HEXAMINE ELE1 AND ELE2/10(7E17.8/))
      IF (NERR.EQ.1.OR.NERR.EQ.2) STOP 665
C                                                                        STOP 665
575   CONTINUE
      IF (IX.EQ.1) GO TO 580
      IF (IPSI.EQ.6.AND.IX.EQ.6) GO TO 580
      IF (VAR(1).GE.VARI(IZTERM)) GO TO 580
      IF (IPSI.LT.6.AND.VAR(1).GE.DELX) GO TO 580
      KIPF=KIPF+1
      IF (KIPF.NE.IPF) GO TO 625
      KIPF=0
C
580   CONTINUE
      IMAXP2=IMAX+2
      SUMCI=0.
      DO 590 ISUM=3,IMAXP2
      IF (VAR(ISUM).LT.0.) NEG=-1
      IF (VAR(ISUM).LT.0.) PRINT 585
585   FORMAT (/5X,21H-----NEGATIVE CI-----/)
590   SUMCI=SUMCI+VAR(ISUM)
      DO 595 ICM=1,IMAX
C
C                      PRINT ANSWERS
595   CM(ICM)=VAR(ICM+2)*MU/MUI(ICM)
      PRINT 600, IPSI,IX,XVAR,H,MU,PFTL,RHC,U,T,E,SPEC,SUMCI
600   FORMAT (2XI2,I5,8X,2HX=D15.8,7X,2HH=D15.8,6X,3HMU=E15.8,7X,2HP=E15
     1.8,5X,4HRHO=E15.8/17X,2HU=E15.8,7X,2HT=E15.8,7X,2HE=E15.8,6X,3HCI=
     2E15.8,1X,8HSUM(CI)=E15.8)
      PRINT 605, (VAR(I),I=3,IMAXP2)
605   FORMAT (10X,9H   CI( 1)=D15.8,9H  CI( 2)=D15.8,9H   CI( 3)=D15.8,9H
     1 CI( 4)=D15.8,9H  CI( 5)=D15.8/10X,9H  CI( 6)=D15.8,9H  CI( 7)=D15
     2.8,9H  CI( 8)=D15.8,9H  CI( 9)=D15.8,9H  CI(10)=D15.8/10X,9H  CI(1
     31)=D15.8,9H  CI(12)=D15.8,9H  CI(13)=D15.8,9H  CI(14)=D15.8,9H  CI
     4(15)=D15.8/10X,9H  CI(16)=D15.8,9H  CI(17)=D15.8,9H  CI(18)=D15.8,
     59H  CI(19)=D15.8,9H  CI(20)=D15.8/10X,9H  CI(21)=D15.8,9H  CI(22)=
     6D15.8,9H  CI(23)=D15.8,9H  CI(24)=D15.8,9H  CI(25)=D15.8)
      PRINT 610, (CM(I),I=1,IMAX)
610   FORMAT (10X,9H  CM( 1)=E15.8,9H  CM( 2)=E15.8,9H  CM( 3)=E15.8,9H
     1 CM( 4)=E15.8,9H  CM( 5)=E15.8/10X,9H  CM( 6)=E15.8,9H  CM( 7)=E15
     2.8,9H  CM( 8)=E15.8,9H  CM( 9)=E15.8,9H  CM(10)=E15.8/10X,9H  CM(1
     31)=E15.8,9H  CM(12)=E15.8,9H  CM(13)=E15.8,9H  CM(14)=E15.8,9H  CM
     4(15)=E15.8/10X,9H  CM(16)=E15.8,9H  CM(17)=E15.8,9H  CM(18)=E15.8,
     59H  CM(19)=E15.8,9H  CM(20)=E15.8/10X,9H  CM(21)=E15.8,9H  CM(22)=
     6E15.8,9H  CM(23)=E15.8,9H  CM(24)=E15.8,9H  CM(25)=E15.8)
      IMAXL=2+IMAX+IMAX
      IMAXP3=2+IMAX+1
      PRINT 615, (VAR(I),I=IMAXP3,IMAXL)
615   FORMAT (10X,9H EVI( 1)=D15.8,9H EVI( 2)=D15.8,9H EVI( 3)=D15.8,9H
     1EVI( 4)=D15.8,9H EVI( 5)=D15.8/10X,9H EVI( 6)=D15.8,9H EVI( 7)=D15
     2.8,9H EVI( 8)=D15.8,9H EVI( 9)=D15.8,9H EVI(10)=D15.8/10X,9H EVI(1
     31)=D15.8,9H EVI(12)=D15.8,9H EVI(13)=D15.8,9H EVI(14)=D15.8,9H EVI
     4(15)=D15.8/10X,9H EVI(16)=D15.8,9H EVI(17)=D15.8,9H EVI(18)=D15.8,
```

```
     59H EVI(19)=D15.8,9H EVI(20)=D15.8/10X,9H EVI(21)=D15.8,9H EVI(22)=
     6D15.8,9H EVI(23)=D15.8,9H EVI(24)=D15.8,9H EVI(25)=D15.8)
      PRINT 620
620   FORMAT (/)
C
      IF (IBUG(11).EQ.0) IBUG(11)=1
625   CONTINUE
      IF (NEG.EQ.-1) PRINT 630
630   FORMAT (31H    A NEGATIVE CONCENTRATION,CI)
      IF (NEG.EQ.-1) STOP 670
C                                                             STOP 670
C
C     WHEN IPSI=6, DELX AND STAGNATION STREAMLINES WILL BE COMPUTED
C
C        IUNEG = 1 IF U**2 NEG. IN BASIC
      IF (IUNEG.EQ.1) GO TO 735
      IF (IPSI.LT.6.AND.VAR(1).LT.XPST(1)) GO TO 505
      IF (ISTAG.EQ.1.OR.ISTAG.EQ.2) GO TO 690
C        ISTAG=0 UNTIL AFTER EXTRAPOLATION FOR PSI=0. STREAMLINE
C        ISTAG=1 FOR PSI =0.0 STREAMLINE
C        ISTAG=2 FOR DELX STREAMLINE AND THEREAFTER
C
635   CONTINUE
      IG=IG+1
      IGC=0
      IGE=IMAX+2
      PSIG(IG)=PSIS
      DO 640 IG1=3,IMAXP2
      IGC=IGC+1
      CIG(IGC,IG)=VAR(IG1)
      IGE=IGE+1
      EIG(IGC,IG)=VAR(IGE)
640   CONTINUE
C
      EG(IG)=E
      TG(IG)=T
      HG(IG)=H
      IF (IPSI.LT.6) PRINT 725
      IF (IPSI.LT.6) GO TO 730
C               IPSI=6    STAGNATION STREAMLINE
C                              AT  DELX EXTRAPOLATE FOR PSI=0. VALUES
      PSI=0.
      MG=1
      CALL FTLUP (PSI,E,MG,IG,PSIG,EG)
      CALL FTLUP (PSI,T,MG,IG,PSIG,TG)
      CALL FTLUP (PSI,H,MG,IG,PSIG,HG)
C
      DO 650 IG2=1,IMAX
      DO 645 IG1=1,6
      CIT(IG1)=CIG(IG2,IG1)
645   EIT(IG1)=EIG(IG2,IG1)
      CALL FTLUP (PSI,CI(IG2),MG,IG,PSIG,CIT)
      IF (CI(IG2).LT.0.0) CI(IG2)=0.00000001
      CALL FTLUP (PSI,EVI(IG2),MG,IG,PSIG,EIT)
      I3=2+IMAX+IG2
      PRINT 646,IG,I3,CIT,CI(IG2),EIT,EVI(IG2),PSIG
  646 FORMAT(2I5/(7E17.8))
650   VAR(2+IMAX+IG2)=EVI(IG2)
      DO 655 IG1=1,6
      CALL RECIN (10,1,IRECIN,X,ZS,RS,RC,COST,SINT)
655   CONTINUE
C               INITIALIZE FOR PSI=0. STREAMLINE
      CJ=XI
      SPEC=0.0
```

```
      II=0
      KEYINT=0
      IX=0
      SUM=0
      DO 660 I=1,IMAX
      SUM=SUM+CI(I)/MUI(I)
      IF (EVI(I).EQ.0.) TVI(I)=0.
      IF (EVI(I).EQ.0.) GO TO 660
      XL=((DGENI(I)*R*THETAI(I))/(MUI(I)*EVI(I))+1.0)
      ALN=ALOG(XL)
      TVI(I)=THETAI(I)/ALN
660   CONTINUE
      PRINT 661,(EVI(I),TVI(I),I=1,IMAX)
  661 FORMAT(5X,D17.8,E17.8)
C
      U=SQRT(2.0*(HSTAG-H))
C
      VAR(1)=DELX
C                       COMPUTE P AND DPDX AT IPSI=6
      PRINT 665
665   FORMAT (24H  PSI=0.000 STREAMLINE--)
      P(6)=PS+US/(RC*RS)*(-PSIS)
      RHO=P(6)/(H-E)
      DO 670 I=7,IZTERM
      CALL RECIN (11,1,IRECIN,IX,TS,ES,PS,RHOS,US,PSIS,HS)
      CALL RECIN (11,2,IRECIN,EVIS,1,IMAX,1)
      CALL RECIN (10,1,IRECIN,X,ZS,RS,RC,COST,SINT)
670   P(I)=PS+US/(RC*RS)*(-PSIS)
      REWIND 10
      REWIND 11
      MG=1
      NPG=IZTERM-5
      DO 675 I=7,IZTERM
      LG=I-6
675   DPDX(I)=DIF(LG,MG,NPG,VARI(6),P(6))
      DO 680 I=1,5
      CALL RECIN (11,1,IRECIN,IX,TS,ES,PS,RHOS,US,PSIS,HS)
      CALL RECIN (11,2,IRECIN,EVIS,1,IMAX,1)
680   CONTINUE
      ISTAG=1
      PSIS=0.
      CALL SECOND (CHECKT)
      PRINT 685, CHECKT
685   FORMAT (14H ----- CHECKT=E15.8,6H -----/)
      PRINT 686,(EVI(I),I=1,IMAX)
  686 FORMAT(7D17.8)
      GO TO 500
C
690   CONTINUE
C
C     AT EACH X WHERE PHYSICAL SPACE CALCULATIONS ARE DESIRED SAVE
C         1./(RHO*U) ON EACH STREAMLINE
C
      IF (VAR(1).LT.XPST(LPS2)) GO TO 720
      IF (VAR(1).GT.XPST(LPS2)) GO TO 705
C        VAR(1) =  XPST(LPS2)
      RHOURT=1./(RHO*U)
      IF (IBUG(13).NE.0) GO TO 700
      PRINT 695, IPSI,RHOURT
695   FORMAT (7H  IPSI=I3,9H  RHOURT=E15.8)
700   CONTINUE
      CALL RECOUT (12,1,0,IPSI,RHOURT,VAR(1),PSIS)
      GO TO 715
705   YPSIS=PREPSIS+(XPST(LPS2)-PREX)*((PSIS-PREPSIS)/(VAR(1)-PREX))
      RHOURT=PRERU+(XPST(LPS2)-PREX)*((RHO*U-PRERU)/(VAR(1)-PREX))
      RHOURT=1./RHOURT
```

```
      CALL RECOUT (12,1,0,IPSI,RHOURT,XPST(LPS2),YPSIS)
      IF (IBUG(13).NE.0) GO TO 715
      PRINT 695, IPSI,RHOURT
      PRINT 710, LPS1,LPS2,VAR(1),XPST(LPS2),PREPSIS,PSIS,PRERU,PREX
710   FORMAT (12H  LPS1,LPS2=2I4,33H   X,XPST,PREPSIS,PSIS,PRERU,PREX=/D1
     17.8,5E17.8)
715   CONTINUE
      LPS2=LPS2+1
      KSTAG=KSTAG+1
720   CONTINUE
      PREX=VAR(1)
      PRERU=RHO*U
      PREPSIS=PSIS
      IF (VAR(1).LT.VARI(IZTERM)) GO TO 505
C                    END OF A STREAMLINE
      PRINT 725
725   FORMAT (/20H   XXXXXXXXXXXXXXXXXX/)
      IF (IPSI.EQ.6.AND.ISTAG.EQ.1) GO TO 425
730   CONTINUE
      GO TO 420
C
C               COMPUTE PHYSICAL SPACE VALUES
C
735   CONTINUE
      CALL SECOND (CHECKT)
      PRINT 685, CHECKT
      REWIND 8
      REWIND 9
      REWIND 10
      REWIND 11
      PRINT 740, KSTAG
740   FORMAT(37H BEGIN PHYSICAL SPACE CALCULATIONS AT,I5,10H LOCATIONS/)
C
      DO 840 LPS=1,NXPST
      REWIND 12
      IK=0
745   CALL RECIN (10,1,IRECIN,X,ZS,RS,RC,COST,SINT)
      IF (ENDFILE 10) 845,750
750   CONTINUE
      IF (IBUG(13).NE.0) GO TO 760
      PRINT 755, LPS,X,XPST(LPS)
755   FORMAT (18H  LPS,X,XPST(LPS) I5,2E30.15/)
760   CONTINUE
      IF (ABS(X-XPST(LPS)).GT.1.0E-8) GO TO 745
      IF (IBUG(13).NE.0) GO TO 765
      PRINT 755, LPS,X,XPST(LPS)
C
765   CONTINUE
      DO 780 IPS=1,KSTAG
      CALL RECIN (12,1,IRECIN,IPSI,RHOURT,VAR(1),PSIS)
      VARMX=VAR(1)-XPST(LPS)
      IF (ABS(VARMX).GT.1.0E-8) GO TO 780
      IK=IK+1
      IF (IK.GT.200) PRINT 770, IK
770   FORMAT (1X,50HIK.GT.200, CHANGE DIMENSION OF RUT AND PSISTG, IK=,I
     13)
      RUT(IK)=RHOURT
      PSISTG(IK)=PSIS
      IF (IBUG(13).NE.0) GO TO 780
      PRINT 775, PSIS,RHOURT
775   FORMAT (14H  PSIS,RHOURT=2E17.8)
780   CONTINUE
C                    FIND SMALLEST DELTA PSI
```

```
      SMALL=200.
      DO 785 I=2,IK
      IF (PSISTG(I)-PSISTG(I-1).LT.SMALL) SMALL=PSISTG(I)-PSISTG(I-1)
 785  CONTINUE
      XDEL=PSISTG(IK)/SMALL
C               TRUNCATE
      L=INT(XDEL+1.)
C               REMAINDERING            M=0 FOR EVEN, M=1 FOR ODD
      M=MOD(L,2)
C                                       MAKE L EVEN
      IF (M.NE.0) L=L+1
C         FIND INTEGRAL 1./(RHO*U) DELTA PSI FROM BODY TO SHOCK
C         SIMPSON-S RULE    L INCREMENTS, L+1 POINTS
      FL=L
      DPSIS=PSISTG(IK)/FL
      PSII=0.
      RB=RUT(1)+RUT(IK)
      LM1=L-1
      IF (IBUG(13).NE.0) GO TO 795
      PRINT 790, L,M,SMALL,XDEL,DPSIS,RB
 790  FORMAT (25H  L,M,SMALL,XDEL,DPSIS,RB/2I5,4E17.8)
 795  CONTINUE
      DO 800 I=2,L,2
      PSII=PSII+DPSIS
      CALL FTLUP (PSII,RU1,1,IK,PSISTG,RUT)
      IF (I.EQ.L) RB=RB+4.*RU1
      IF (I.EQ.L) GO TO 800
      PSII=PSII+DPSIS
      CALL FTLUP (PSII,RU2,1,IK,PSISTG,RUT)
      RB=RB+4.*RU1+2.*RU2
 800  CONTINUE
C
      RB=RB*DPSIS/3.
      IF (IBUG(13).NE.0) GO TO 810
      PRINT 805, RB,RS,COST,RB,SINT
 805  FORMAT (21H  RB,RS,COST,RB,SINT=5E17.8)
 810  CONTINUE
      ARR=SQRT(RS**2-2.*COST*RB)
      YI=(RS-ARR)/COST
      ZE=ZS+YI*SINT
      PRINT 815, X,ARR,YI,ZE,PSISTG(1)
 815  FORMAT (3H X=E15.8,5H   R=E15.8,5H   Y=E15.8,5H   Z=E15.8,7H   PSI
     1=E15.8)
C
      DO 830 I=2,IK,1
      DPSI=PSISTG(I)-PSISTG(I-1)
C               TRAPEZOIDAL  RULE
      TR=(DPSI/2.)*(RUT(I)+RUT(I-1))
      RB=RB-TR
      IF (IBUG(13).NE.0) GO TO 825
      PRINT 820, TR,RB
 820  FORMAT (5HTR,RB,2E17.8)
 825  CONTINUE
      ARR=SQRT(RS**2-2.*COST*RB)
      YI=(RS-ARR)/COST
      ZE=ZS+YI*SINT
      PRINT 815, X,ARR,YI,ZE,PSISTG(I)
 830  CONTINUE
      PRINT 835
 835  FORMAT (/)
C
 840  CONTINUE
 845  CONTINUE
      PRINT 850
 850  FORMAT (29H    END THIS CASE, HALLELUJAH)
```

```
      STOP
      END
      SUBROUTINE BASIC
C      BASIC CALLED BY CALINTH TO EVALUATE DERIVATIVES H DOT,
C                                  C SUB I DOT AND EV SUB I DOT
C      DERIVATIVES START IN DER(1)
C
      COMMON M,IX,IMAX,IPSI,IBUG(15)
      COMMON P( 500),DPDX( 500),VARI( 500)
      COMMON EVIINF(25),THETAI(25),MUI(25),FI(25),DELHI(25),CIINF(25),
     1         LI(25)
      COMMON R,MUINF,DELTA,LAMSQ,OMEGSQ,OMEGA,MU,T,U
      COMMON EPSIIL(20,25),GIL(20,25)
      COMMON VAR(52),CUVAR(52),DER(51)
C
      COMMON ZS,RS,RC,SINT,COST,PS,US,PSIS
      COMMON MJ(50),EJ(50),AJ(50),BJ(50)
      COMMON TVI(25),NI(25),DGENI(25)
      COMMON NUIJ(26,50),AIJ(25,50),NUPIJ(25,50)
      COMMON SIGIK(25,25),ALPIK(25,25),BETAIK(25,25)
C
      COMMON /LAB2/ DELX,ZSTERM,IZTERM
      COMMON /LAB3/ EINF,PINF,RHOINF,VINF,E,JMAX,KEYINT,RHO,HSTAG
      COMMON /LAB4/ PFTL,KITR1,EITR1
      COMMON /LAB5/ IUNEG
      COMMON /LAB7/ ITNEG,IEXP
C
      DOUBLE PRECISION VAR
C
      DIMENSION PHI(50),KJ(50),SJ(50)
      DIMENSION CI(25),EVI(25),DCIDX(25),DEVIDX(25),EVIBAR(25)
C
      EQUIVALENCE (CUVAR(2),H),(CUVAR(3),CI(1))
      EQUIVALENCE (DER(1),DHDX),(DER(2),DCIDX(1))
C
      REAL KJ,LAMSQ,MU,MUI,MUINF,NI,NUIJ,NUPIJ
C
C      DER(1)=DHDX             MUST BE DHDX AS H MAY BE + OR -
C      DER(2)= DCIDX(1)
C          -       -
C      DER(1+IMAX      )=DCIDX(IMAX)
C      DER(1+IMAX+1    )=DEVIDX(1)
C      DER(1+IMAX+IMAX)=DEVIDX(IMAX)
C
C     CUVAR(1) = X
C     CUVAR(2) = H,ENTHALPY - IT MUST BE H WHICH MAY BE + OR -
C     CUVAR(3) = CI(1)
C          -       -
C     CUVAR(2+IMAX      )=CI(IMAX)
C     CUVAR(2+IMAX+1    )=EVI(1)
C     CUVAR(2+IMAX+IMAX)=EVI(IMAX)
C
      EXTERNAL FOFE
C                  KEYINT=1 AT END OF 1ST INTERVAL
      IF (ITNEG.EQ.1.OR.IEXP.EQ.1) RETURN
      IF (M.NE.0) GO TO 10
      DO 5 I=1,IMAX
      J1=I+IMAX+2
 5    CUVAR(J1)=VAR(J1)
 10   CONTINUE
C        INTERPOLATE FOR P ACROSS INTEGRATION INTERVAL
      DO 15 I=1,IMAX
 15   EVI(I)=CUVAR(2+IMAX+I)
      MFTL=1
      NFTL=IZTERM-IPSI+1
      CALL FTLUP (CUVAR(1),PFTL,MFTL,NFTL,VARI(IPSI),P(IPSI))
```

```
C        INTERPOLATE FOR DPDX
      CALL FTLUP (CUVAR(1),DPFTL,MFTL,NFTL,VARI(IPSI),DPDX(IPSI))
      IF (IBUG(10).NE.0) GO TO 30
      PRINT 20, E,PFTL,P(IPSI),P(IPSI+1),CUVAR(1),DPFTL,DPDX(IPSI)
20    FORMAT (25H  E,PFTL,P(IT  ),P(IT  +1/7E17.8)
      PRINT 25, (CI(IU),IU=1,IMAX),(EVI(IU),IU=1,IMAX)
25    FORMAT (5E18.8)
30    CONTINUE
      IF (KEYINT.EQ.0) GO TO 95
      SUM=0.
C                     COMPUTE TVI
      DO 45 I=1,IMAX
C        USE SHOCK VALUES FOR INITIAL COMPUTATION ON EACH STREAMLINE
      SUM=SUM+CI(I)/MUI(I)
      IF (EVI(I).EQ.0.) TVI(I)=0.
      IF (EVI(I).EQ.0.) GO TO 35
      XL=((DGENI(I)*R*THETAI(I))/(MUI(I)*EVI(I))+1.0)
      ALN=ALOG(XL)
      TVI(I)=THETAI(I)/ALN
35    CONTINUE
      IF (IBUG(10).GT.0) GO TO 45
      PRINT 40, I,DGENI(I),R,THETAI(I),MUI(I),EVI(I),XL,ALN,TVI(I)
40    FORMAT (26H  I,DGENI,R,THETAI,MUI,EVI/I5,6E17.8/11H XL,ALN,TVI/3E1
     18.8/)
45    CONTINUE
      MU=1.0/SUM
C
      U2=2.0*(HSTAG-H)
C
      IF (U2.LT.0.) PRINT 50, H
50    FORMAT (32H  USQUARED IS NEG. IN DERSUB, H=E15.8,29H   END STREAML
     1INE INTEGRATION)
      IF (U2.LT.0.) IUNEG=1
      IF (U2.LT.0.) RETURN
      U=SQRT(U2)
C                             ITERATE FOR E
      KCODE=0
55    CONTINUE
      KITR1=0
      DELTE=100000.
      E1=.00001
      E2=.001
      MAXI=10
C
      CALL ITR1 (E,DELTE,FOFE,E1,E2,MAXI,ICODE)
C                             C5.002  LF-ITR1
      IF (ICODE.EQ.0) GO TO 75
      IF (ICODE.EQ.1) PRINT 60
60    FORMAT (38H  FOFE, MAXIMUM ITERATION EXCEEDED ***/)
      IF (ICODE.EQ.2) PRINT 65
65    FORMAT (25H  FOFE, DERIVATIVE=0 ****/)
      PRINT 70, ICODE
70    FORMAT (13H  ITR1,ICODE=I2)
      IF (ICODE.NE.1) STOP 66
C                                                                  STOP 66
C        WHEN ICODE=1, TRY A NEW STARTING E. DO THIS 2 TIMES
      IF (KCODE.EQ.3) STOP 66
C                                                                  STOP 66
      E=EITR1
      KCODE=KCODE+1
      GO TO 55
75    CONTINUE
      IF (IEXP.NE.1) GO TO 85
      E=EITR1
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      KCODE=1+KCODE
      IEXP=0
      PRINT 80, KCODE
80    FORMAT (8H  KCODE=I2)
      IF (KCODE.EQ.1) GO TO 55
      IF (KCODE.GT.2) RETURN
      E=H-0.00001*H
      GO TO 55
85    CONTINUE
      RHO=PFTL/(H-E)
      T=(PFTL*MU)/(RHO*R)
      IF (T.GT.0.0) GO TO 95
      PRINT 90, T,RHO,PFTL,H,E,MU
90    FORMAT (14H  T NEGATIVE =E15.8,2X,4HRHO=E15.8,2X,5HPFTL=E15.8,2X,2
     1HH=E15.8,2X,2HE=E15.8,2X,3HMU=E15.8)
      E=H-0.000001*H
      ITNEG=1
      RETURN
C
95    CONTINUE
      KEYINT=1
      IF (IBUG(9).NE.0) GO TO 110
      PRINT 100, IX,IPSI,RHO,T,MU,U,H
100   FORMAT (16H  IX,IPSI,RHO,T=2I4,4E17.8,E17.8/)
      PRINT 105, E
105   FORMAT (4H  E=E18.8/)
110   CONTINUE
C                 COMPUTE DCIDX AND DEVIDX FOR EACH SPECIE
      DO 210 I=1,IMAX
C        FOR EACH REACTION
      DCIDX(I)=0.
      DO 190 J=1,JMAX
C        SELECTED SPECIE FOR THIS REACTION
      II=MJ(J)
      IF (M.EQ.0) GO TO 115
      IF (FI(II).NE.0.) GO TO 120
115   PHI(J)=1.0
      GO TO 125
120   CONTINUE
      TEM=EXP(THETAI(II)/TVI(II))
      TEM1=EXP(THETAI(II)/T)
      TEM2=EXP(-NI(II)*(THETAI(II)/TVI(II)-THETAI(II)/T))
      TEM3=EXP(THETAI(II)/TVI(II)-THETAI(II)/T)

      IF (TEM3.EQ.1.0) PHI(J)=1.0
      IF (TEM3.EQ.1.0) GO TO 125
C     PHI=COUPLING COEFFICIENT, VIBRATION AND DISSOCIATION INTERACTION
      PHI(J)=((1.0-TEM2)/(TEM3-1.0)*(TEM-1.0)/(TEM1-1.0))/NI(II)
125   TEM4=EXP(-EJ(J)/T)
C        KJ = RATE CONSTANT
      KJ(J)=AJ(J)*T**BJ(J)*TEM4
      IF (NUIJ(IMAX+1,J).EQ.0.) SJ(J)=1.0
      IF (NUIJ(IMAX+1,J).EQ.0.) GO TO 140
      SUM=0.
      DO 135 ISUM=1,IMAX
C
      SUM=SUM+AIJ(ISUM,J)*CI(ISUM)/MUI(ISUM)
      IF (IBUG(7).NE.0) GO TO 135
      PRINT 130, I,J,ISUM,SUM,AIJ(ISUM,J),CI(ISUM),MUI(ISUM)
130   FORMAT (25H  I,J,ISUM,SUM,AIJ,CI,MUI/3I5,5E17.8/)
C
135   CONTINUE
      SJ(J)=RHO*SUM
140   CONTINUE
      IF (IBUG(7).NE.0) GO TO 150
C
```

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      PRINT 145, I,J,FI(II),PHI(J),TEM,TEM1,TEM2,TEM3,TEM4,AJ(J),BJ(J),T
     1,KJ(J),SUM,RHO,SJ(J)
145   FORMAT (26H  I,J,FI,PHI,TEM,TEM1,TEM2/2I5,5E18.8/22H  TEM3,TEM4,AJ
     1,BJ,T,KJ/6E18.8/12H  SUM,RHO,SJ/3E18.8/)
C
150   CONTINUE
      PROD=1.0
      DO 180 IPROD=1,IMAX
      IF (NUIJ(IPROD,J).EQ.0.0) GO TO 170
      TEM=RHO*CI(IPROD)/MUI(IPROD)
      IF (TEM.GE.0.) GO TO 165
C             LET PROBLEM COMPUTE THRU DERSUB WHEN CI NEG,
C              MAKE DECISION IN MAIN ABOUT ACCEPTING NEG CI
      ABW=AMOD(NUIJ(IPROD,J),2.0)
      IF (IBUG(8).NE.0) GO TO 160
      IF (TEM.LT.0.) PRINT 155, I,J,IX,IPROD,TEM,RHO,MUI(IPROD),NUIJ(IPR
     1OD,J),CI(IPROD),PROD,ABW
155   FORMAT (2X,32HI,J,IX,IPROD,TEM,RHO,MUI,NUIJ,CI/4I3,7E17.8)
160   CONTINUE
C             ABW=0.0 FOR EVEN NUIJ,   ABW=1.0 FOR ODD NUIJ
      IF (ABW.EQ.0.0) PROD=PROD*(-TEM)**NUIJ(IPROD,J)
      IF (ABW.EQ.1.0) PROD=-1.0*PROD*(-TEM)**NUIJ(IPROD,J)
      GO TO 170
165   CONTINUE
      PROD=PROD*TEM**NUIJ(IPROD,J)
C
170   CONTINUE
      IF (IBUG(8).NE.0) GO TO 180
      IF (IX.LT.3) GO TO 180
      PRINT 175, I,J,IPROD,TEM,PROD,RHO,CI(IPROD),NUIJ(IPROD,J)
175   FORMAT (48H  I,J,IPROD,TEM,PROD,RHO,CI(IPROD),NUIJ(IPROD,J)/3I5,6E
     117.8/)
180   CONTINUE
      DCIJDX=PHI(J)*KJ(J)*SJ(J)*(MUI(I)/(RHO*U))*(NUPIJ(I,J)-NUIJ(I,J))*
     1PROD
C
C          DCIDX = RATE OF APPEARANCE AND DISAPPEARANCE OF CONCENTRATION
C                   OF SPECIE
      DCIDX(I)=DCIDX(I)+DCIJDX
C
      IF (IBUG(8).NE.0) GO TO 190
      PRINT 185, I,J,DCIJDX,PHI(J),KJ(J),SJ(J),MUI(I),RHO,U,NUPIJ(I,J),N
     1UIJ(I,J),PROD,DCIDX(I)
185   FORMAT (25H I,J,DCIJDX,PHI,KJ,SJ,MUI/2I5,5E18.8/29H  RHO,U,NUPIJ,N
     1UIJ,PROD,DCIDX/6E18.8/)
190   CONTINUE
      TEM=EXP(THETAI(I)/T)
      TEM1=(FI(I)*DGENI(I)*R*THETAI(I))/MUI(I)
      EVIBAR(I)=TEM1/(TEM-1.0)
      IF (M.NE.0) GO TO 195
      VAR(I+IMAX+2)=EVIBAR(I)
      DEVIDX(I)=0.
      GO TO 210
195   CONTINUE
      TAUSUM=0.
      IF (FI(I).EQ.0.) GO TO 210
      DO 205 K=1,IMAX
      TEM3=EXP(-THETAI(I)/T)
      TEM4=EXP(SIGIK(K,I)*T**(-1./3.))
      TEM5=(FI(I)*ALPIK(K,I))/PFTL
      TAUIK=TEM5*(T**BETAIK(K,I)*TEM4)/(1.0-TEM3)
      TEM6=CI(K)*(EVIBAR(I)-EVI(I))
      TAUSUM=TAUSUM+TEM6/(TAUIK*U)
C
```

```
      IF (IBUG(9).NE.0) GO TO 205
      PRINT 200, I,K,TEM3,TEM4,TEM5,TAUIK,TAUSUM,SIGIK(K,I),ALPIK(K,I),B
     1ETAIK(K,I),U,EVI(I),EVIBAR(I),TEM,TEM1,TEM2,TEM6,TEM6
200   FORMAT (33H  I,K,TEM3,TEM4,TEM5,TAUIK,TAUSUM/2I5,5E18.8/33H  SIGIK
     1,ALPIK,BETAIK,U,EVI,EVIBAR/6E17.8/22H  TEM,TEM1,TEM2,TEM6  /4E18.8
     2,022/)
205   CONTINUE
C
C        DEVIDX = EQUILIBRIUM VIBRATIONAL ENERGY
      DEVIDX(I)=TAUSUM
      DER(1+IMAX+I)=DEVIDX(I)
210   CONTINUE
C                     COMPUTE  DHDX
      DHDX=DPFTL/RHO
      IF (IBUG(10).NE.0) RETURN
      PRINT 215, DEVIDX(I)
215   FORMAT (9H  DEVIDX=E22.14)
      PRINT 220, DPFTL,DHDX
220   FORMAT (12H  DPDX,DHDX=2E18.8,16H       END BASIC////)
      RETURN
      END
      FUNCTION  FOFE(DUM)
C
C     CALLED BY ITR1 IN EASIC TO EVALUATE E
C
      COMMON M,IX,IMAX,IPSI,IBUG(15)
      COMMON P( 500),DPDX( 500),VARI( 500)
      COMMON EVIINF(25),THETAI(25),MUI(25),FI(25),DELHI(25),CIINF(25),
     1       LI(25)
      COMMON R,MUINF,DELTA,LAMSQ,OMEGSQ,OMEGA,MU,T,U
      COMMON EPSIIL(20,20),GIL(20,20)
      COMMON VAR(52),CUVAR(52),DER(51)
C
      COMMON ZS,RS,RC,SINT,COST,PS,US,PSIS
      COMMON MJ(50),EJ(50),AJ(50),BJ(50)
      COMMON TVI(25),NI(25),DGENI(25)
      COMMON NUIJ(21,30),AIJ(20,30),NUPIJ(20,30)
C
      COMMON /LAB4/ PFTL,KITR1,EITR1
      COMMON /LAB7/ ITNEG,IEXP
C
      DOUBLE PRECISION VAR
C
      DIMENSION CI(25)
C
      EQUIVALENCE (CUVAR(3),CI(1)),(CUVAR( 2),H)
C
      REAL MUI,LAMSQ,MUINF,MU
C
      IF(ITNEG.EQ.1.OR.IEXP.EQ.1) RETURN
      KITR1=KITR1+1
      IF (KITR1.EQ.3) EITR1=DUM
      PORHO=H-DUM
      E=0
      EDUM=DUM
      T=PORHO*MU/R
      IF (IBUG(11).NE.0) GO TO 10
      PRINT 5, EDUM,MU,T,RHO,PFTL,H
    5 FORMAT(1X,5HEDUM=E15.8,2X,3HMU=E15.8,2X,2HT=E15.8,2X,4HRHO=E15.8,
     1 2X,5HPFTL=E15.8,2X,2HH=E15.8)
10    CONTINUE
C
      DO 35 I=1,IMAX
      IF (TVI(I).EQ.0.) TEM1=(1.5*R*T)/MUI(I)+(FI(I)*R*T)/MUI(I)
      IF (TVI(I).EQ.0.) GO TO 15
```

```
      TEM=EXP(THETAI(I)/TVI(I))
      TEM1=(1.5*R*T)/MUI(I)+(FI(I)*R*T)/MUI(I)+(FI(I)*R*THETAI(I))/(MUI(
     1I)*(TEM-1.C))
15    CONTINUE
      SUMG=0.
      SUMGE=0.
C
      LII=LI(I)
      DO 25 L=1,LII
      TEM3=-EPSIIL(L,I)/T
      IF(TEM3.LT.741.67) GO TO 42
      PRINT 41, TEM3,EPSIIL(L,I),T,EDUM,L,I,H,MU,KITR1
   41 FORMAT(56H EXP(TEM3), TEM3.GT.741.67, TEM3,EPSIIL(L,I),T,EDUM,L,I=
     1 /4E17.8,2I5,13H  H,MU,KITR1=2E17.8,I5)
      IEXP=1
C      SET IEXP=1 TO TRIGGER REDUCTION IN COMPUTING INTERVAL
C      AND A NEW E ESTIMATE
      RETURN
   42 TEM2=EXP(TEM3)
      SUMG=SUMG+GIL(L,I)*TEM2
      SUMGE=SUMGE+GIL(L,I)*EPSIIL(L,I)*TEM2
      IF(SUMGE.GT.10.E300) IBUG(11)=0
C
      IF (IBUG(11).NE.0) GO TO 25
      PRINT 20, I,L,TEM2,EPSIIL(L,I),T,SUMG,GIL(L,I),SUMGE
20    FORMAT (34H  I,L,TEM2,EPSIIL,T,SUMG,GIL,SUMGE/2I5,6E18.8/)
25    CONTINUE
      IF(SUMGE.LT.10.E30C) GO TO 26
      PRINT 27
C
   27 FORMAT( 56H IN FCFE,SUMGE.GT.10.E300, SET IEXP=1 TO REDUCE INTERVA
     1L/)
C
      IBUG(11)=1
      IEXP=1
      RETURN
   26 CONTINUE
      EI=TEM1+R/MUI(I)*(SUMGE/SUMG)+DELHI(I)/MUI(I)
      E=E+EI*CI(I)
      IF (IBUG(11).NE.0) GO TO 35
      PRINT 30, I,L,IX,IPSI,PORHO,E,EDUM,H,RHO,T,TEM,TEM1,SUMG,SUMGE,EI,
     1E
30    FORMAT (32H  I,L,IX,IPSI,PORHO,E,EDUM,H,RHO/4I4,6E18.8/23H  T,TEM,
     1TEM1,SUMG,SUMGE/7E18.8//)
35    CONTINUE
      FOFE=E
      IF (E.GT.H) PRINT 4C, E,H
   40 FORMAT(26H  IN ITR1-FOFE, E.GT.H, E=E15.8, 6H    H=E15.8,
     1 5X, 17H  REDUCE INTERVAL)
      IF(E.GT.H) ITNEG=1
C
      RETURN
      END
      FUNCTION   FOFTS(DUM)
C
C     CALLED BY ITR1 IN MAIN PROGRAM TO EVALUATE TS
C
      COMMON M,IX,IMAX,IPSI,IBUG(15)
      COMMON P( 500),DPDX( 500),VARI( 500)
      COMMON EVIINF(25),THETAI(25),MUI(25),FI(25),DELHI(25),CIINF(25),
     1       LI(25)
      COMMON R,MUINF,DELTA,LAMSQ,OMEGSQ,OMEGA,MU,T,U
      COMMON EPSIIL(20,2C),GIL(20,20)
      COMMON VAR(52),CUVAR(52),DER(51)
C
```

```
      DOUBLE PRECISICN VAR
C
      DIMENSION CI(25)
C
      EQUIVALENCE (CUVAR(3),CI(1))
C
      REAL MUI,LAMSQ,MUINF,MU
C
      ES=0
      DO 25 I=1,IMAX
      IF (M.EQ.1) EVIS=EVIINF(I)
      IF (M.EQ.1) GO TC 5
C
      TEM=EXP(THETAI(I)/DUM)
C
      EVIS=(R*THETAI(I))/(MUI(I)*(TEM-1.0))*FI(I)
5     SUMG=0
      SUMGE=0
C
      LII=LI(I)
      DO 10 L=1,LII
      TEM1=EXP(-EPSIIL(L,I)/DUM)
      SUMG=SUMG+TEM1*GIL(L,I)
10    SUMGE=SUMGE+TEM1*GIL(L,I)*EPSIIL(L,I)
      EEIS=(R/MUI(I))*(SUMGE/SUMG)
      EIS=(1.5*R*DUM)/MUI(I)+(FI(I)*R*DUM)/MUI(I)+EVIS+EEIS+DELHI(I)/MUI
     1(I)
      ES=ES+EIS*CIINF(I)
      IF (IBUG(4).NE.0) GC TO 20
      T=DUM
      PRINT 15, IX,I,M,EVIS,TEM,T,SUMG,SUMGE,TEM1,EEIS,EIS,ES,CIINF(I)
15    FORMAT (32H  IX,I,M,EVIS,TEM,DUM,SUMG,SUMGE/3I5,5E18.8/30H  TEM1,E
     1EIS,EIS(I),ES,CIINF(I)/5E18.8/)
C
20    CONTINUE
25    CONTINUE
C
      FAC=SQRT(OMEGSQ-2.*LAMSQ*(DELTA-ES))
      FIN=(2.*MUINF*(DELTA-ES)*FAC)/(R*(OMEGA+FAC))
      FOFTS=FIN
      IF (IBUG(4).NE.0) RETURN
      PRINT 30, CMEGSQ,LAMSQ,DELTA,ES,MUINF,FAC,R,OMEGA,FIN
30    FORMAT (44H OMEGSQ,LAMSQ,DELTA,ES,MUINF,FAC,R,OMEGA,FIN/2(5E18.8/)
     1)
      RETURN
      END
      SUBROUTINE FDPCX
C
C     TO CCMPUTE P AND CFCX
C     AND SAVE ON TAPES 9 AND 8
C
      COMMON M,IX,IMAX,IPSI,IBUG(15)
      COMMON P( 500),DPCX( 500),VARI( 500)
      COMMON EVIINF(25),THETAI(25),MUI(25),FI(25),DELHI(25),CIINF(25),
     1       LI(25)
      COMMCN R,MUINF,DELTA,LAMSC,OMEGSC,CMEGA,MU,T,U
      COMMCN EPSIIL(20,20),GIL(20,20)
      COMMON VAR(52),CUVAR(52),DER(51)
C
      COMMON ZS,RS,RC,SINT,COST,PS,US,PSIS
      CCMMCN MJ(50),EJ(50),AJ(50),BJ(50)
      COMMON TVI(25),NI(25),DGENI(25)
      COMMON NUIJ(21,20),AIJ(20,30),NUPIJ(20,30)
      COMMON SIGIK(20,20),ALPIK(20,20),BETAIK(20,20)
      COMMON KSTAG,IMAXP2,IMAXL,N,IG,ISTAG,LPS2,LPS1,IMAXP1
```

```
      COMMON X,TS,ES,RHOS,HS,RHOURT,PHMAX,CIMAX,PREPSIS,PREX,PRERU
      COMMON EVIS(25),XPST(100)
C
      COMMON /LAB2/ DELX,ZSTERM,IZTERM
C
      DOUBLE PRECISION VAR
C
C                    BEGIN PRESSURE DISTRIBUTION
C                    FOR EACH PSI FIND RANGE OF X
C
      DO 20 IPSI=1,IZTERM
      DO 15 IX=1,IZTERM
      IEOF=10
      CALL RECIN (10,1,IRECIN,X,ZS,RS,RC,COST,SINT)
      IF (EOF,10) 75,5
5     CONTINUE
      IF (IX.EQ.IPSI) XX=X
      IEOF=11
      CALL RECIN (11,1,IRECIN,IXT,TS,ES,PS,RHOS,US,PSIS,HS)
      CALL RECIN (11,2,IRECIN,EVIS,1,IMAX,1)
      IF (EOF,11) 75,10
10    CONTINUE
      IF (IXT.LT.IPSI) GO TO 15
      IF (IXT.EQ.IPSI) PSISHK=PSIS
      IF (IPSI.EQ.IX) P(IX)=PS
      IF (IPSI.EQ.IX) GO TO 15
      P(IX)=PS+US/(RC*RS)*(PSISHK-PSIS)
C
15    CONTINUE
      REWIND 10
      REWIND 11
C
      CALL RECOUT (9,1,0,XX)
      CALL RECOUT (9,2,0,P,IPSI,IZTERM,1)
C
20    CONTINUE
      REWIND 9
      N=1
      IEOF=9
      DO 65 IPSI=1,IZTERM
      CALL RECIN (9,1,IRECIN,X)
      CALL RECIN (9,2,IRECIN,P,IPSI,IZTERM,1)
      IF (EOF,9) 75,35
35    CONTINUE
      ITHIS=0
      DO 40 IX=IPSI,IZTERM
      IF (IX.EQ.IPSI) XT=X
      IF (IX.GT.IPSI.AND.IPSI.LT.7) XT=XT+DELX/5.
      IF (IX.GT.IPSI.AND.IPSI.GT.6) XT=XT+DELX
      IF (IX.EQ.IZTERM-1) P(IX+2)=0.0
      ITHIS=ITHIS+1
      VARI(ITHIS)=XT
40    CONTINUE
      IHERE=0
C
      DO 60 IX=IPSI,IZTERM
      IF (IX.EQ.IZTERM) P(IX+1)=0.
      IF (IX.EQ.IZTERM) P(IX+2)=0.0
      IHERE=IHERE+1
C                   DIFFERENTIATE
      IF (IX.NE.IPSI) GO TO 45
      DPDX(IX)=(-3.*P(IX)+4.*P(IX+1)-P(IX+2))/(2.*DELX)
      GO TO 50
45    CONTINUE
      DPDX(IX)=(-P(IX-1)+P(IX+1))/(2.*DELX)
      IF (IX.NE.IZTERM) GO TO 50
```

```
      DPDX(IX)=(P(IX-2)-4.*P(IX-1)+3.*P(IX))/(2.*CELX)
50    CONTINUE
      IF (IBUG(1).NE.0) GO TO 60
      PRINT 55, IPSI,IX,A,DPDX(IX),P(IX)
55    FORMAT (2I5,3E18.8)
60    CONTINUE
C
      CALL RECOUT (8,2,0,DPDX,IPSI,IZTERM,1)
C
65    CONTINUE
      DO 70 IX=1,IZTERM
      IF(IX.EQ.1) VARI(1)=0.
      IF(IX.EQ.1) GO TO 70
      IF (IX.LT.7) VARI(IX)=VARI(IX-1)+DELX/5.
      IF (IX.GT.6) VARI(IX)=VARI(IX-1)+DELX
70    CONTINUE
      REWIND 9
      REWIND 8
      REWIND 10
      REWIND 11
      RETURN
75    PRINT 80, IEOF
   80 FORMAT( 7H  EOF  I5, 13H     IN FDPDX)
      STOP 50
C                                                                  STOP 50
      END
      SUBROUTINE CHECK
C
C     CHECK CALLED BY CALINTH TO MAKE DECISION TO ACCEPT ANSWERS
C        IF ACCEPTABLE, SET ELB=0 AND RETURN
C        IF NOT ACCEPTABLE MODIFY SPEC AND CI. SET ELB=1.0 AND RETURN
C
      COMMON M,IX,IMAX,IPSI,IBUG(15)
      COMMON P( 500),DPDX( 500),VARI( 500)
      COMMON EVIINF(25),THETAI(25),MUI(25),FI(25),DELHI(25),CIINF(25),
     1       LI(25)
      COMMON R,MUINF,DELTA,LAMSQ,OMEGSQ,OMEGA,MU,T,U
      COMMON EPSIIL(20,20),GIL(20,20)
      COMMON VAR(52),CUVAR(52),DER(51)
C
      COMMON /LAB6/ ELB,SPEC,CJ,TPREV,HPREV,HCHECK,TCHECK
      COMMON /LAB7/ ITNEG,IEXP
C
      EQUIVALENCE (CUVAR( 2),H)
C
      DOUBLE PRECISION VAR
C
      IF(IEXP.NE.1) GO TO 1
      GO TO 15
C          REDUCE COMPUTING INTERVAL TO TRY TO AVOID EXP ERROR STOP
    1 CONTINUE
      IF(ITNEG.EQ.0) GO TO 4
C        E.GT.H LEADS TO NEG T SOMETIMES---LETS REDUCE INTERVAL TO TRY
C        TO AVOID INSTABILITY
      GO TO 15
    4 CONTINUE
      IMAXP1=IMAX+1
      DO 10 I=3,IMAXP1
C              CUVAR(2)=H   MAY BE NEG
      IF (CUVAR(I).LT.0.) PRINT 5, I,IX,CUVAR(I)
    5 FORMAT(24H  NEG CI, I,IX,CUVAR(I)=2I5,E17.8)
      IF (CUVAR(I).LT.0.) GO TO 15
10    CONTINUE
      IF (IX.LT.3) GO TO 30
      IF (IPSI.EQ.6.AND.IX.LT.8) GO TO 30
      IF(ABS(TPREV-T)/T.LT.TCHECK) GO TO 25
```

```
      PRINT 11
   11 FORMAT(33H  CHECK-ABS(TPREV-T)/T.GE.TCHECKT)
15    CONTINUE
      IF(SPEC.LT.1.0E-15) STOP 30
C                                                                 STOP 30
C        REDUCE INTERVAL
      SPEC=SPEC/4.
      CJ=SPEC
      ELB=1.0
      PRINT 44,SPEC,IPSI,IX,T,TPREV,H,HPREV,IEXP,ITNEG
   44 FORMAT(14H REDUCED SPEC=E15.8,10H  IPSI,IX=2I5,18H  T,TPREV,H,HPRE
     1V=4E16.7/13H  IEXP,ITNEG=2I3)
      ITNEG=0
      IEXP=0
      RETURN
25    CONTINUE
      IF(ABS((HPREV-H)/H).GT.HCHECK) PRINT 42
   42 FORMAT(35H  CHECK,ABS((HPREV-H)/H).GT.HCHECKT)
      IF(ABS((HPREV-H)/H).GT.HCHECK) GO TO 15
30    CONTINUE
C                 ACCEPTABLE
      TPREV=T
      HPREV=H
      ELB=0.
      RETURN
      END
      SUBROUTINE SHOCKG(DELX,ZSTERM,IZTERM)
C     SUBROUTINE SHOCKG CALLED BY MAIN
C
C     SHOCKG SUBROUTINE MUST BE SUPPLIED BY USER. IT SHOULD DEFINE THE
C     SHOCK GEOMETRY AND STORE ON TAPE 10,X,ZS,RS,RC,COST,SINT FOR EACH
C     X FROM 0.0 TO X AT ZSTERM IN INCREMENTS OF DELX/5.0 TO DELX AND
C     INCREMENTS OF DELX THEREAFTER
C         X=DISTANCE ALONG SHOCK
C        ZS=DISTANCE ALONG SHOCK AXIS OF SYMMETRY
C        RS=RADIUS OF SHOCK
C        RC=RADIUS OF CURVATURE OF SHOCK
C      COST=COS OF ANGLE OF ATTACK
C      SINT=SIN OF ANGLE OF ATTACK
C
C     USER MUST STORE THE NUMBER OF X VALUES IN IZTERM
C     USE STOP 13 FOR ERROR STOPS IN SHOCKG
C
C
      DIMENSION ZDUM(1000),RSDUM(1000),RCDUM(1000),SIDUM(1000),
     1 CODUM(1000),XC(1000)
C
C
C        NEQ A    12-16-68
C        Z/L=COSH(R/L)-1.0
C        L=2.109211 CM
C        NEQ2 INPUT
C
C
      EL=2.109216
      X=0.
      DRS=.0078125
      NRS=0
   10 NRS =NRS+1
      IF(NRS.EQ.1) RSDUM(1)=0.
      IF(NRS.NE.1) RSDUM(NRS)=RSDUM(NRS-1)+DRS
      ZDUM(NRS) =COSH(RSDUM(NRS))-1.0
      XC(NRS) = SQRT(2.*ZDUM(NRS)+ZDUM(NRS)**2)
      CODUM(NRS)= XC(NRS)/SQRT(XC(NRS)**2+1.0)
      RCDUM(NRS)= 1.0+XC(NRS)**2
```

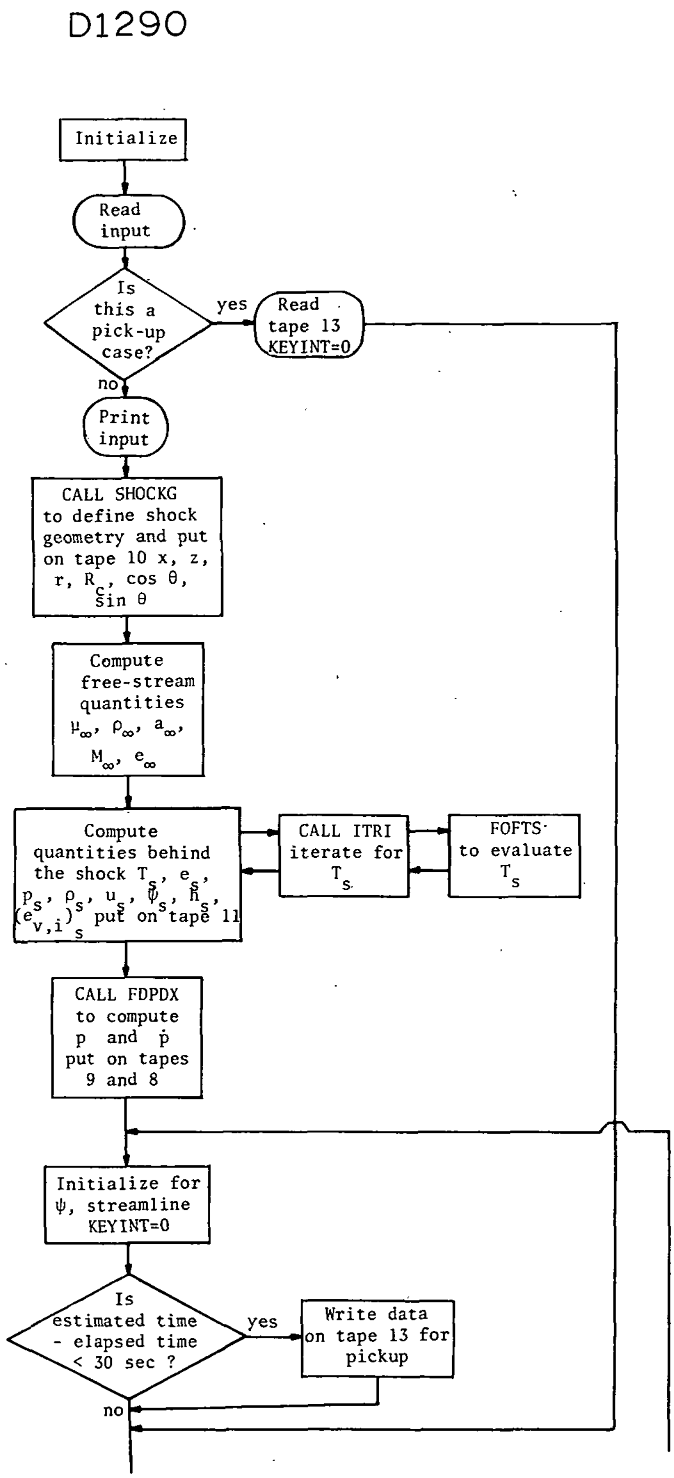
```
      SIDUM(NRS)= SQRT(1.0-CODUM(NRS)**2)
      RCDUM(NRS)=EL*RCDUM(NRS)
      XC   (NRS)=EL*XC   (NRS)
      RSDUM(NRS)=EL*RSDUM(NRS)
      Z DUM(NRS)=EL*Z DUM(NRS)
      IF(ZDUM(NRS).LT.ZSTERM) GO TO 10
      X=0.
      NOX=0
      PRINT 25
25    FORMAT (5X,1HX,16X,2HZS,15X,2HRS,15X,2HRC,15X,4HCOST,13X,4HSINT/)
30    NOX=NOX+1
      IF (NOX.LT.7) X=X+DELX/5.
      IF (NOX.EQ.1) X=0.
      IF (NOX.GT.6) X=X+DELX
      CALL FTLUP (X,ZS,1,NRS,XC,ZDUM)
      CALL FTLUP (X,RS,1,NRS,XC,RSDUM)
      CALL FTLUP (X,RC,1,NRS,XC,RCDUM)
      CALL FTLUP (X,COST,1,NRS,XC,CODUM)
      CALL FTLUP (X,SINT,1,NRS,XC,SIDUM)
      PRINT 35, X,ZS,RS,RC,COST,SINT,NOX
35    FORMAT (6E17.8,I5)
      CALL RECOUT (10,1,0,X,ZS,RS,RC,COST,SINT)
      IF (ZS.LT.0.0) PRINT 45
   45 FORMAT(16H  ZS IS NEGATIVE )
      IF(ZS.LT.0.0) STOP 13
C                                                         STOP 13       STOP 13
      IF (ZS.LT.ZSTERM) GO TO 30
      IZTERM=NOX
      END FILE 10
      REWIND 10
      RETURN
      END
      SUBROUTINE CALINTH(VAR,DER,ELE1,ELE2,CI,SPEC,N,CUVAR,ELT,
     1CIMAX,NERR,PHMAX)
C    ----- IN THE CALINTH VERSION OF CALINT THE VARIABLE IN VAR(2) AND
C    ----- CUVAR(2) MAY BE + OR -.VALUES OF OTHER DEPENDENT VARIABLES
C    ----- ARE EXPECTED TO BE PLUS.                        10-69
      DOUBLE PRECISION VAR
      DIMENSION VAR(52),DER(51),ELE1(51),ELE2(51),CUVAR(52),F1(51),
     1F2(51),F3(51),CAPF1(51),CAPF2(51),CAPF3(51),P(51),PH(51),
     2DELTY(51),Y3(51),Y4(51),F4(51),Y2(51)
C
C     NERR=1              CI OR N IS EQUAL TO ZERO
C
C     NERR=2              ELE1 LESS THAN OR EQUAL TO ELE2
C
C
C        TEST INPUT
C
      FN=N
      TEST=CI*FN
      IF(TEST)998,997,998
  997 NERR=1
      RETURN
  998 IF(ELE1-ELE2)999,999,1000
  999 NERR=2
      RETURN
 1000 IF(SPEC)5,1,5
C
C        SECTION FOR INITIALIZATION COMPUTATION OF DERIVATIVES
C
    1 SPEC=CI
      ICONT=1
    2 N1=N+1
      DO 3 I=1,N1
```

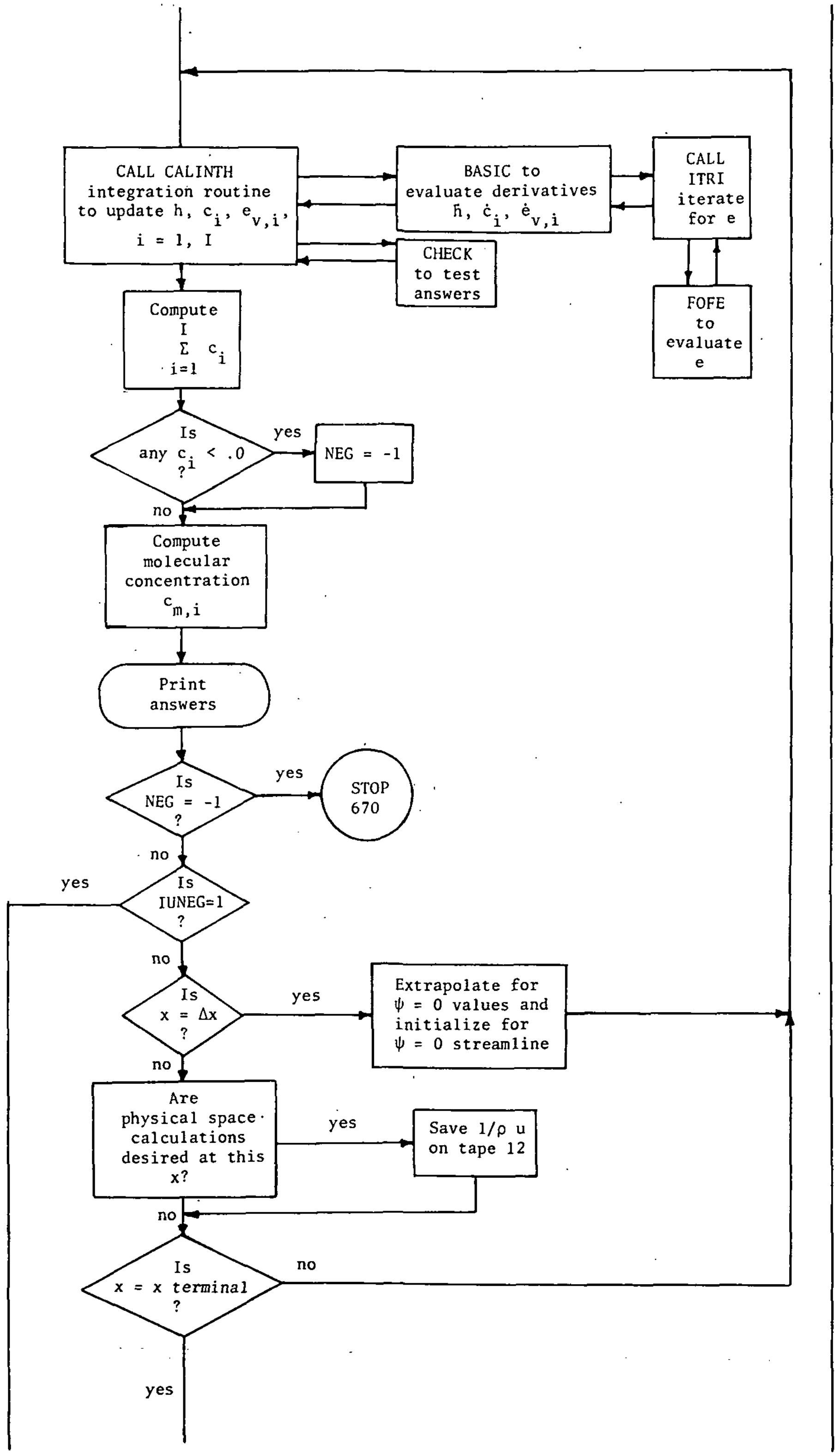
```
C
    3 CUVAR(I)=VAR(I)
      CALL BASIC
C
C         RETURN WITH DERIVATIVES IN DER
C
      DO 4 I=1,N
    4 F1(I)=DER(I)
C
      RETURN
C
C         COMPUTE Y2,X2
C
    5 CUVAR(1)=VAR(1)+CI/2.
      DO 6 I=1,N
      I1=I+1
      Y2(I)=VAR(I1)+CI/2.*F1(I)
      IF(I.EQ.1) GO TO 6
      IF(Y2(I))65,6,6
    6 CUVAR(I1)=Y2(I)
      GO TO 66
   65 SPEC=CI
      CI=CI/2.
      GO TO 5
C
C         CALL BASIC TO EVALUATE F2
C
   66 CALL BASIC
C
C         RETURN
C
      DO 7 I=1,N
      I1=I+1
      F2(I)=DER(I)
C
C         COMPUTE Y3
C
      Y3(I)=VAR(I1)+CI/2.*F2(I)
      IF(I.EQ.1) GO TO 7
      IF(Y3(I))65,7,7
    7 CUVAR(I1)=Y3(I)
C
C         CALL BASIC TO EVALUATE F3
C
      CALL BASIC
C         RETURN
C
      DO 10 I=1,N
      F3(I)=DER(I)
C
C         COMPUTE P,PH AND CAP F TERMS
C
      IF(Y3(I)-Y2(I)) 9,8,9
    8 P(I)=0.
      GO TO 91
    9 P(I)=-((F3(I)-F2(I))/(Y3(I)-Y2(I)))
   91 PH(I)=P(I)*CI
      IF(PH(I))83,83,103
   83 PH(I)=0.
      P(I)=0.
      GO TO 84
  103 IF(ABS(Y3(I)-Y2(I))/((ABS(Y3(I))+ABS(Y2(I)))/2.)-.5E-4)83,83,84
   84 IF(PH(I)-.1)85,85,95
   85 CAPF1(I)=1.-PH(I)/2.+(PH(I)**2)/6.-(PH(I)**3)/24.
```

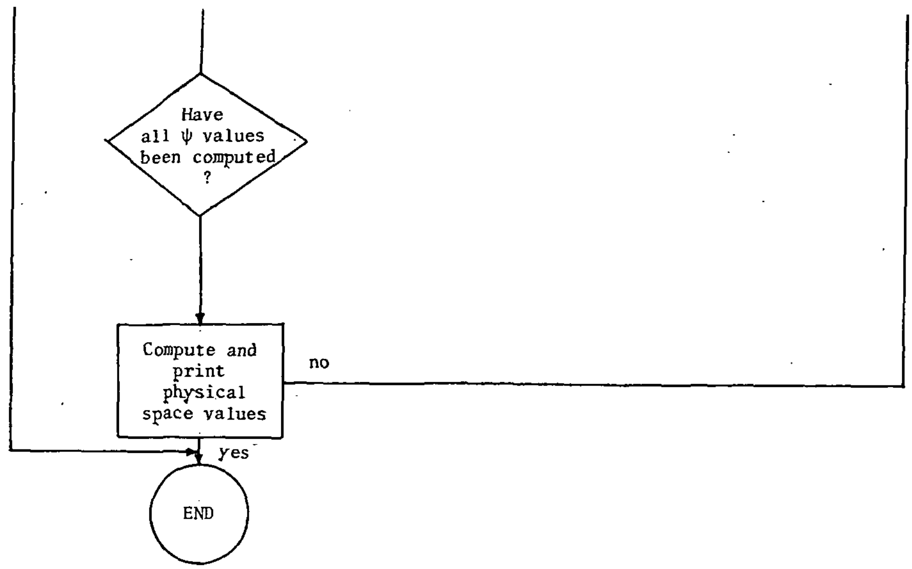
```
      CAPF2(I)=.5-PH(I)/6.+(PH(I)**2)/24.-(PH(I)**3)/120.
      CAPF3(I)=1./6.-PH(I)/24.+(PH(I)**2)/120.-(PH(I)**3)/720.
      GO TO 10
   95 CAPF1(I)=(EXP(-PH(I))-1.)/(-PH(I))
      CAPF2(I)=(CAPF1(I)-1.)/(-PH(I))
      CAPF3(I)=(CAPF2(I)-.5)/(-PH(I))
   10 CONTINUE
C
C        IS PH BETWEEN ELE2 AND ELE1
C
      IF(ICONT-1)101,101,102
  102 ICONT=ICONT-1
      SPEC=CI
      GO TO 17
  101 DO 11 I=1,N
  104 IF(ABS(PH(I))-ELE1(I))11,11,13
   11 CONTINUE
C
   12 SPEC=CI
      GO TO 15
C
C        HALVE INTERVAL AND DOUBLE PH RANGE
C
   13 DO 96 I=1,N
      ELE1(I)=ELE1(I)*2.
      IF(ELE1(I)-PHMAX)94,94,955
   94 ELE2(I)=ELE2(I)*2.
      GO TO 96
  955 ELE1(I)=ELE1(I)/2.
   96 CONTINUE
      SPEC=CI

      CI=CI/2.
      ICONT=3
      GO TO 5
C
C     RETURN TO RECOMPUTE INTERVAL
C
C
C        RETURN TO RECOMPUTE INTERVAL
C
   15 DO 16 I=1,N
      IF(ABS(PH(I))-ELE2(I))16,17,17
   16 CONTINUE
C
C        DOUBLE INTERVAL
C
      CI=2.*CI
      IF(CI-CIMAX)17,17,165
  165 CI=CIMAX
   17 CONTINUE
C
C        COMPUTE Y4,X4
C
      DO 18 I=1,N
      I1=I+1
      CUVAR(I1)=VAR(I1)+SPEC*(F3(I)*(2.*CAPF2(I))+F1(I)*
     1(CAPF1(I)-2.*CAPF2(I))+F2(I)*PH(I)*CAPF2(I))
      IF(I.EQ.1) GO TO 18
      IF(CUVAR(I1))175,18,18
  175 CI=SPEC
      CI=CI/2.
      GO TO 5
   18 Y4(I)=CUVAR(I1)
C
      CUVAR(1)=VAR(1)+SPEC
```

```
C
C        CALL BASIC TO EVALUATE F4
C
      CALL BASIC
C        RETURN
C
      DO 20 I=1,N
      I1=I+1
      F4(I)=DER(I)
C
C        COMPUTE DELTA Y
C
      DELTY(I)=SPEC*(F1(I)*CAPF1(I)+(-3.*(F1(I)+P(I)*VAR(I1))
     1+2.*(F2(I)+P(I)*Y2(I))+2.*(F3(I)+P(I)*Y3(I))-F4(I)
     2-P(I)*Y4(I))*CAPF2(I)+4.*((F1(I)+P(I)*VAR(I1))-(F2(I)
     3+P(I)*Y2(I))-(F3(I)+P(I)*Y3(I))+(F4(I)+P(I)*Y4(I)))*
     4CAPF3(I))
C
C        COMPUTE Y+DELTA Y
C
   20 CUVAR(I1)=VAR(I1)+DELTY(I)
C
C        CALL CHECK FOR DECISION TO ACCEPT OR RECOMPUTE
C          INTERVAL
      CALL CHECK
      IF (ELT)21,21,23
C
C        UPDATE Y VALUES
C
   21 N1=N+1
      DO 22 I=2,N1
      I1=I-1
   22 VAR(I)=VAR(I)+DELTY(I1)
      VAR(1)=VAR(1)+SPEC
C
C        RETURN TO COMPUTE DERIVATIVES AT Y+DELTA Y
C
      GO TO 2
C
C        RETURN TO RECOMPUTE INTERVAL
C
   23 GO TO 5
C
      END
```

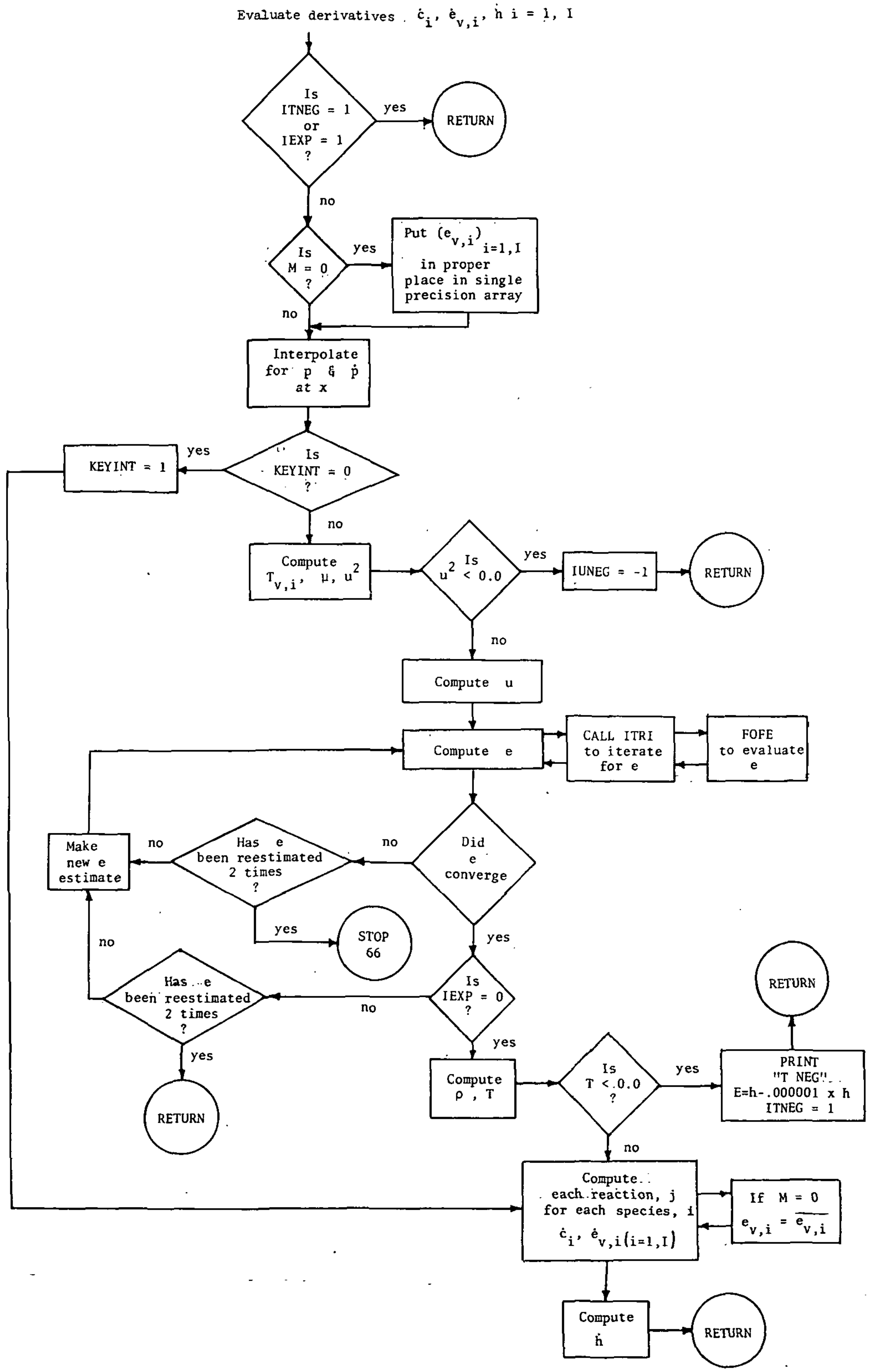
The flow charts for the program are presented below:




CALL CALINTH integration routine to update h, c_i, e_v,i, i = 1, I
BASIC to evaluate derivatives ḣ, ċ_i, ė_v,i
CALL ITRI iterate for e
CHECK to test answers
FOFE to evaluate e
Compute Σ_{i=1}^{I} c_i
Is any c_i < .0 ?
yes
NEG = -1
no
Compute molecular concentration c_m,i
Print answers
Is NEG = -1 ?
yes
STOP 670
no
Is IUNEG=1 ?
yes
no
Is x = Δx ?
yes
Extrapolate for ψ = 0 values and initialize for ψ = 0 streamline
no
Are physical space calculations desired at this x?
yes
Save 1/ρ u on tape 12
no
Is x = x terminal ?
no
yes

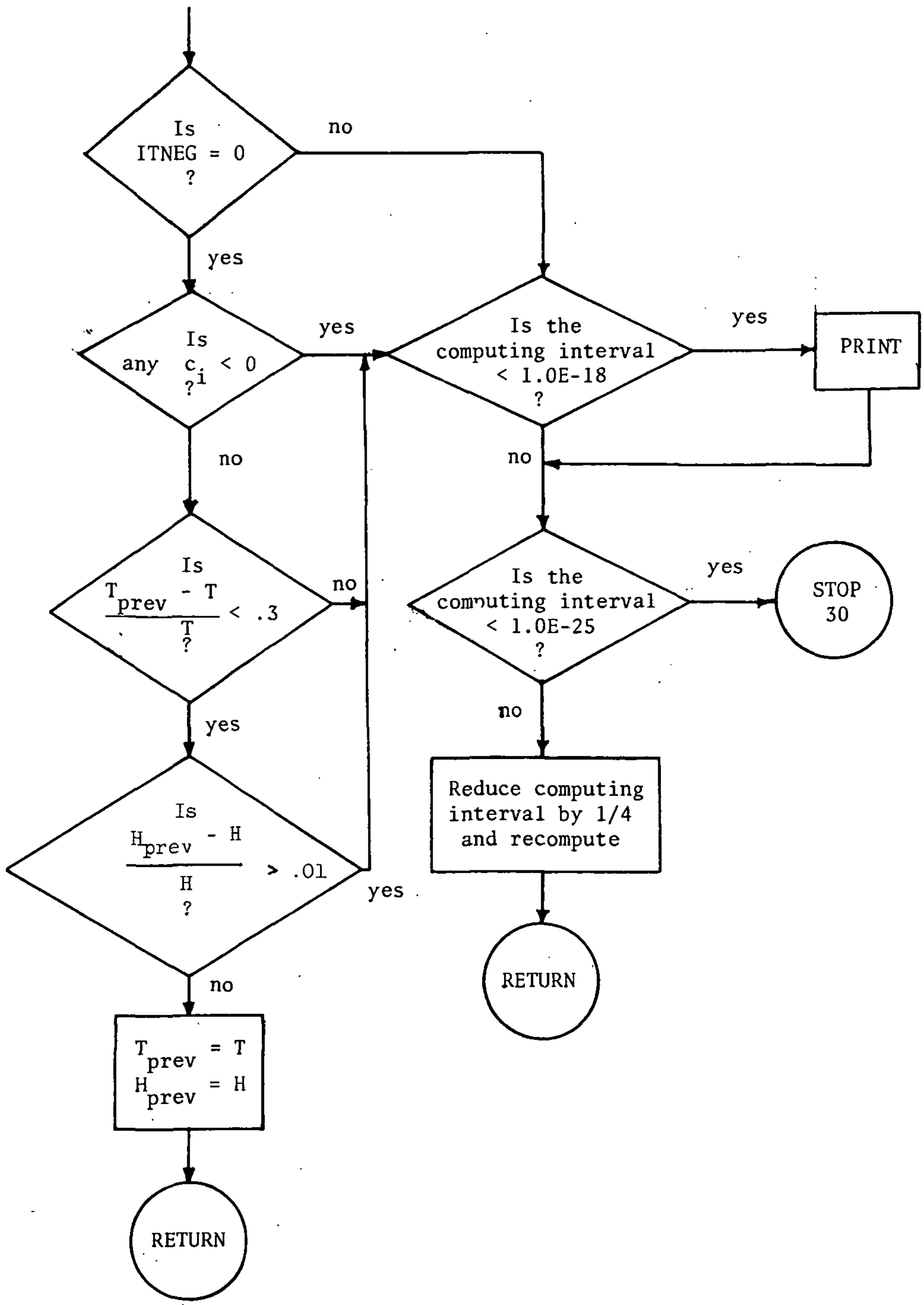

Have all ψ values been computed ?
Compute and print physical space values
no
yes
END

BASIC

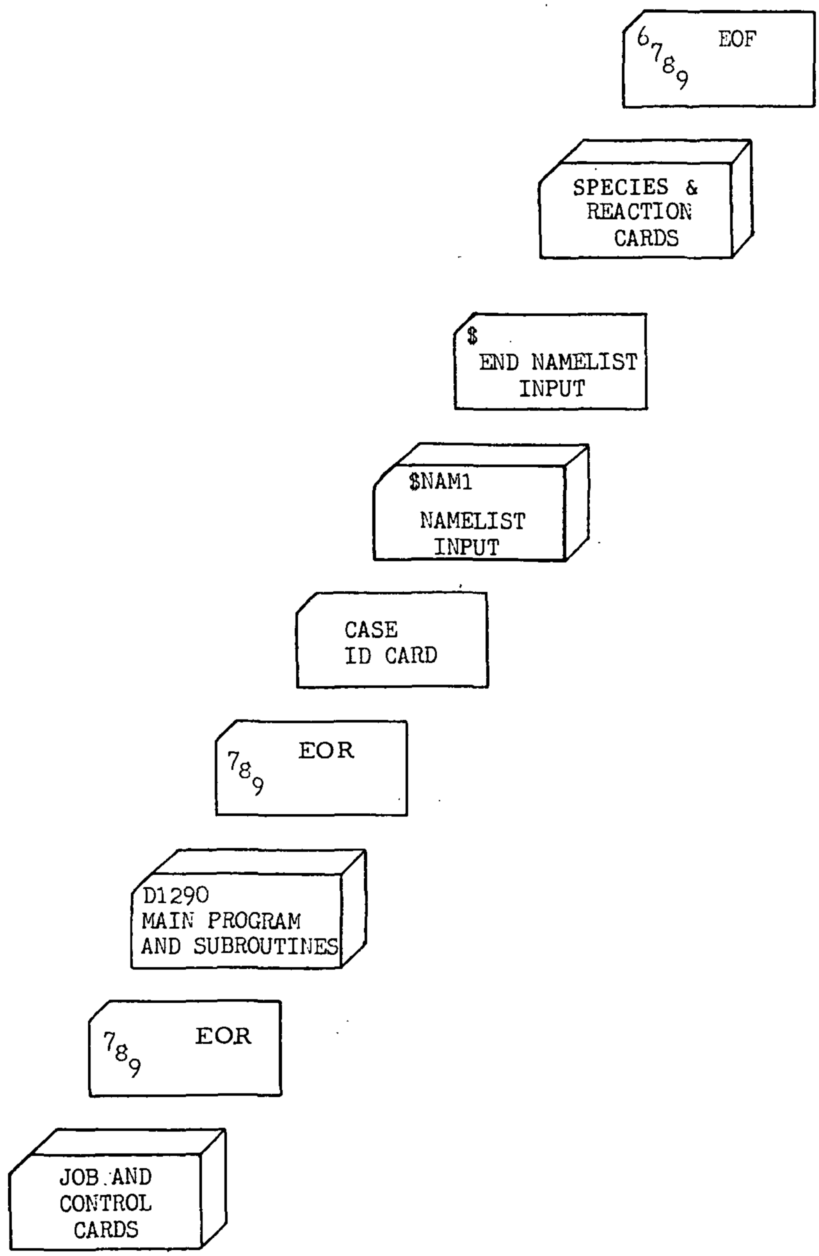

Evaluate derivatives . ċi, ėv,i, ḣ i = 1, I
Is ITNEG = 1 or IEXP = 1 ?
yes
RETURN
no
Is M = 0 ?
yes
Put (ev,i) i=1,I in proper place in single precision array
no
Interpolate for p & ṗ at x
Is KEYINT = 0 ?
yes
KEYINT = 1
no
Compute Tv,i, μ, u2
Is u2 < 0.0
yes
IUNEG = -1
RETURN
no
Compute u
Compute e
CALL ITRI to iterate for e
FOFE to evaluate e
Did e converge
no
Has e been reestimated 2 times ?
no
Make new e estimate
yes
STOP 66
yes
Is IEXP = 0 ?
no
Has e been reestimated 2 times ?
no
yes
RETURN
yes
Compute ρ, T
Is T < 0.0 ?
yes
PRINT "T NEG" E=h-.000001 x h ITNEG = 1
RETURN
no
Compute each reaction, j for each species, i ċi, ėv,i(i=1,I)
If M = 0 ev,i = ev,i
Compute ḣ
RETURN

CHECK

Test answers



The deck setup is as follows:



APPENDIX B

GENERAL RATE EQUATION

In the case of a rate expression being the same for several catalytic species, it is desirable for the sake of convenience to incorporate all these catalysts into one reaction. In order to incorporate these catalysts, the set of catalytic species is treated as a general species designated as M. Those species denoted by M will be related to the jth reaction by a set of input parameters $a_{i,j}$. Thus, if the ith species is one of the set composing M in the jth reaction, $a_{i,j}$ will be unity; otherwise, $a_{i,j}$ will be zero.

If a general species M is included in the general rate expression of equation (34),

$$\left[\left(\frac{\partial c_i}{\partial x}\right)_\psi\right]_j = \left[\frac{K_j\mu_i}{\rho u}\left(\nu'_{i,j} - \nu_{i,j}\right)\prod_{i=1}^{I}\left(\frac{\rho c_i}{\mu_i}\right)^{\nu_{i,j}}\right]\left(\frac{\rho c_M}{\mu_M}\right)^{\nu_{I+1,j}} \tag{B1}$$

where the general species is denoted by the subscript I + 1. The mass fraction of M, that is, c_M is

$$c_M = \sum_{i=1}^{I} a_{i,j}c_i \tag{B2}$$

and the molecular weight μ_M is

$$\mu_M = \sum_{i=1}^{I} m_i\mu_i \tag{B3}$$

m_i being the mole fraction of the ith component of the set composing M. Hence,

$$m_i = \frac{p_{M,i}}{p_M} \tag{B4}$$

and

$$p_{M,i} = \frac{c_i\mu}{\mu_i}\, pa_{i,j} \tag{B5}$$

By using Dalton's law of partial pressures

$$p_M = \sum_{i=1}^{I} p_{M,i} \tag{B6}$$

Substituting the three relations (eqs. (A4), (A5), and (A6)) into equation (A3) results in

$$\mu_M = \frac{\sum_{i=1}^{I} c_i a_{i,j}}{\sum_{i=1}^{I} \frac{c_i a_{i,j}}{\mu_i}} \tag{B7}$$

Inclusion of equations (A2) and (A7) into equation (A1) yields a rate equation incorporating the general species M,

$$\left[\left(\frac{\partial c_i}{\partial x}\right)_\psi\right]_j = \left[\frac{K_j \mu_i}{\rho u}\left(\nu'_{i,j} - \nu_{i,j}\right) \prod_{i=1}^{I} \left(\frac{\rho c_i}{\mu_i}\right)^{\nu_{i,j}}\right]\left(\rho \sum_{i=1}^{I} \frac{c_i a_{i,j}}{\mu_i}\right)^{\nu_{I+1,j}} \tag{B8}$$

APPENDIX C

SPECIES, REACTIONS, AND RATES FOR CASES I TO V

The species, reactions, and rates for Cases I to V are presented in this appendix.

Cases I and II

The species are N_2, N, O_2, O, NO, NO^+, and e^- for Cases I and II.

Number	Reaction	Rates	Reference
1	$O_2 + M \rightarrow 2O + M$	$1.2 \times 10^{21}\ T^{-3/2}\exp\left(-\frac{59\ 380}{T}\right)$	8
2	$2O + M \rightarrow O_2 + M$	$1.0 \times 10^{18}\ T^{-1}$	8
3	$NO + M \rightarrow N + O + M$	$5.2 \times 10^{21}\ T^{-3/2}\exp\left(-\frac{75\ 490}{T}\right)$	8
4	$N + O + M \rightarrow NO + M$	$1.3 \times 10^{21}\ T^{-3/2}$	8
5	$N_2 + M \rightarrow 2N + M$	$3.0 \times 10^{21}\ T^{-3/2}\exp\left(-\frac{113\ 260}{T}\right)$	8
6	$2N + M \rightarrow N_2 + M$	$1.67 \times 10^{20}\ T^{-3/2}$	8
7	$N + O_2 \rightarrow NO + O$	$1.0 \times 10^{12}\ T^{1/2}\exp\left(-\frac{3120}{T}\right)$	8
8	$NO + O \rightarrow N + O_2$	$2.38 \times 10^{11}\ T^{1/2}\exp\left(-\frac{19\ 130}{T}\right)$	8
9	$N_2 + O \rightarrow NO + N$	$5.0 \times 10^{13}\exp\left(-\frac{38\ 000}{T}\right)$	8
10	$NO + N \rightarrow N_2 + O$	1.11×10^{13}	8
11	$N_2 + O_2 \rightarrow 2NO$	$9.1 \times 10^{24}\ T^{-5/2}\exp\left(-\frac{65\ 000}{T}\right)$	8
12	$2NO \rightarrow N_2 + O_2$	$4.79 \times 10^{23}\ T^{-5/2}\exp\left(-\frac{43\ 270}{T}\right)$	8
13	$NO^+ + e^- \rightarrow N + O$	$1.8 \times 10^{21}\ T^{-3/2}$	8
14	$N + O \rightarrow NO^+ + e^-$	$2.17 \times 10^{11}\ T^{0.12}\exp\left(-\frac{31\ 858}{T}\right)$	8

APPENDIX C – Continued

Case III

The species are CO_2, CO, CO^+, C_2, C, O, C^+, O^+, and e^- for Case III.

Number	Reaction	Rates	Reference
1	$CO_2 + M \rightarrow CO + O + M$	$6.955 \times 10^{12}\ T^{1/2} \exp\left(-\frac{63\,286}{T}\right)$	36
2	$CO + O + M \rightarrow CO_2 + M$	$3.39 \times 10^{6}\ T^{1.6175}$	36
3	$CO + M \rightarrow C + O + M$	$7.72 \times 10^{12}\ T^{1/2} \exp\left(-\frac{128\,925}{T}\right)$	36
4	$C + O + M \rightarrow CO + M$	$2.26 \times 10^{8}\ T^{0.7366} \exp\left(\frac{665}{T}\right)$	36
5	$C + O \rightarrow CO^+ + e^-$	$2.049 \times 10^{12} \exp\left(-\frac{33\,300}{T}\right)$	40
6	$CO^+ + e^- \rightarrow C + O$	6.023×10^{16}	40
7	$C + e^- \rightarrow C^+ + 2e^-$	$2.09 \times 10^{14}\ T^{0.5} \exp\left(-\frac{130\,713}{T}\right)$	41
8	$C^+ + 2e^- \rightarrow C + e^-$	$9.65 \times 10^{21}\ T^{-0.836}$	41
9	$O + e^- \rightarrow O^+ + 2e^-$	$2.14 \times 10^{14}\ T^{0.5} \exp\left(-\frac{158\,000}{T}\right)$	41
10	$O^+ + 2e^- \rightarrow O + e^-$	$6.05 \times 10^{22}\ T^{-2}$	41
11	$C_2 + M \rightarrow 2C + M$	$6.74 \times 10^{13}\ T^{0.5} \exp\left(-\frac{70\,529}{T}\right)$	41
12	$2C + M \rightarrow C_2 + M$	$1.61 \times 10^{12}\ T^{0.743}$	41

APPENDIX C – Concluded

Cases IV and V

The species are CO_2, CO, C, O, A, C^+, A^+, and e^- for Cases IV and V.

Number	Reaction	Rates	Reference
1	$CO_2 + M \rightarrow CO + O + M$	$6.955 \times 10^{12}\ T^{1/2} \exp\left(-\frac{63\ 286}{T}\right)$	36
2	$CO + O + M \rightarrow CO_2 + M$	$3.39 \times 10^{6}\ T^{1.6175}$	36
3	$CO + M \rightarrow C + O + M$	$7.72 \times 10^{12}\ T^{1/2} \exp\left(-\frac{128\ 925}{T}\right)$	36
4	$C + O + M \rightarrow CO + M$	$2.26 \times 10^{8}\ T^{0.7366} \exp\left(\frac{665}{T}\right)$	36
5	$C + e^- \rightarrow C^+ + 2e^-$	$2.09 \times 10^{14}\ T^{0.5} \exp\left(-\frac{130\ 713}{T}\right)$	41
6	$C^+ + 2e^- \rightarrow C + e^-$	$9.65 \times 10^{21}\ T^{-0.836}$	41
7	$O + e^- \rightarrow O^+ + 2e^-$	$2.14 \times 10^{14}\ T^{0.5} \exp\left(-\frac{158\ 000}{T}\right)$	41
8	$O^+ + 2e^- \rightarrow O + e^-$	$6.05 \times 10^{22}\ T^{-2}$	41
9	$C + O \rightarrow CO^+ + e^-$	$2.049 \times 10^{12} \exp\left(-\frac{33\ 300}{T}\right)$	40
10	$CO^+ + e^- \rightarrow C + O$	6.023×10^{16}	40
11	$A + e^- \rightarrow A^+ + 2e^-$	$1.94 \times 10^{14}\ T^{0.5} \exp\left(-\frac{182\ 830}{T}\right)$	41
12	$A^+ + 2e^- \rightarrow A + e^-$	$8.55 \times 10^{21}\ T^{-1.075}$	41

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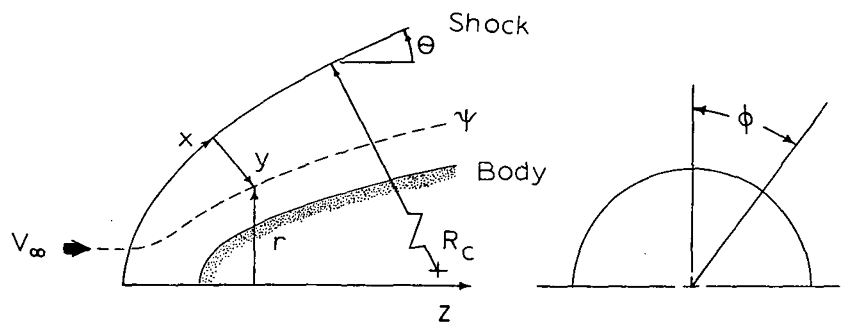


Figure 1.- Shock-oriented coordinate system.

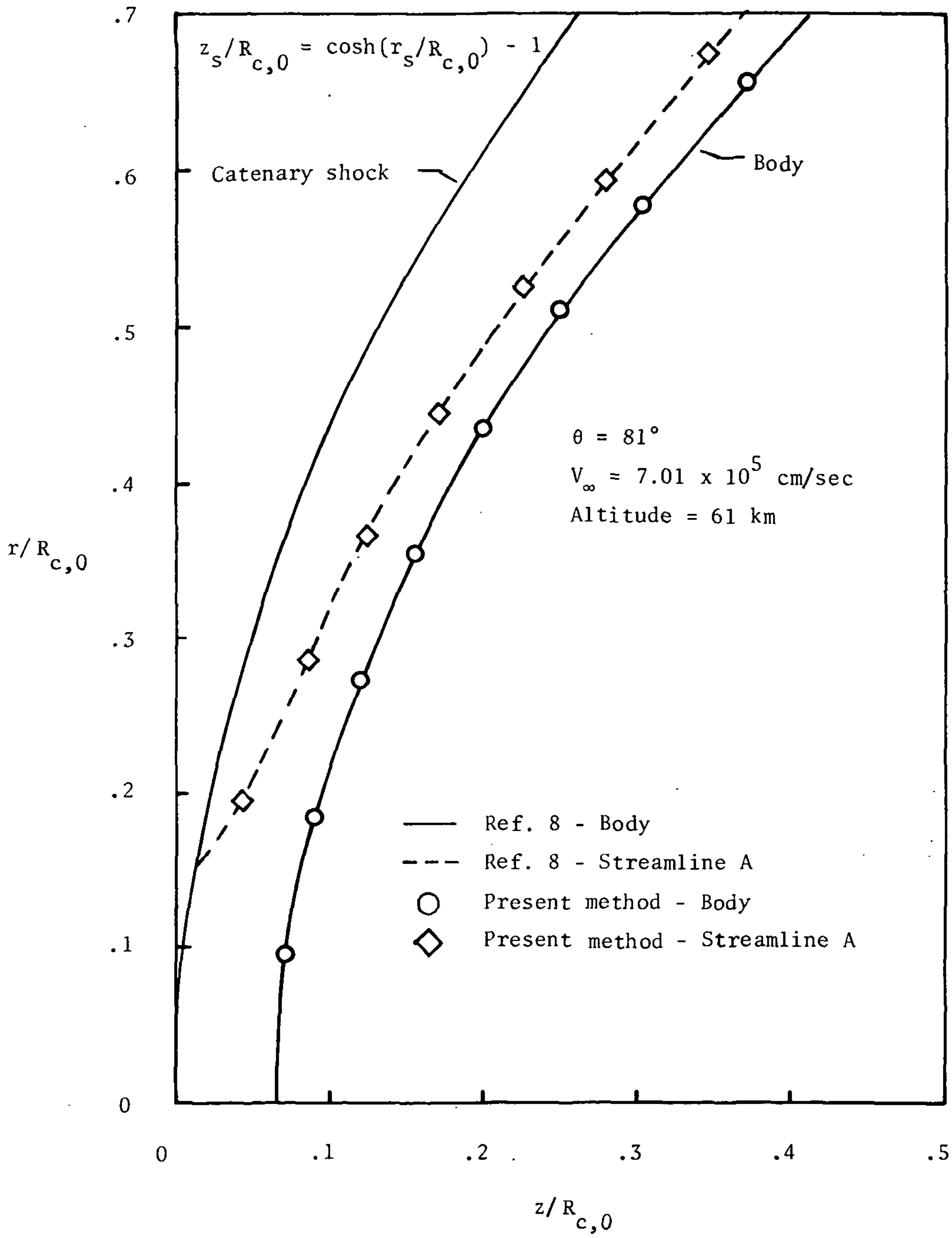


Figure 2.- Comparison of body shape and streamline location crossing the shock at $\theta = 81^{\circ}$ $\left(x/R_{c,0} = 0.16\right)$ with exact inverse method for catenary shock. Case I.

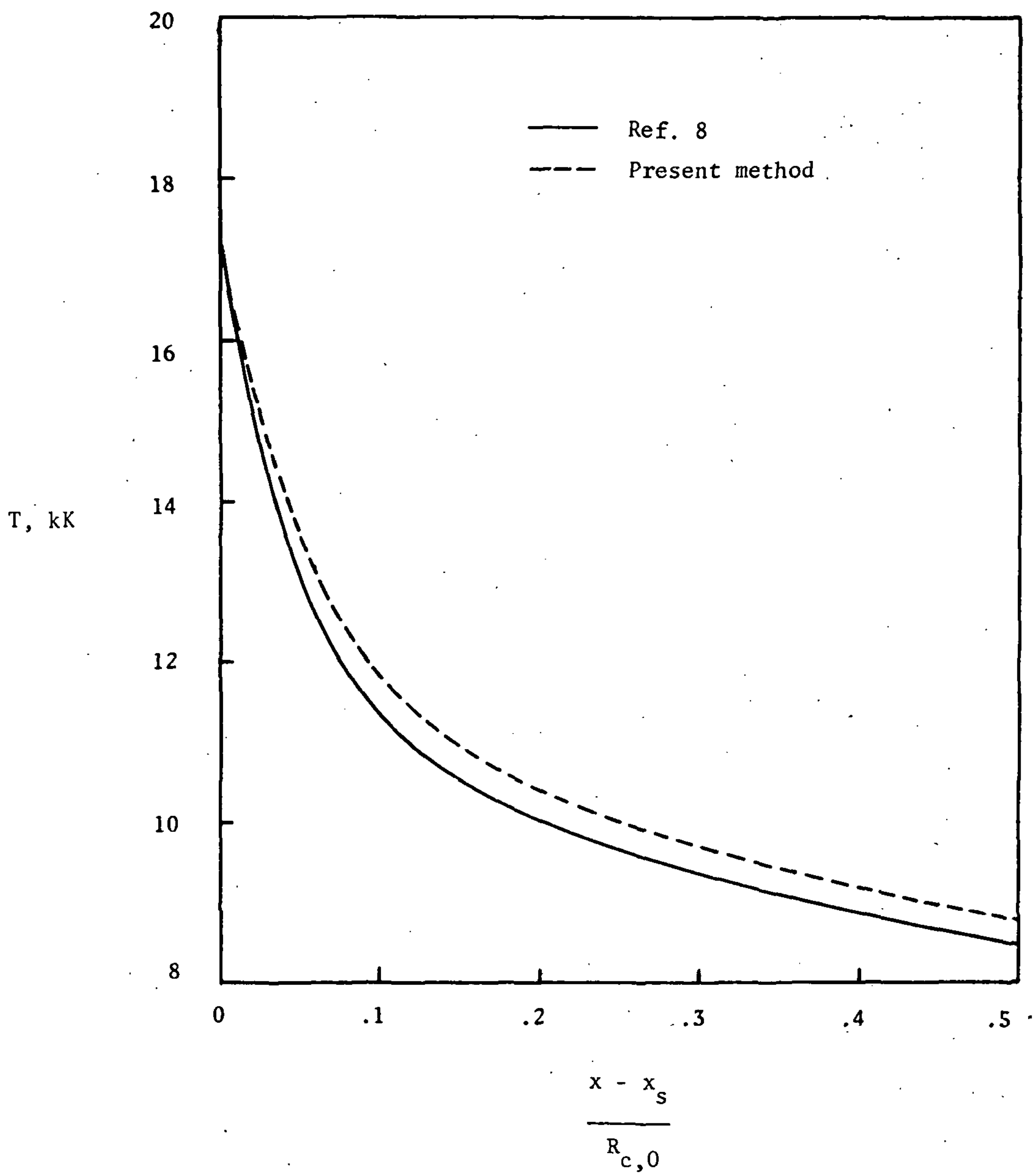


Figure 3.- Temperature variation along streamline A. Case I.

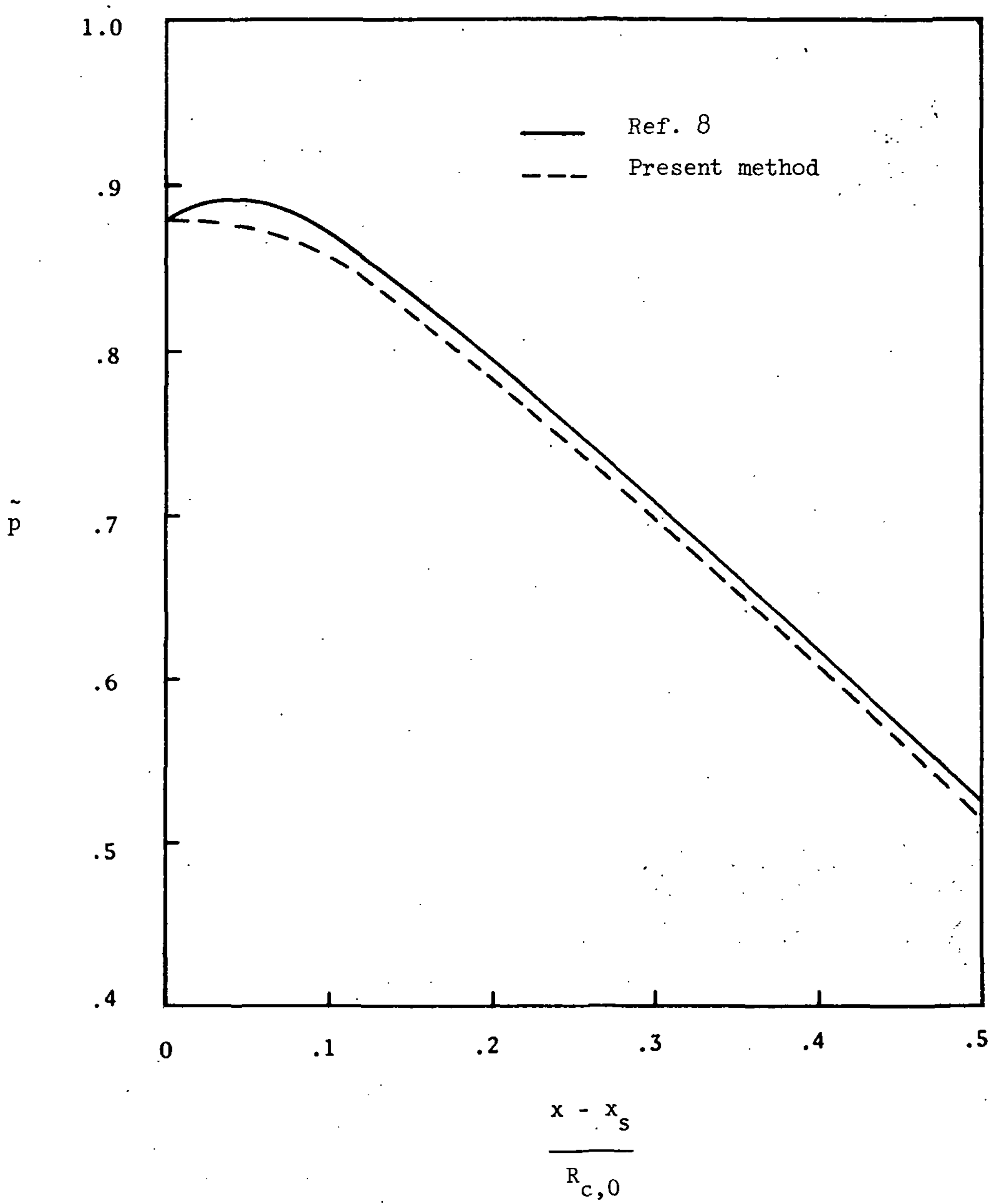


Figure 4.- Pressure variation along streamline A. Case I.

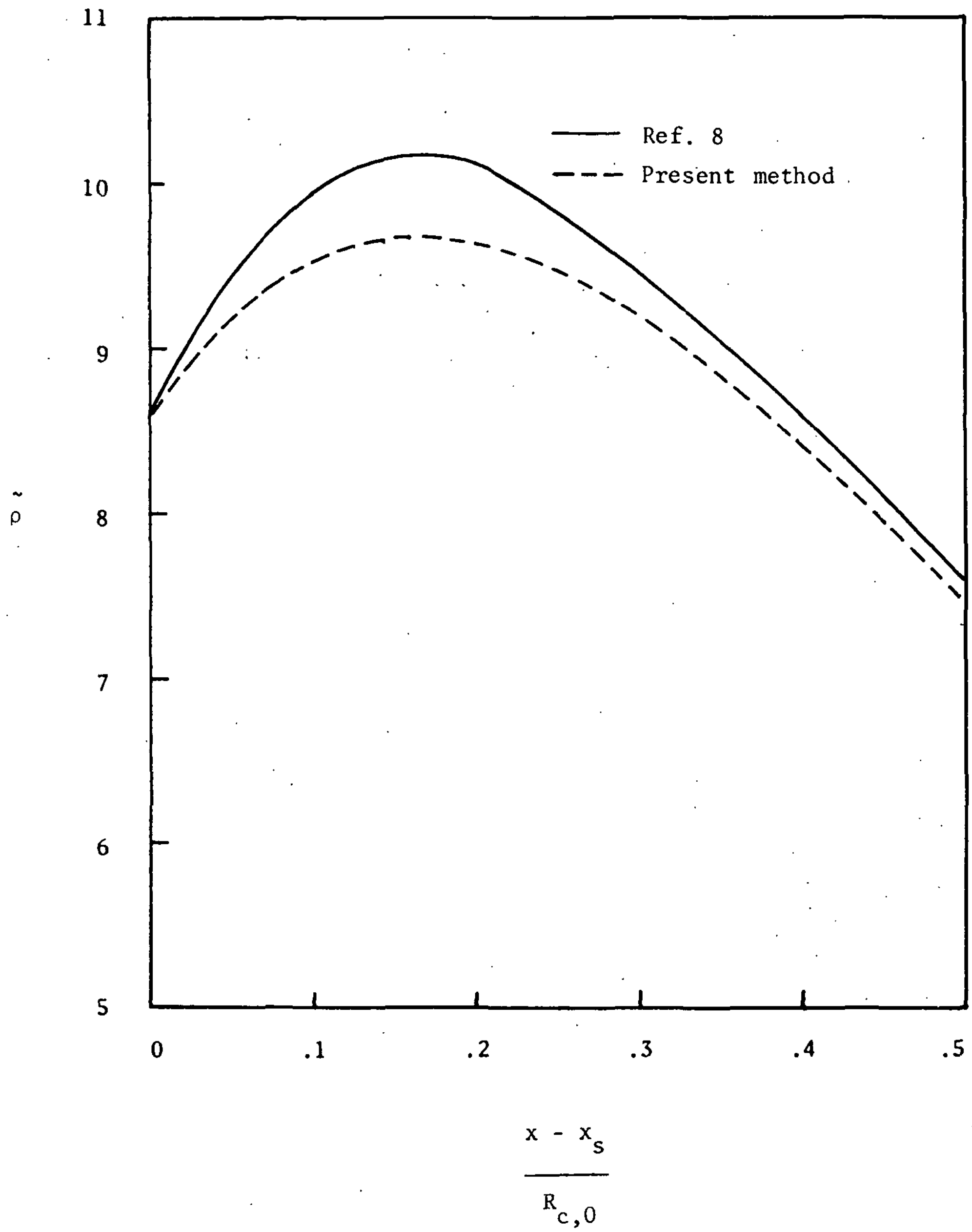
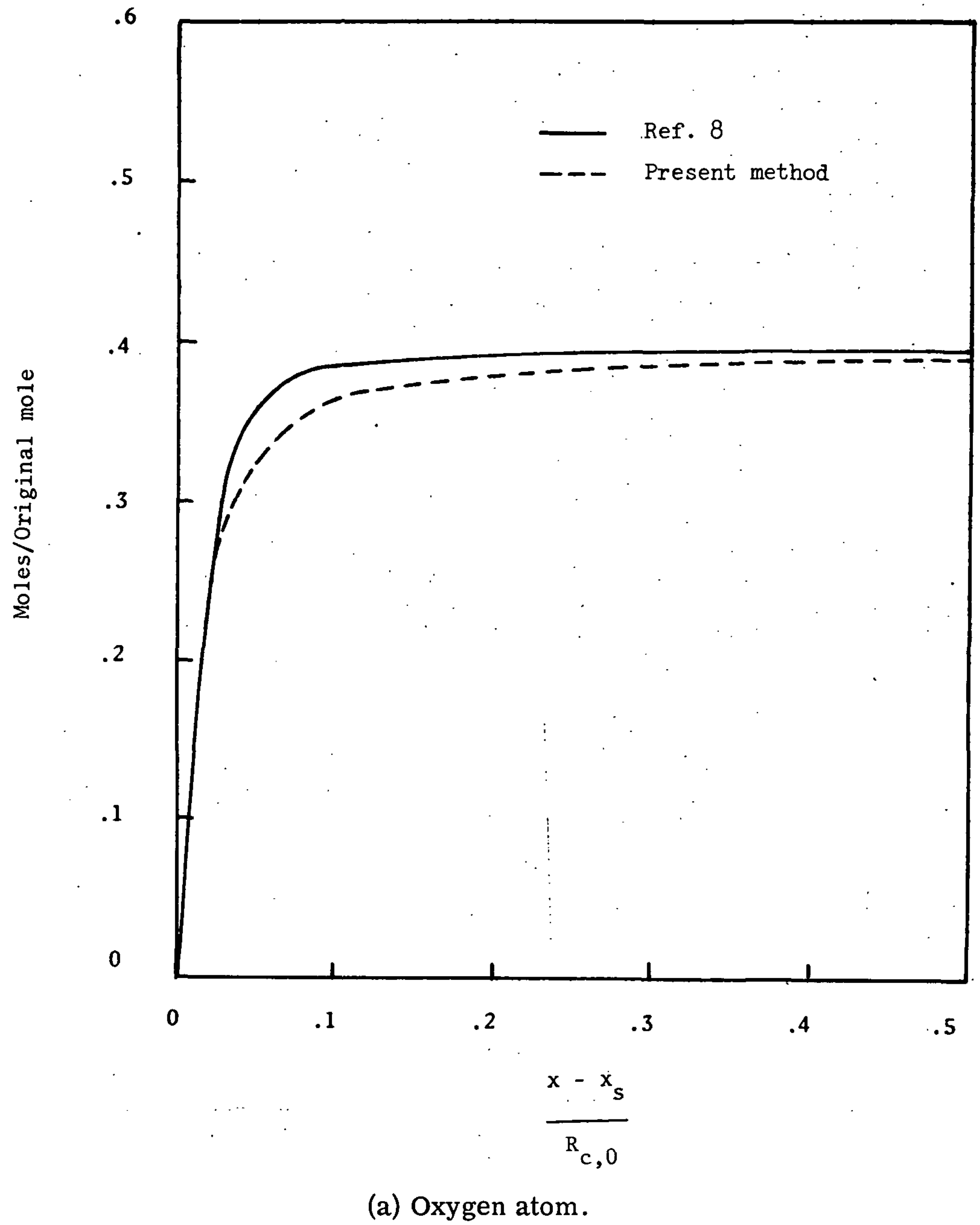
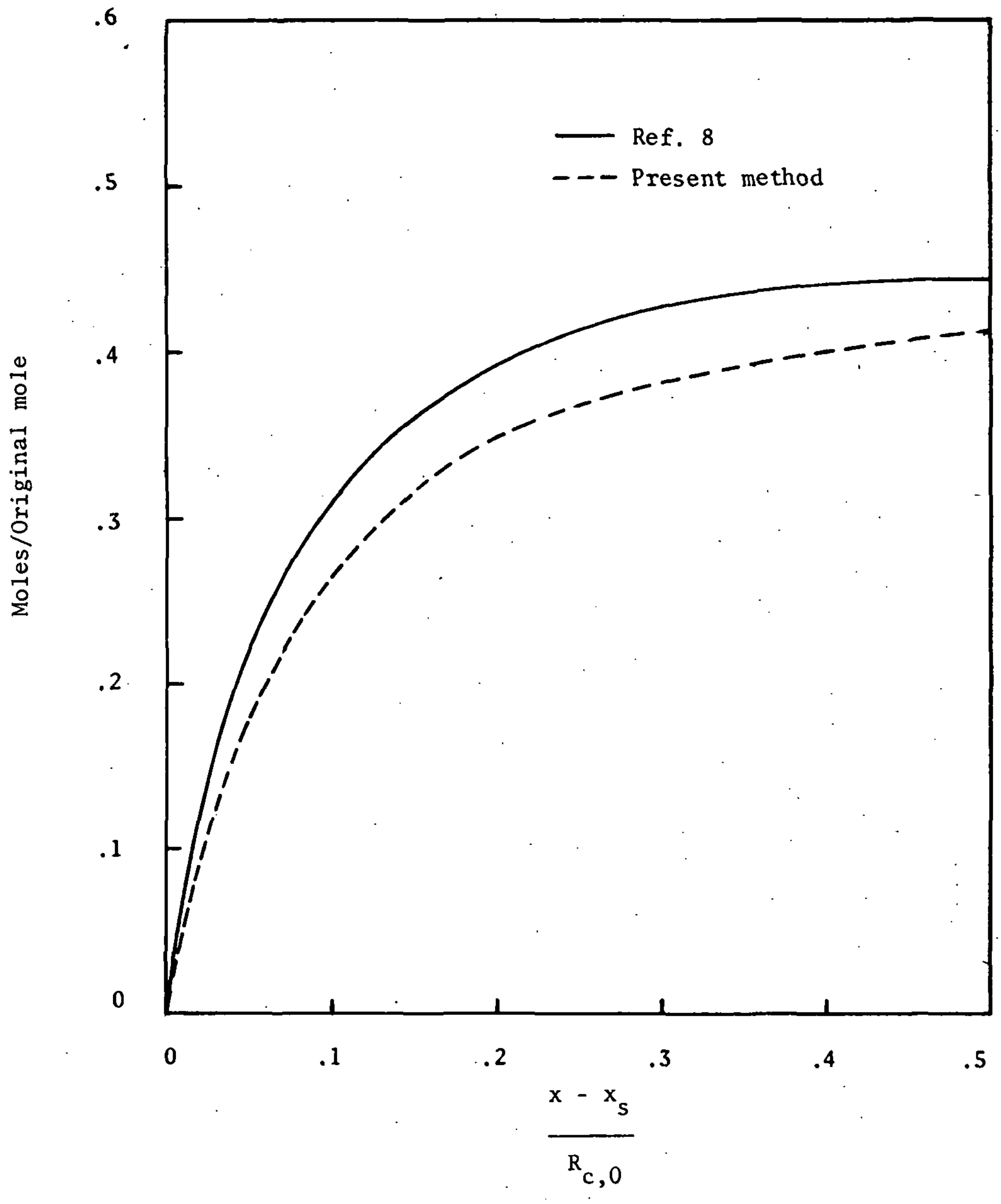


Figure 5.- Density variation along streamline A. Case I.



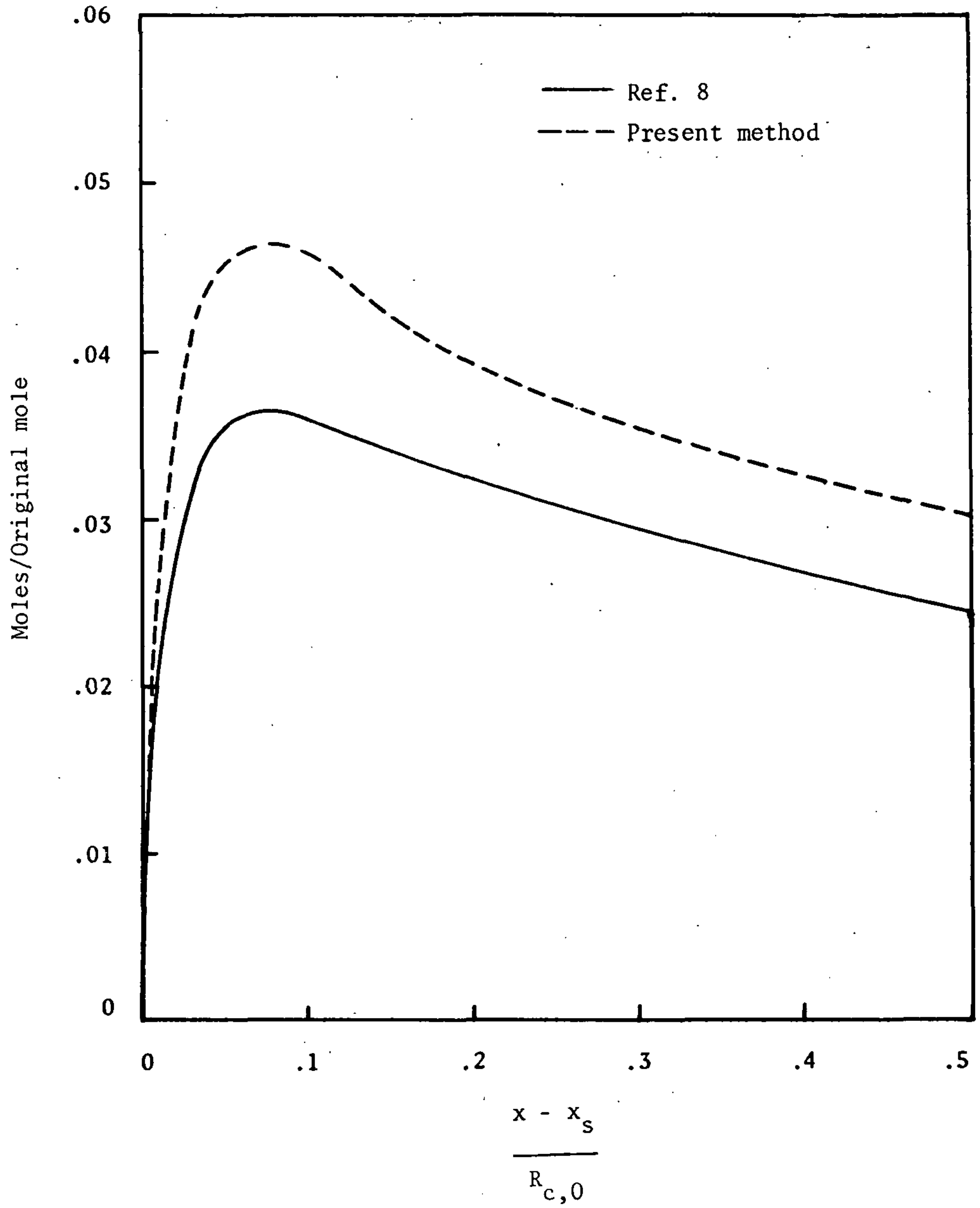
(a) Oxygen atom.

Figure 6.- Concentration variation along streamline A. Case I.



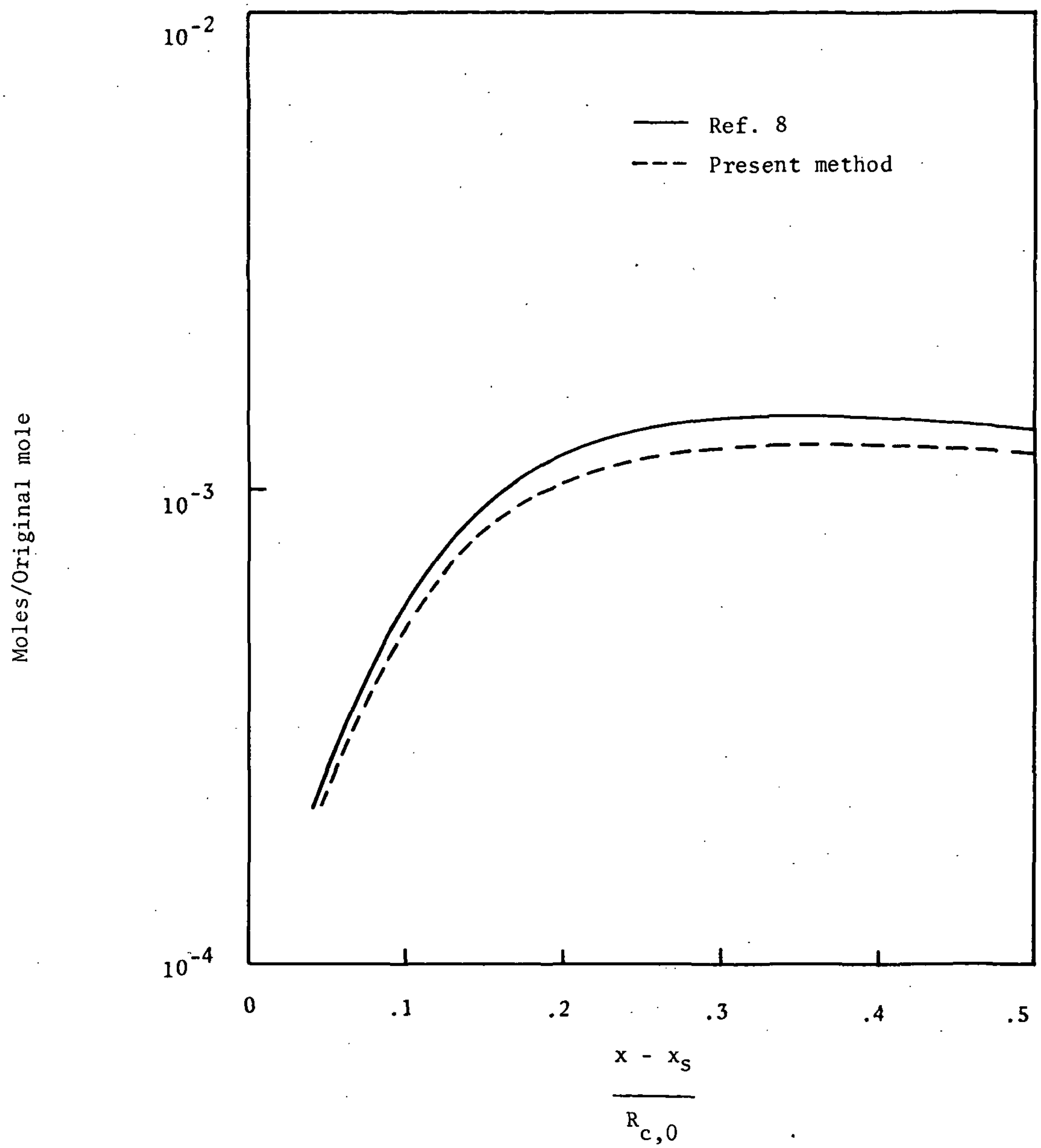
(b) Nitrogen atom.

Figure 6.- Continued.



(c) NO.

Figure 6.- Continued.



(d) Electron.

Figure 6.- Concluded.

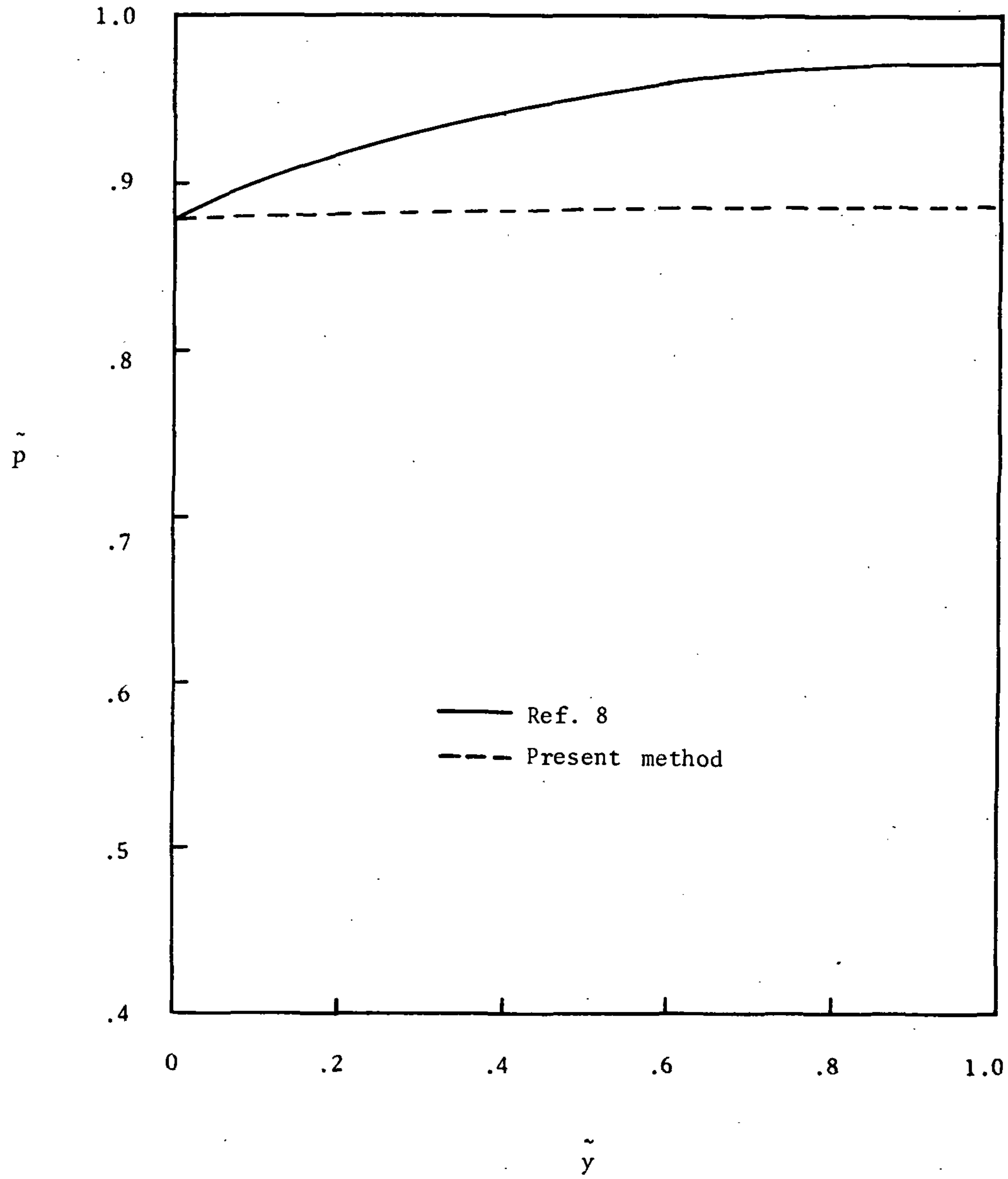


Figure 7.- Pressure variation across shock layer at $\theta = 81^{\circ}$. Case I.

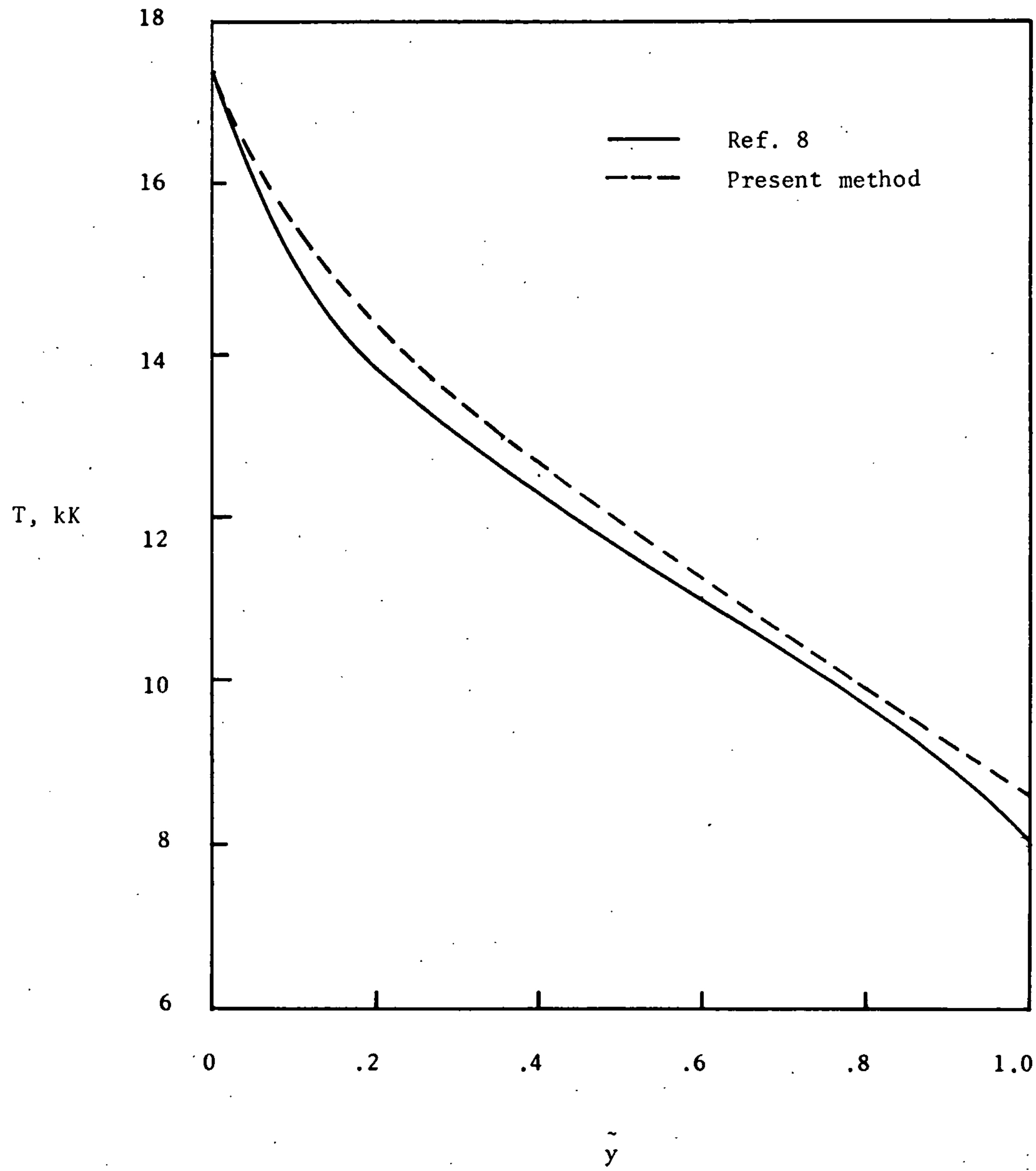


Figure 8.- Temperature variation across shock layer at $\theta = 81^{\circ}$. Case I.

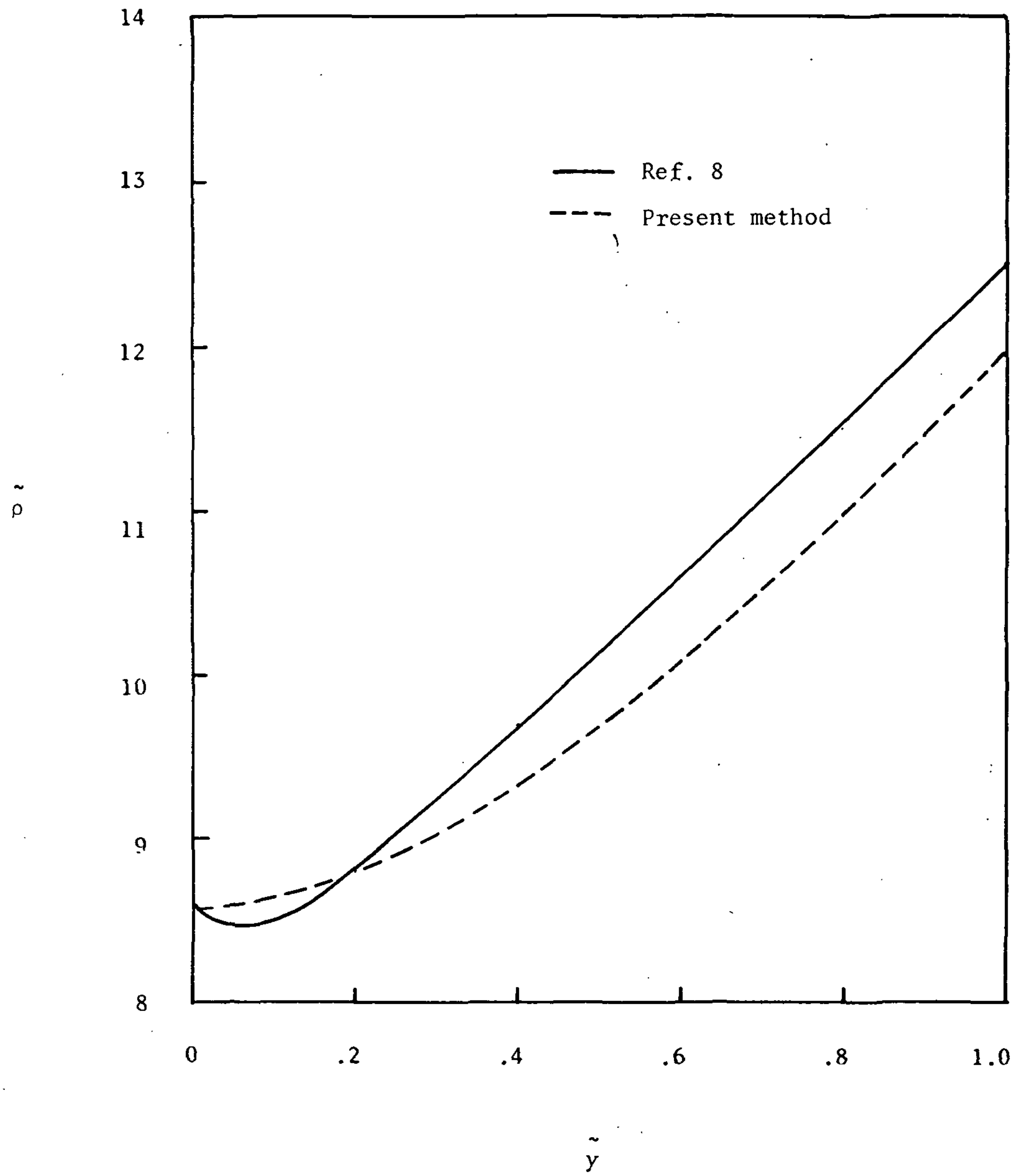
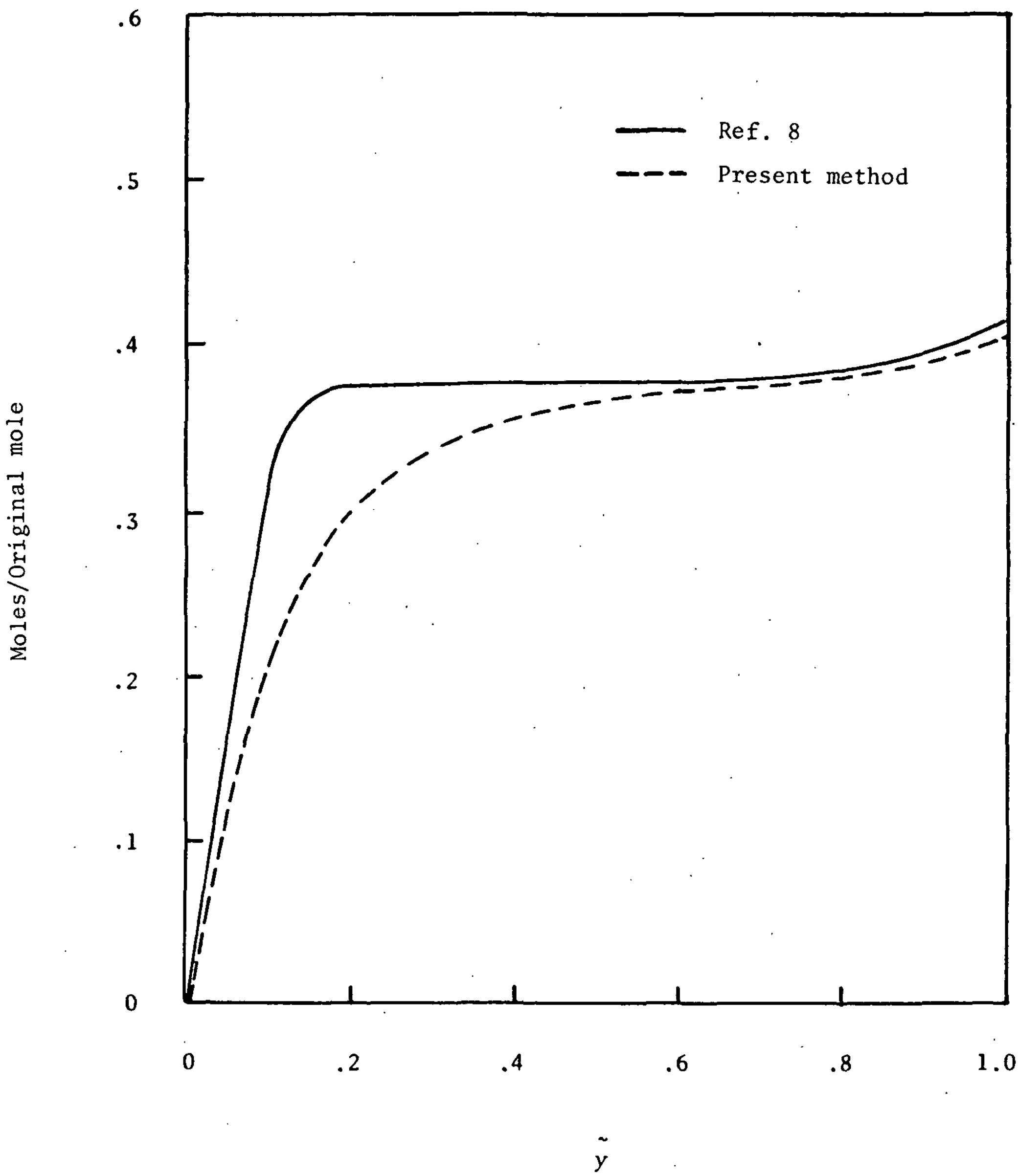
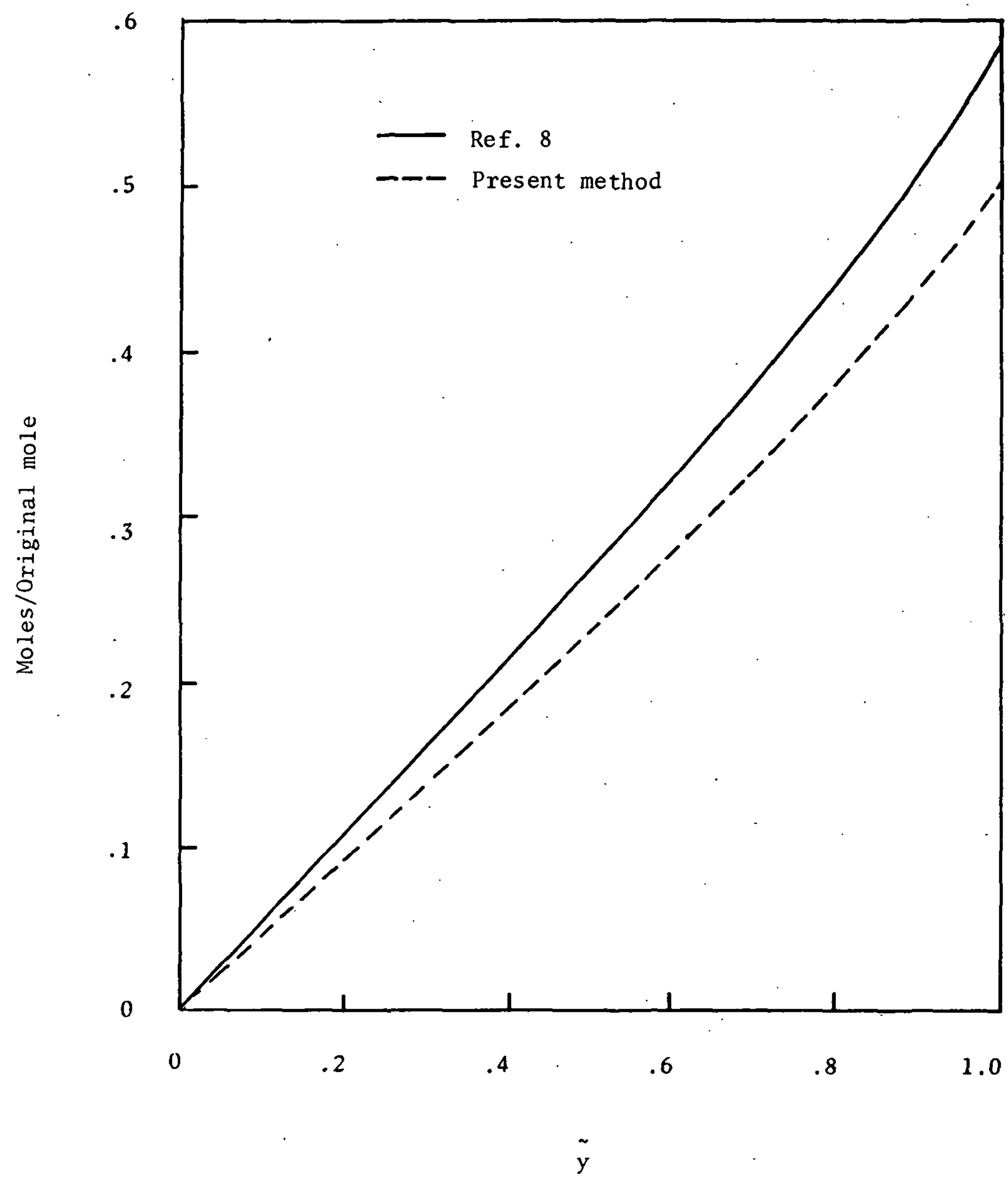


Figure 9.- Density variation across shock layer at $\theta = 81^{\circ}$. Case I.



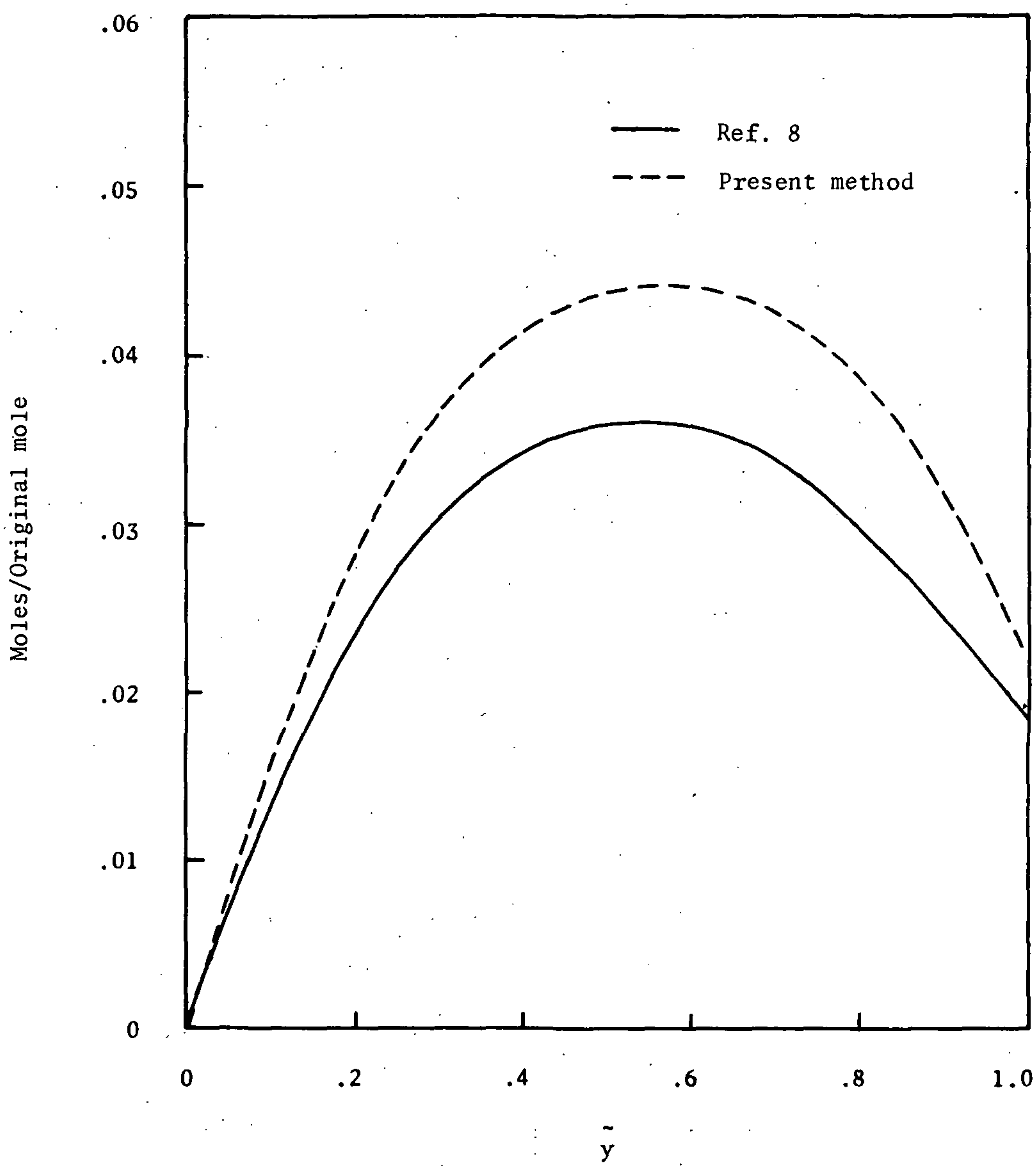
(a) Oxygen atom.

Figure 10.- Concentration variation across shock layer at $\theta = 81^{o}$. Case I.



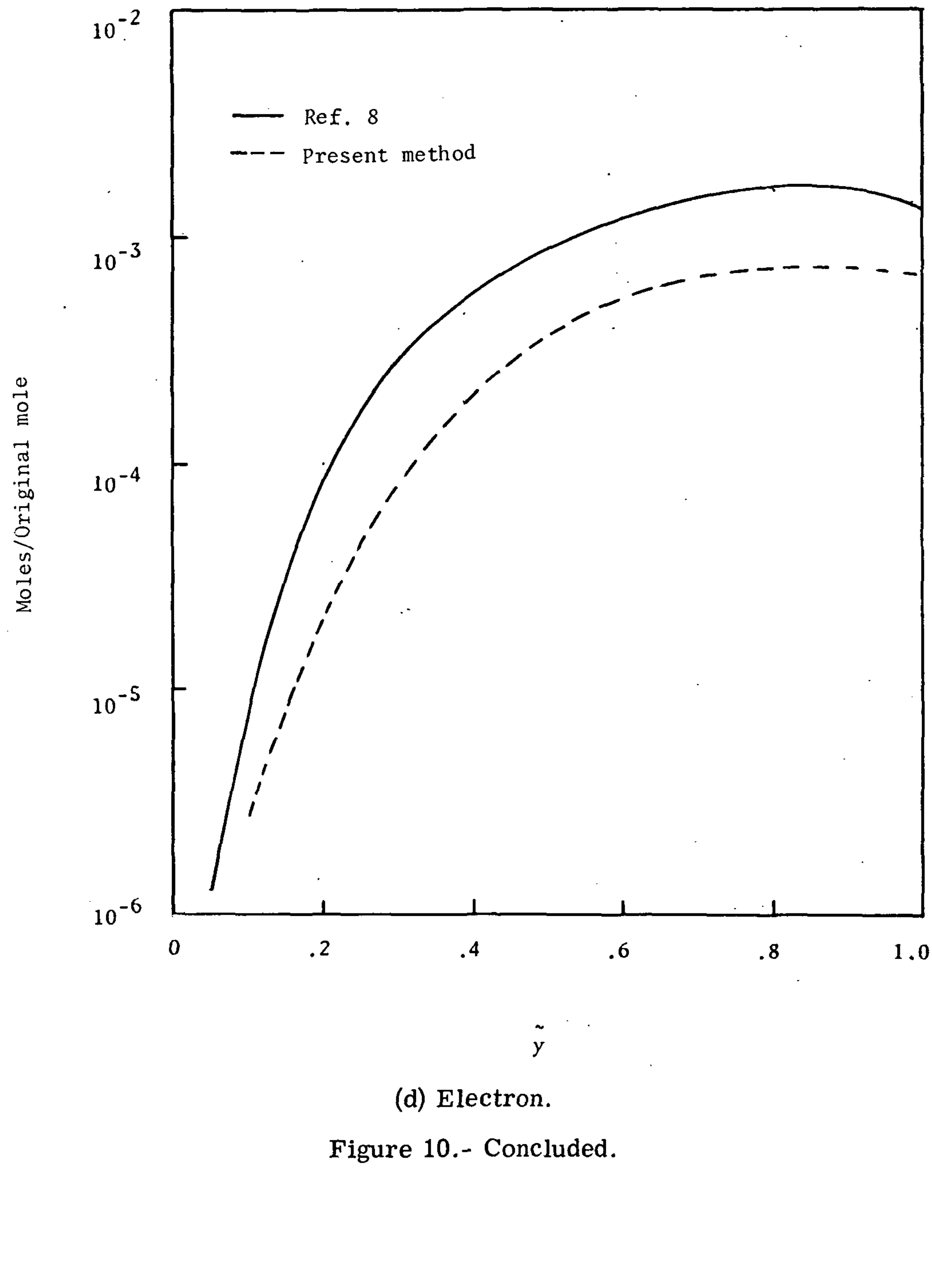
(b) Nitrogen atom.

Figure 10.- Continued.



(c) NO.

Figure 10.- Continued.



(d) Electron.

Figure 10.- Concluded.

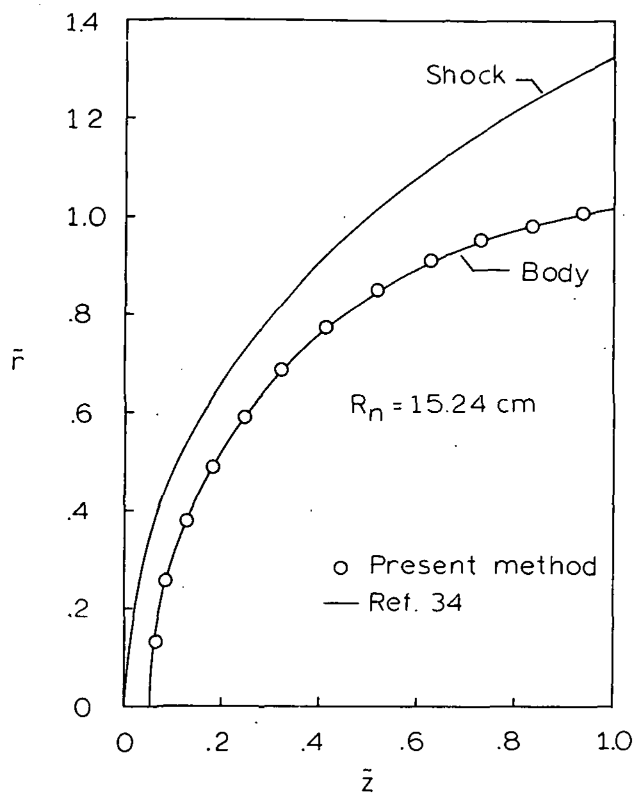


Figure 11.- Assumed shock and computed body shape. Case II.

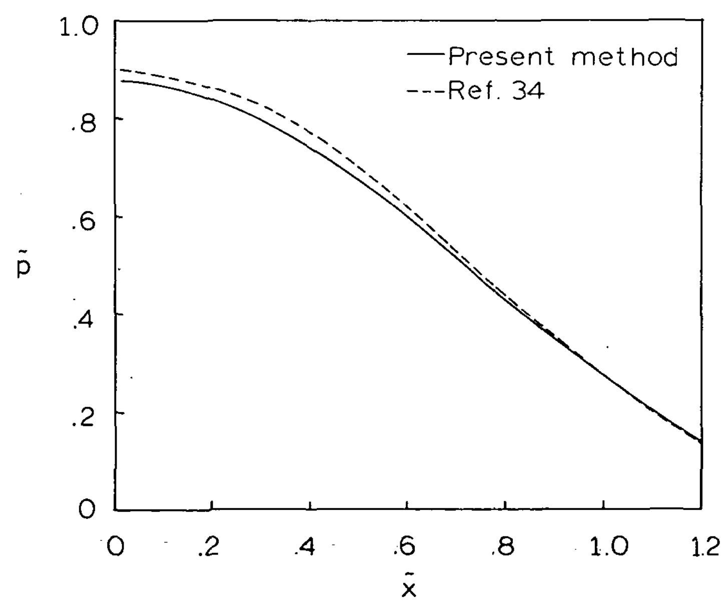


Figure 12.- Pressure variation along body surface. Case II.

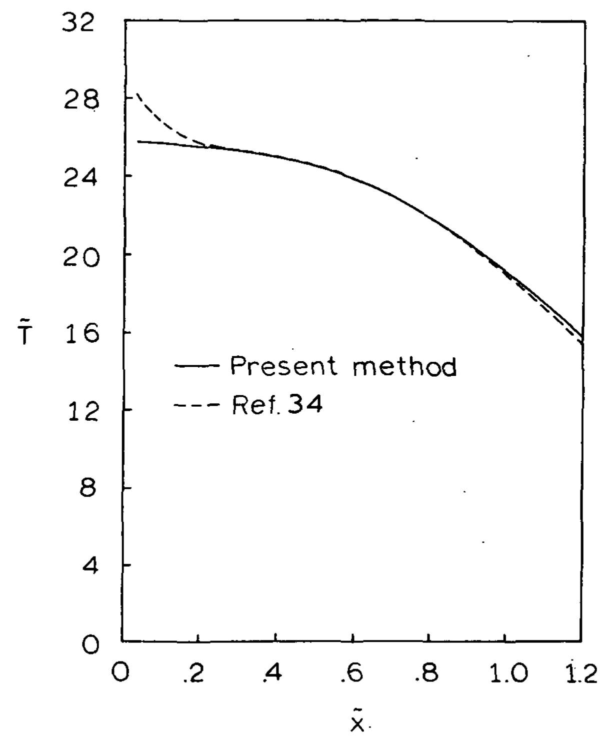


Figure 13.- Temperature variation along body surface. Case II.

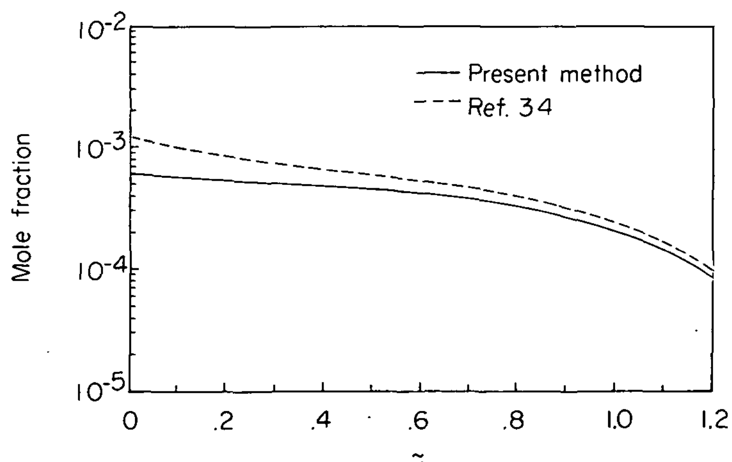


Figure 14.- Electron concentration along body surface. Case II.

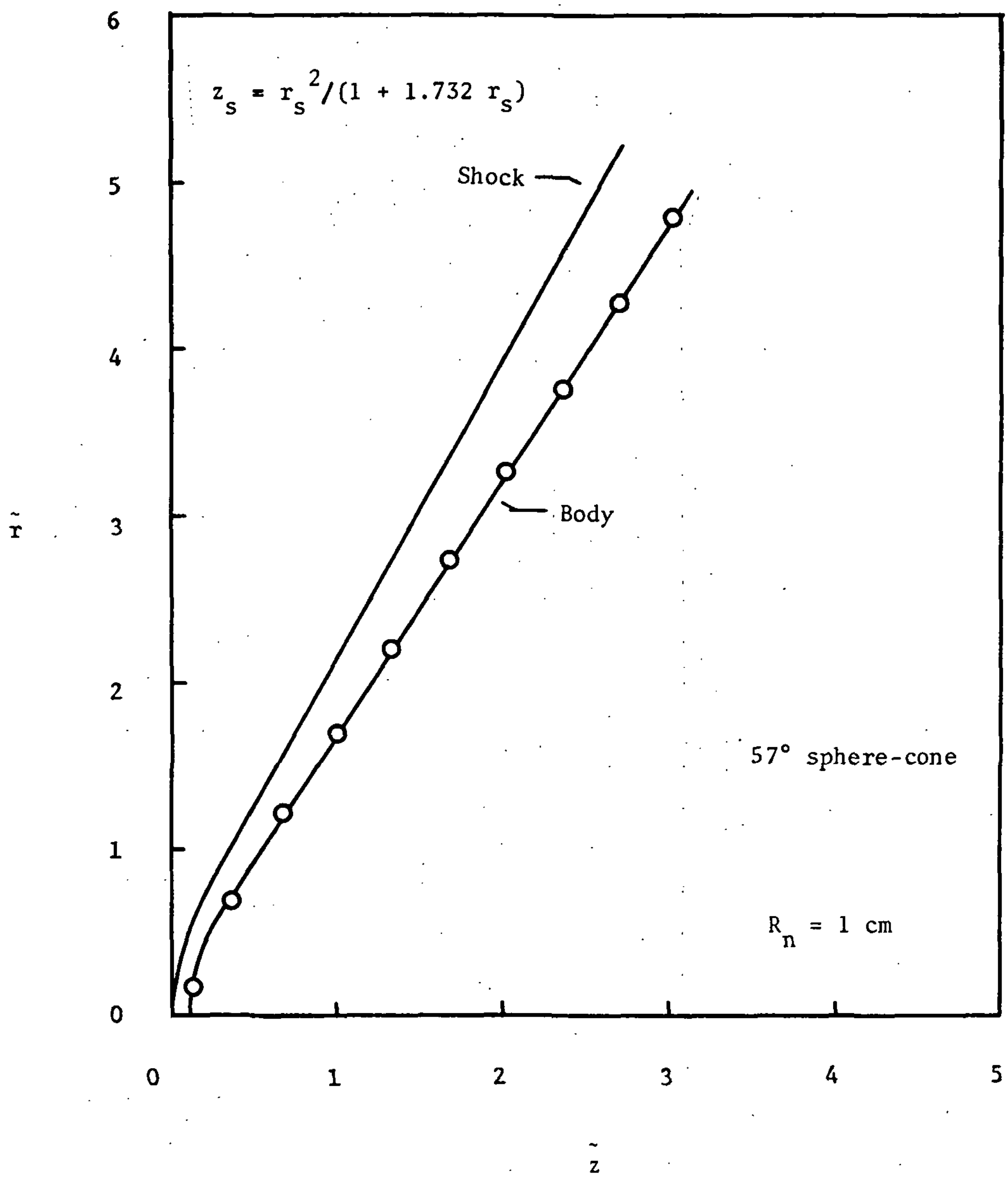


Figure 15.- Assumed shock and computed body shape. Case III.

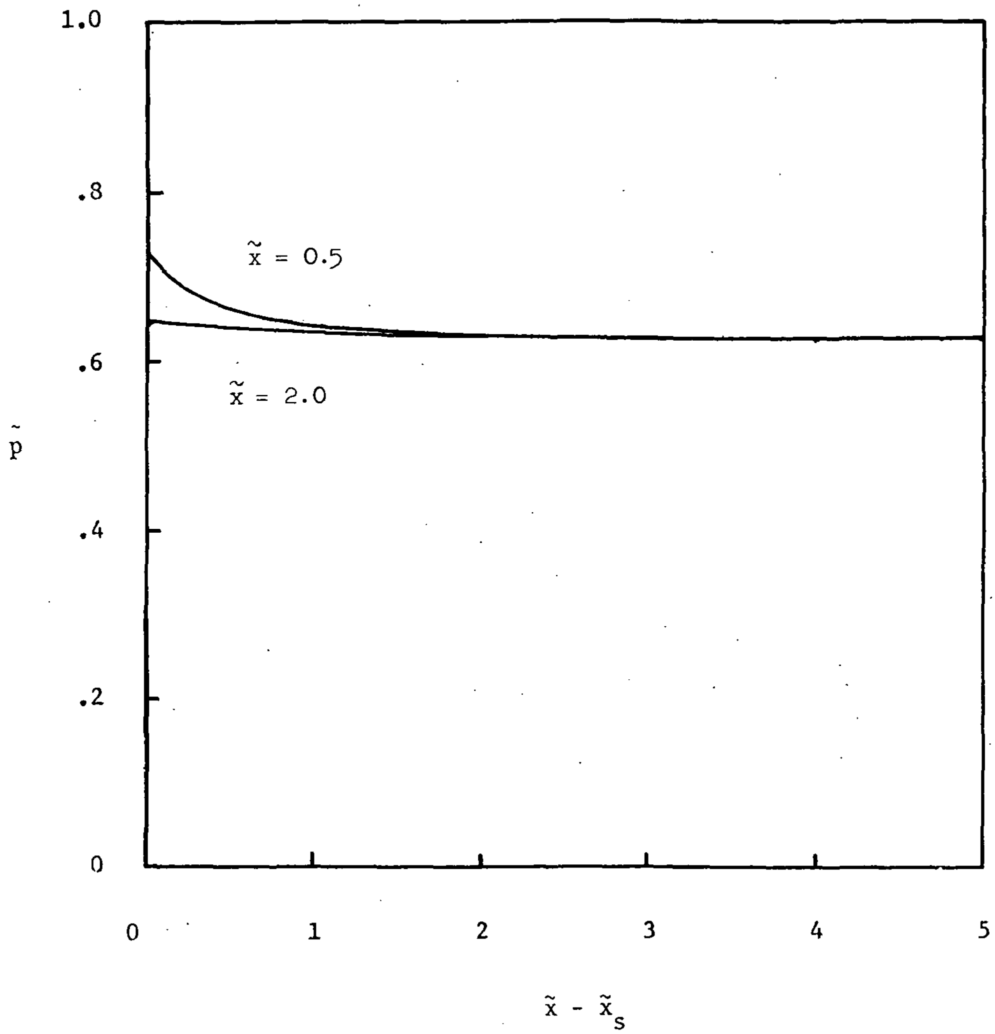


Figure 16.- Pressure variation along streamlines crossing the shock at $\tilde{x} = 0.5$ and $\tilde{x} = 2.0$. Case III.

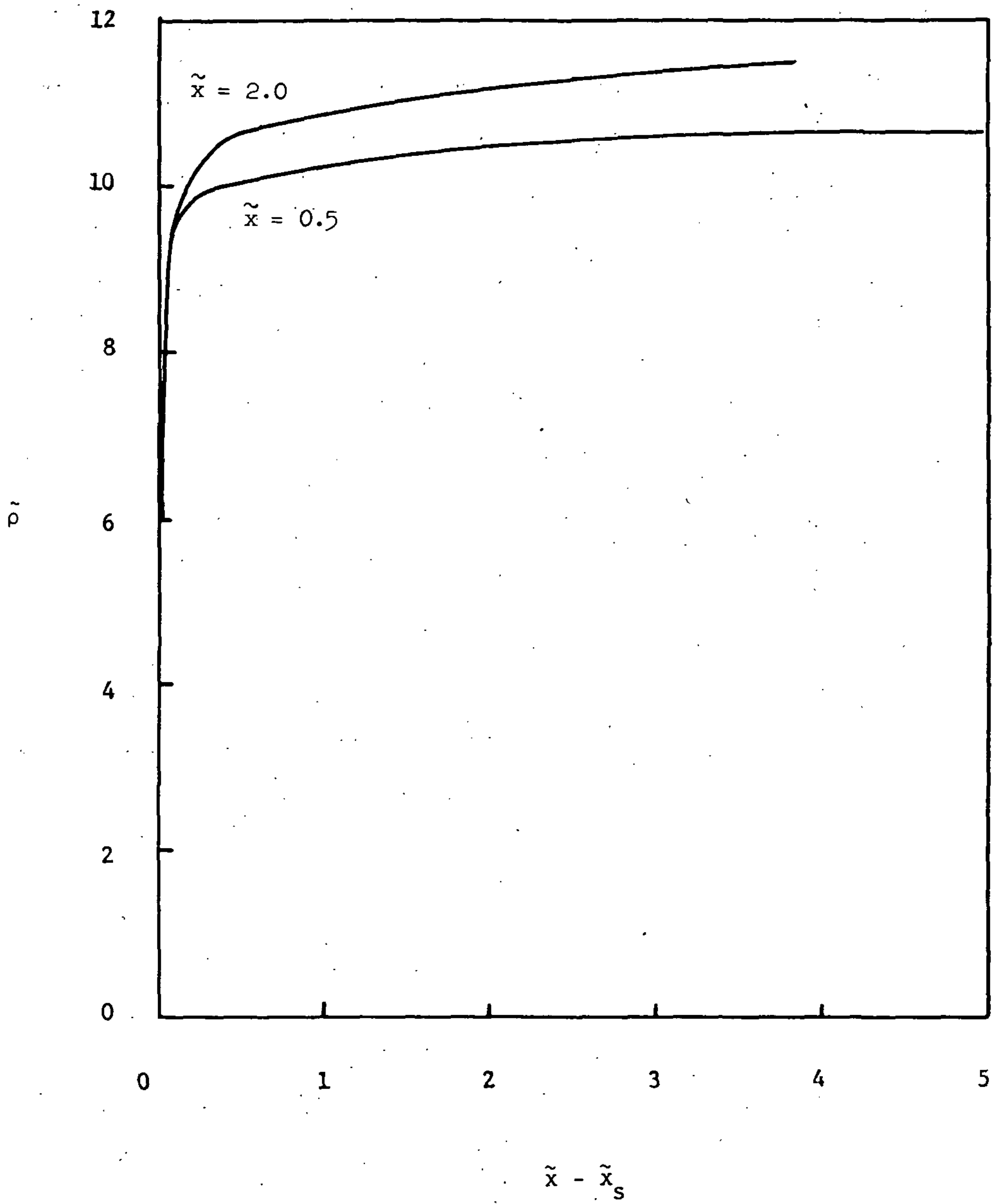


Figure 17.- Density variation along streamlines crossing the shock at $\tilde{x} = 0.5$ and $\tilde{x} = 2.0$. Case III.

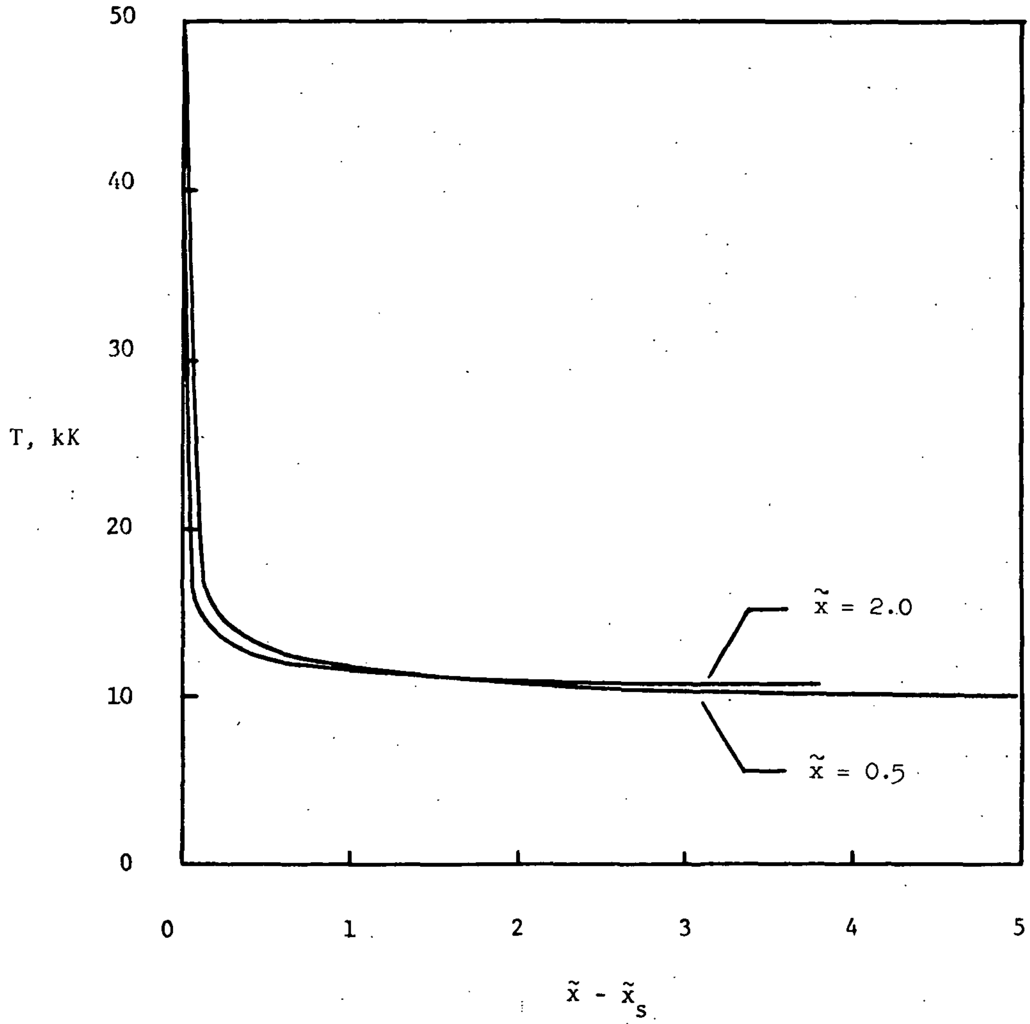
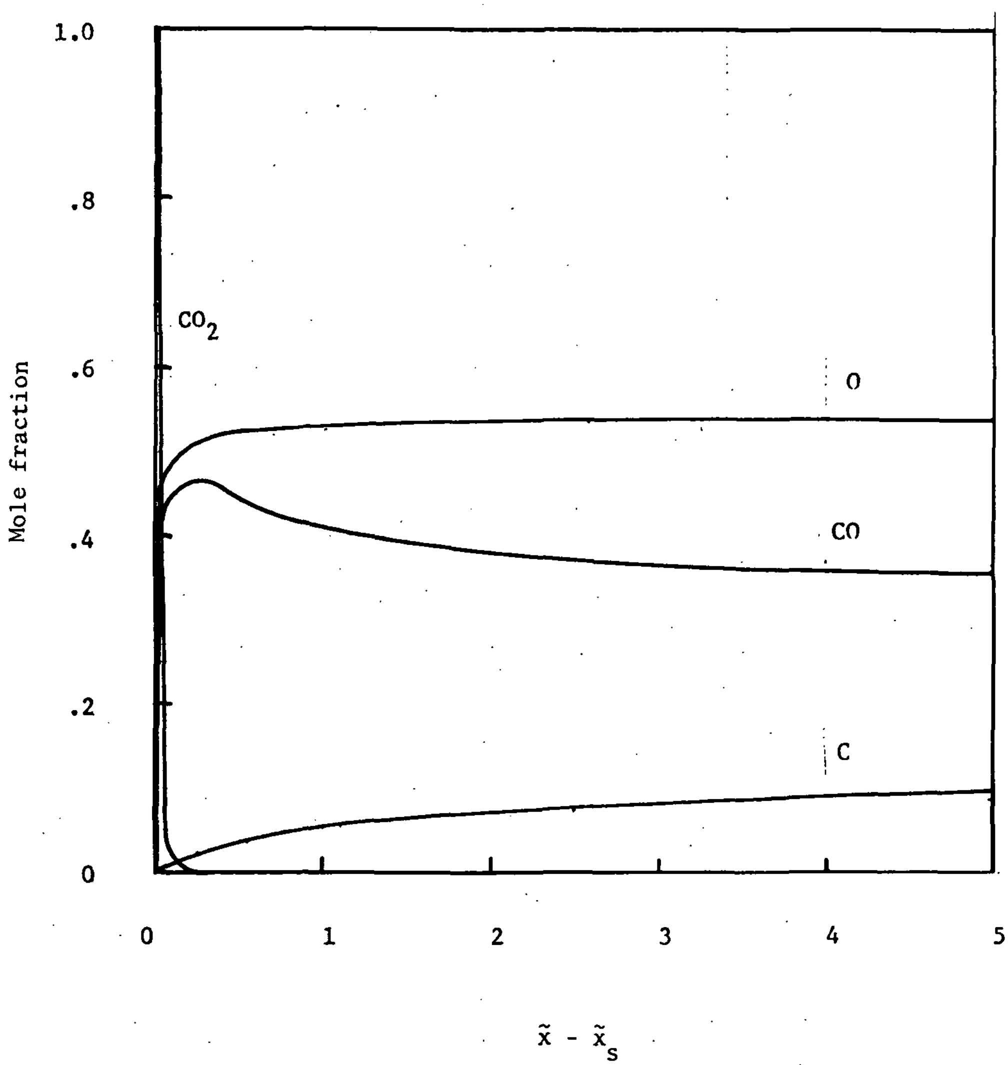
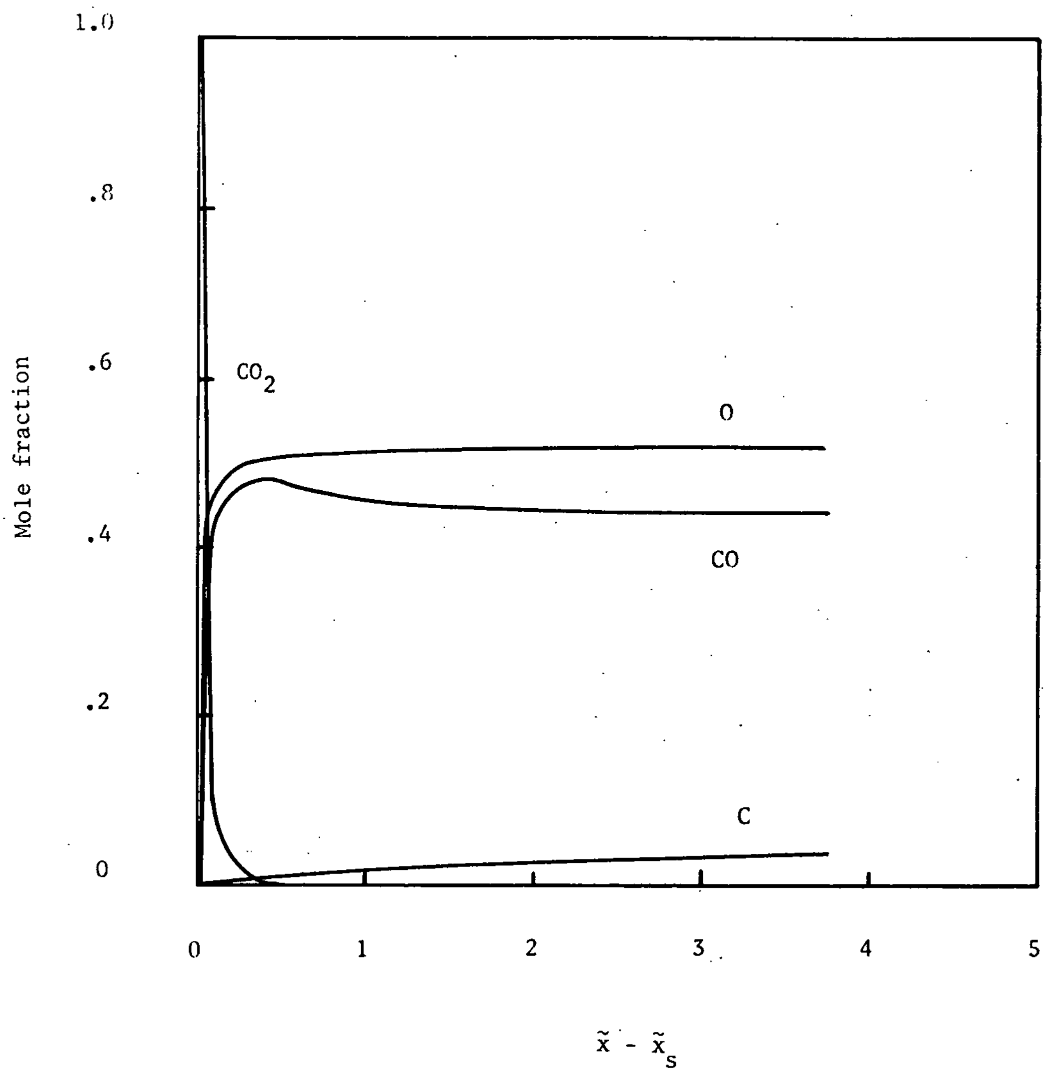


Figure 18.- Temperature variation along streamlines crossing the shock at $\tilde{x} = 0.5$ and $\tilde{x} = 2.0$. Case III.



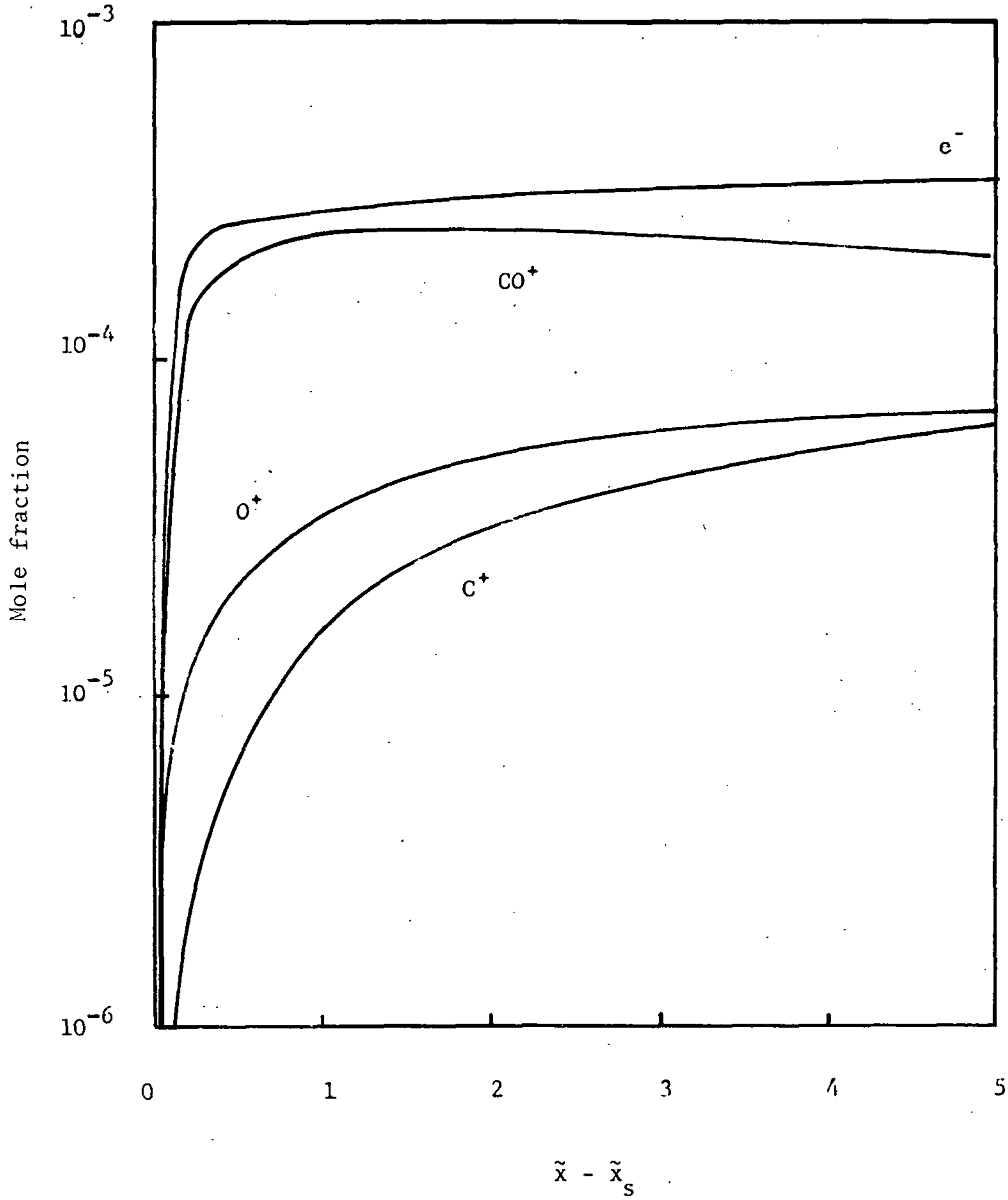
(a) $\tilde{x} = 0.5$; O, CO, C, CO_2.

Figure 19.- Species concentrations along streamline crossing the shock. Case III.



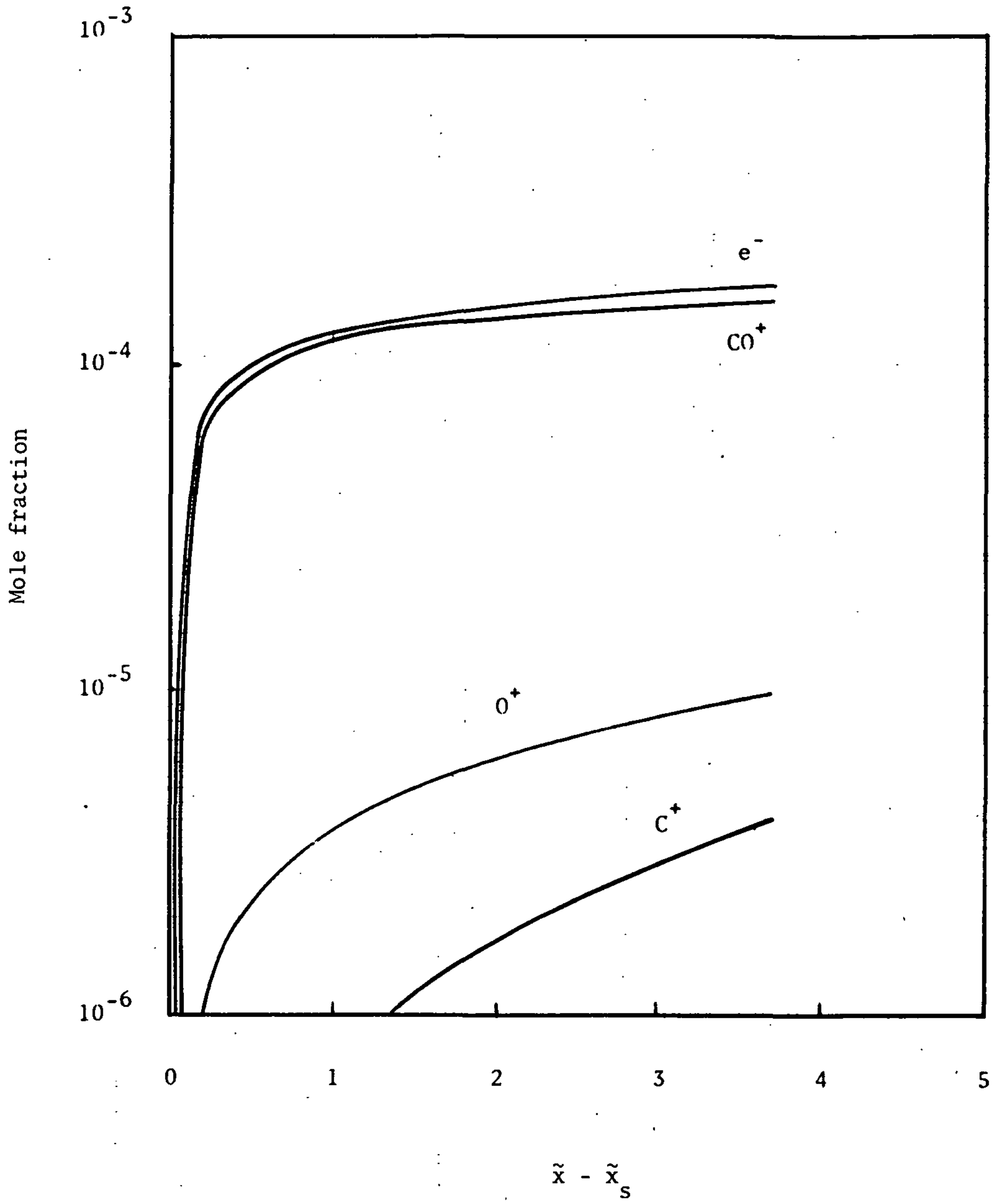
(b) $\tilde{x} = 2.0$; O, CO, C, CO_2.

Figure 19.- Continued.



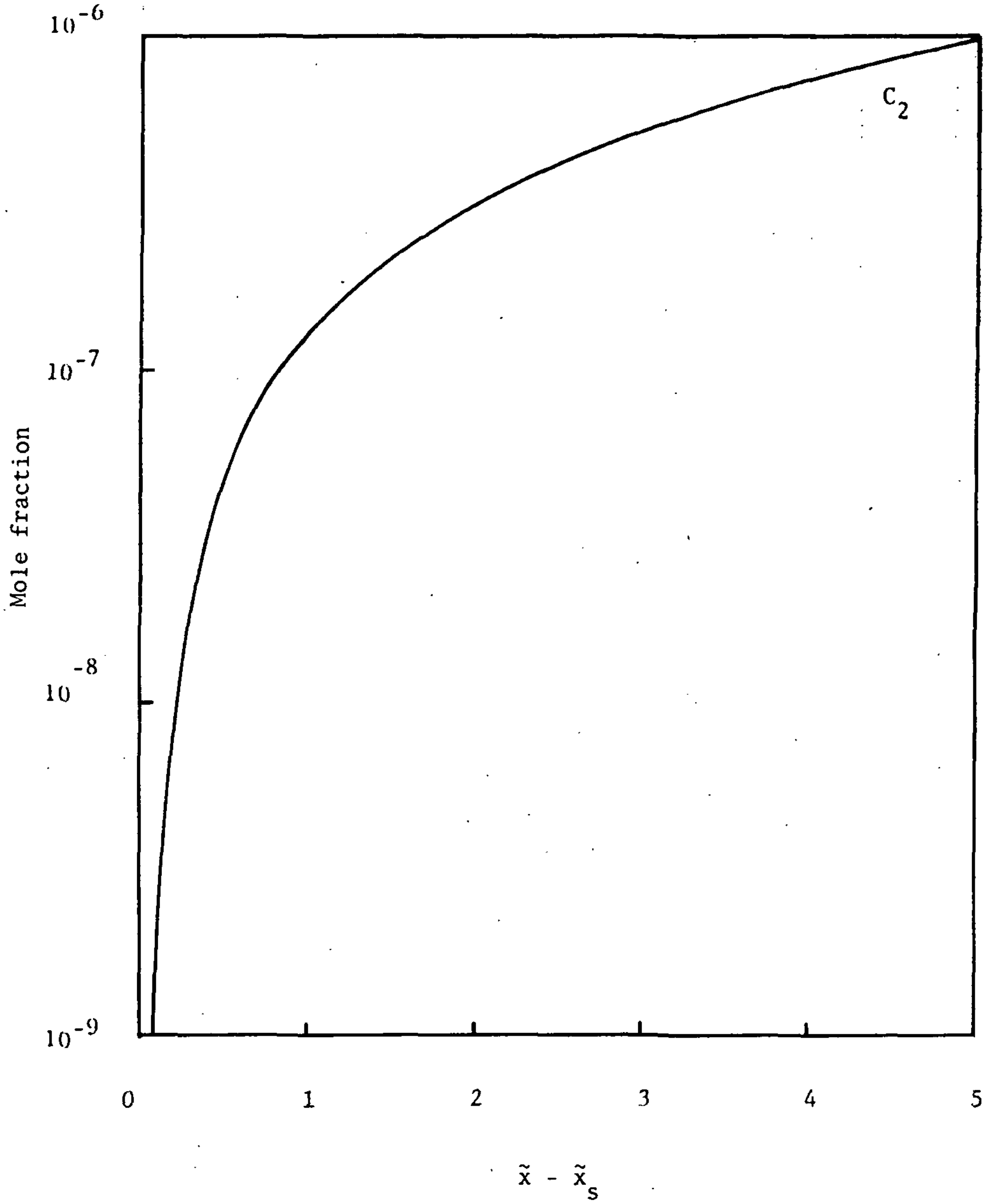
(c) $\tilde{x} = 0.5$; e^-, CO^+, O^+, C^+.

Figure 19.- Continued.



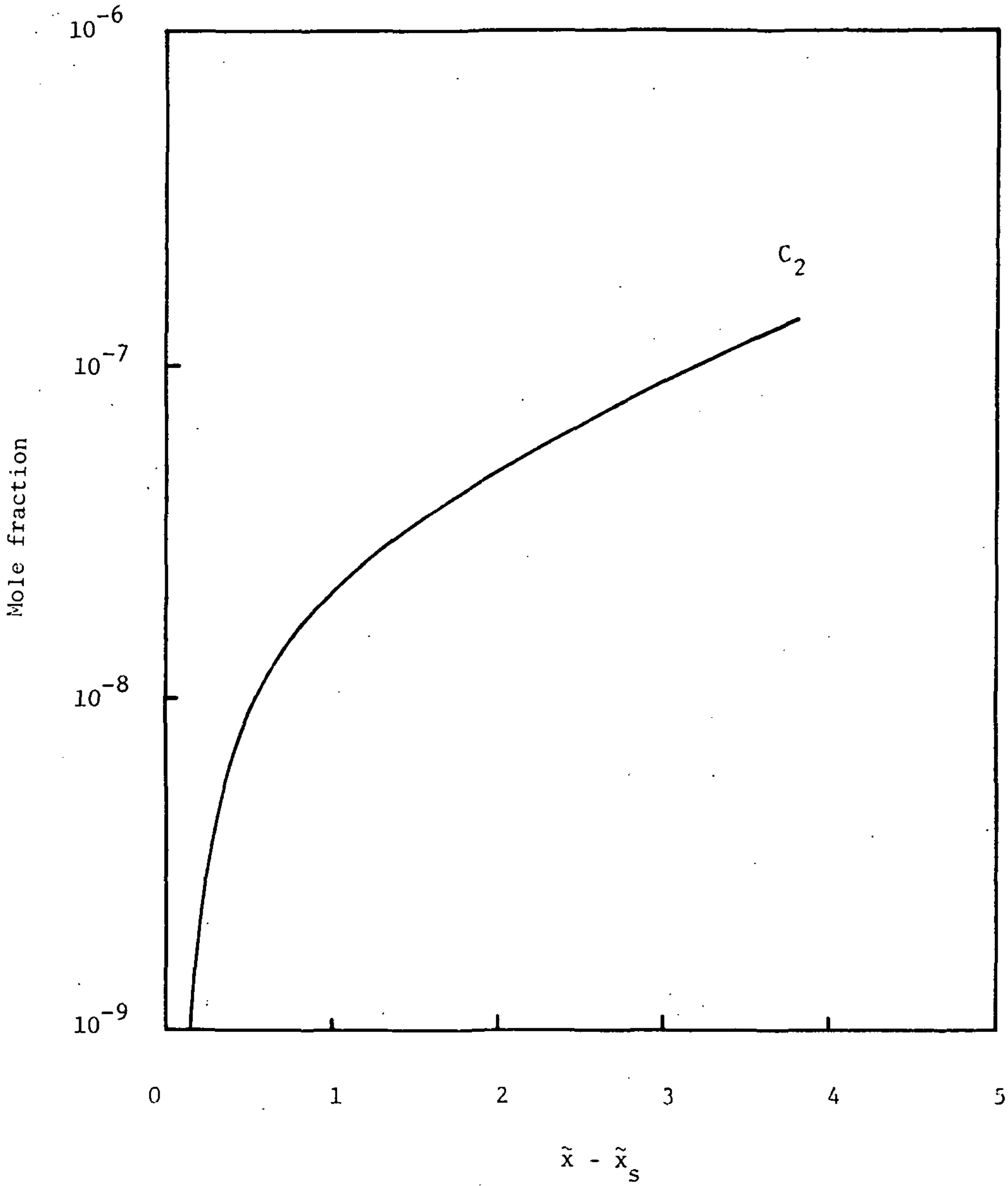
(d) $\tilde{x} = 2.0$; e^-, CO^+, O^+, C^+.

Figure 19.- Continued.



(e) $\tilde{x} = 0.5$; C_2.

Figure 19.- Continued.



(f) $\tilde{x} = 2.0$; C_2.

Figure 19.- Concluded.

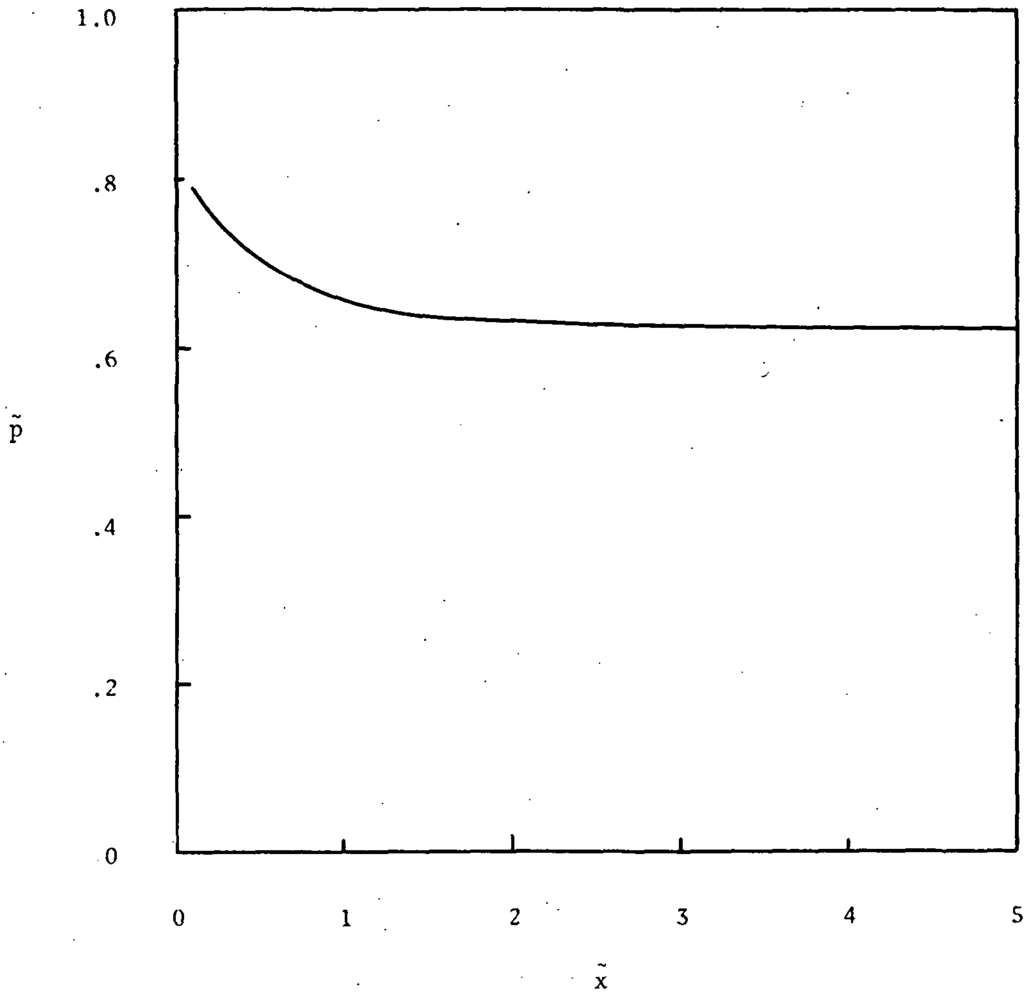


Figure 20.- Pressure distribution along surface of body. Case III.

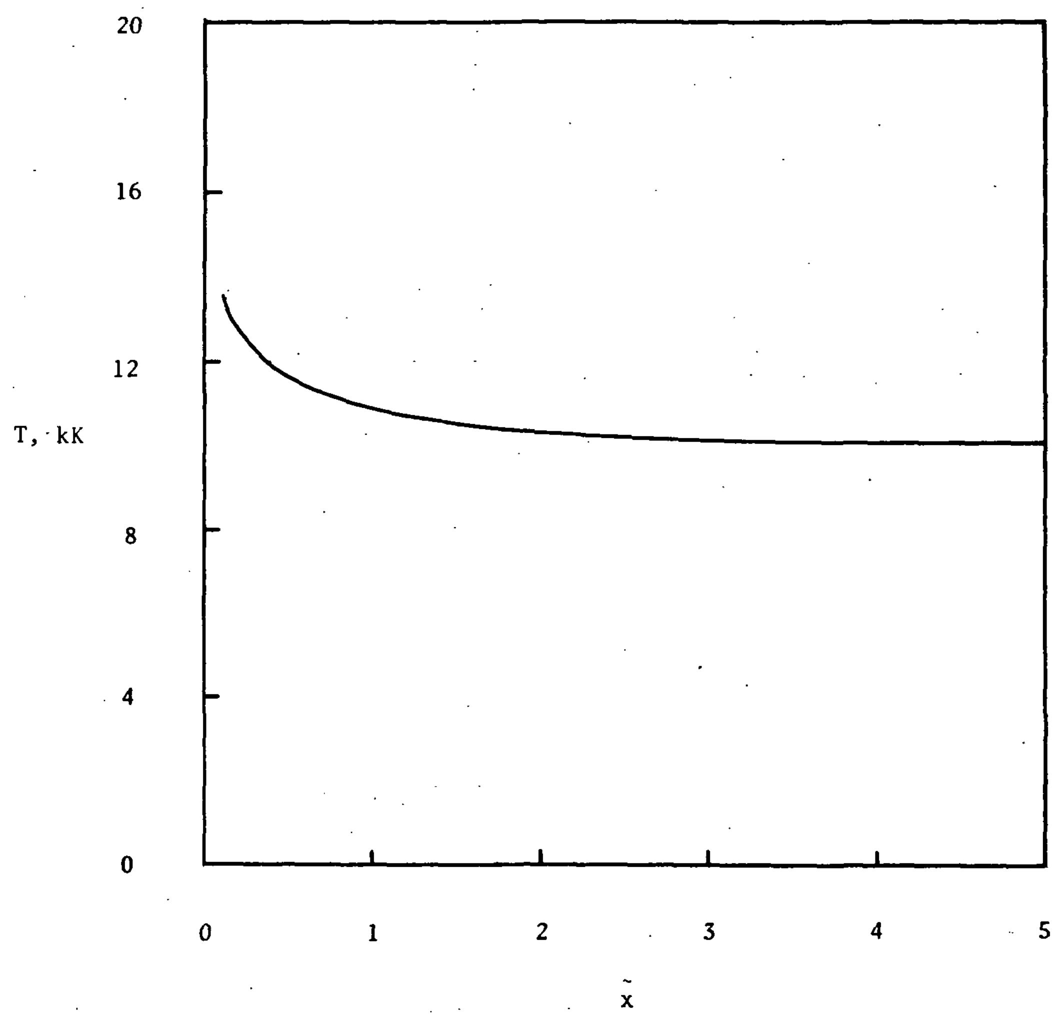
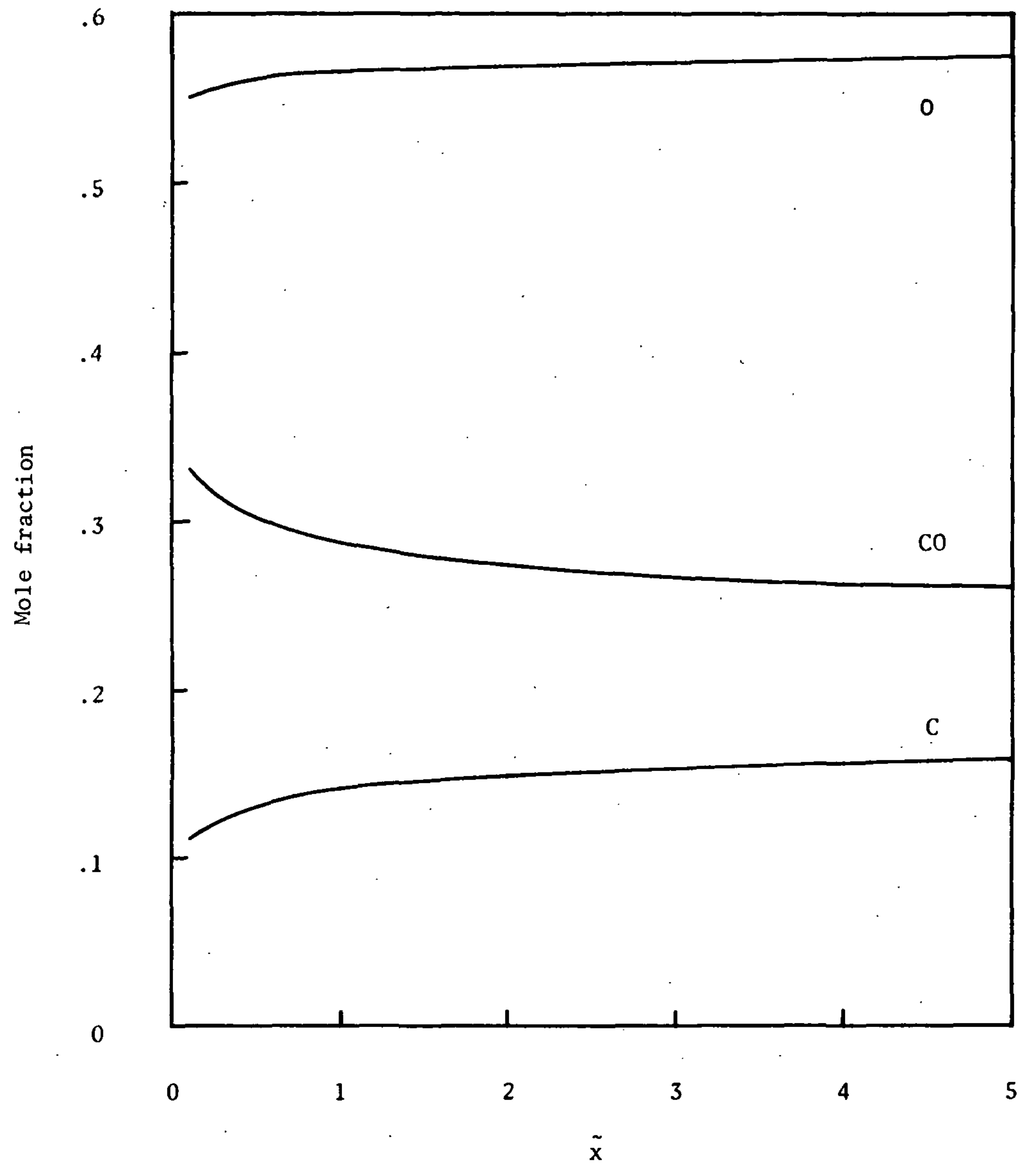
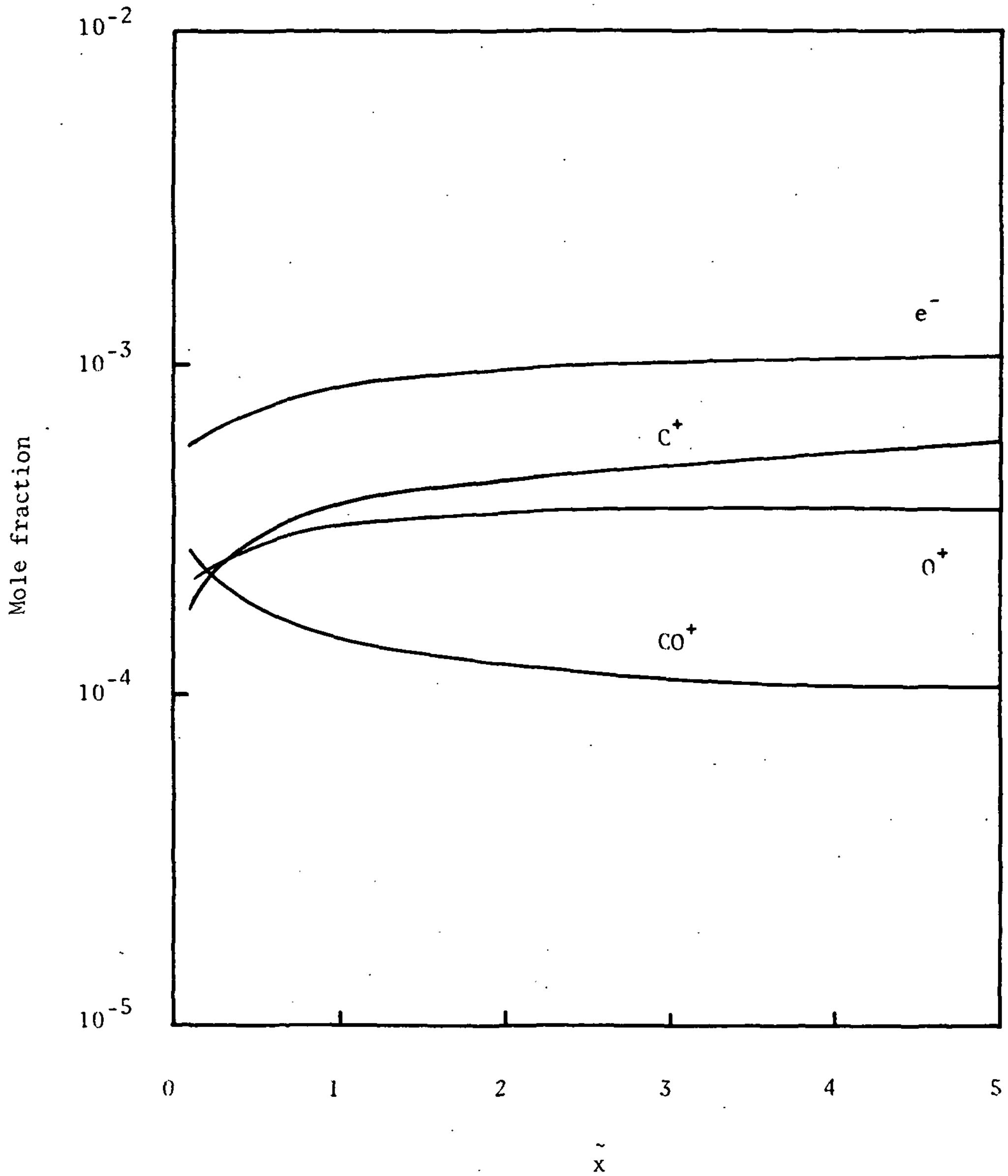


Figure 21.- Temperature distribution along surface of body. Case III.



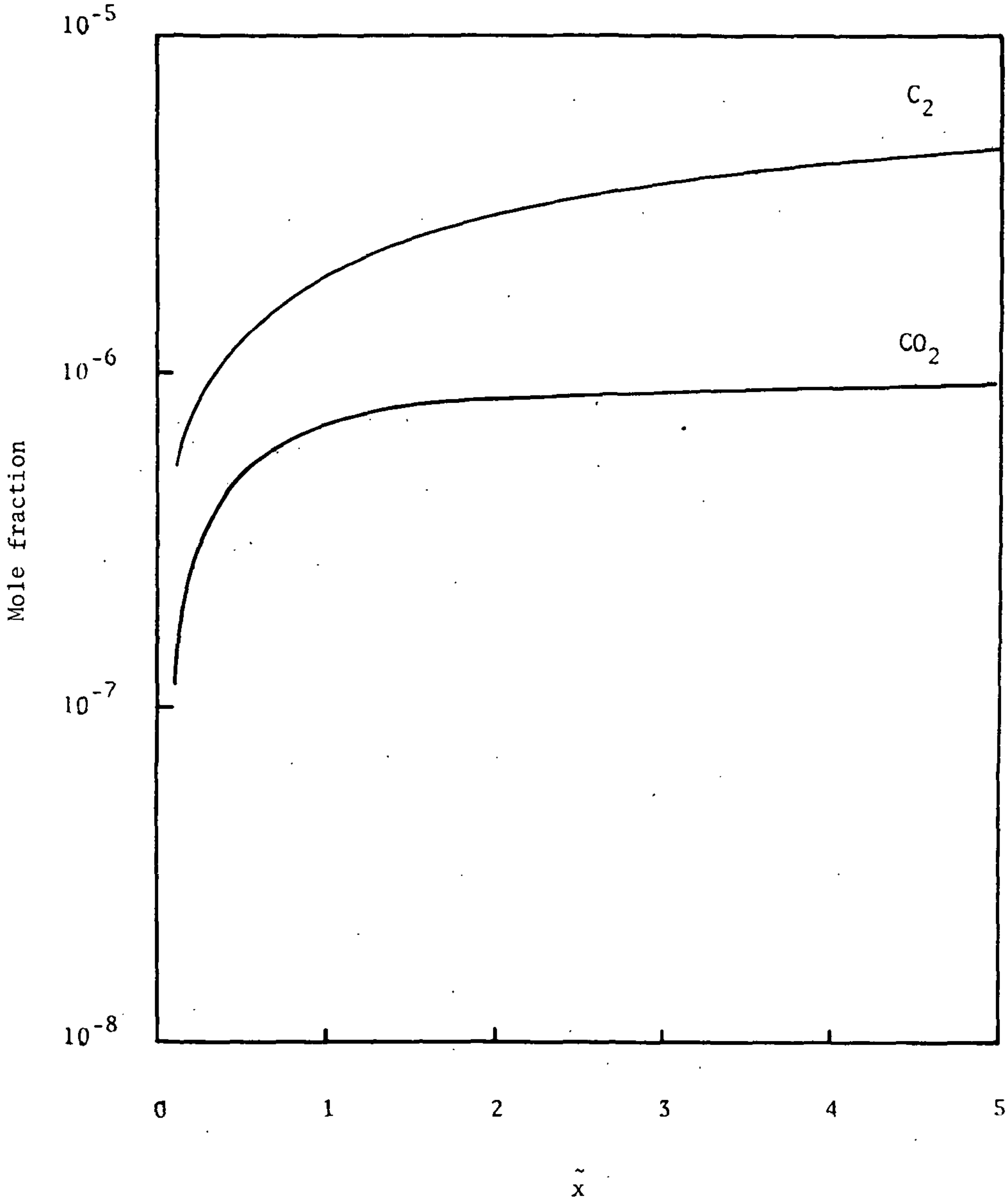
(a) O, CO, and C.

Figure 22.- Species concentrations along surface of body. Case III.



(b) e^-, C^+, O^+, and CO^+.

Figure 22.- Continued.



(c) C_2 and CO_2.

Figure 22.- Concluded.

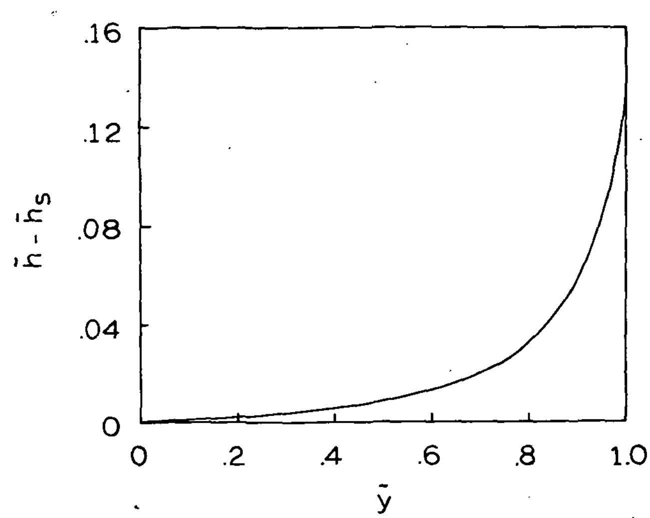


Figure 23.- Static enthalpy profile across shock layer at $\tilde{x} = 2.0$. Case III.

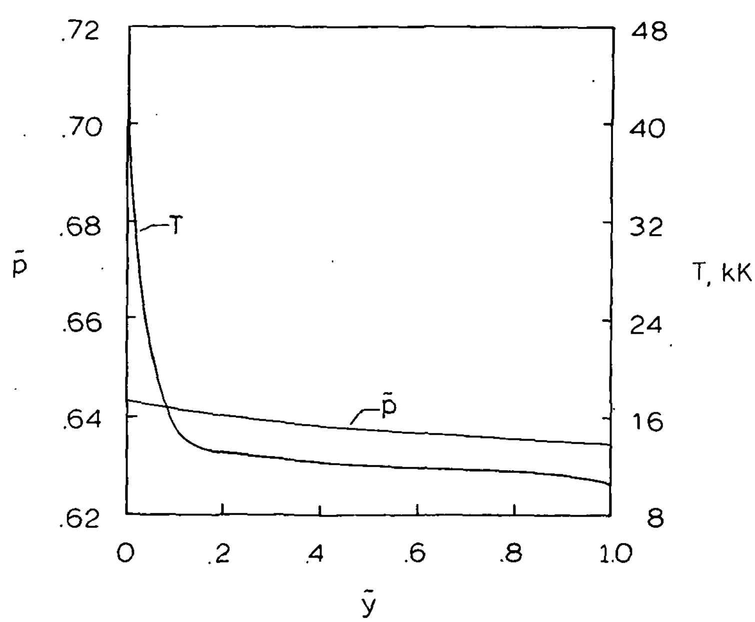


Figure 24.- Pressure and temperature profiles across shock layer at $\tilde{x} = 2.0$. Case III.

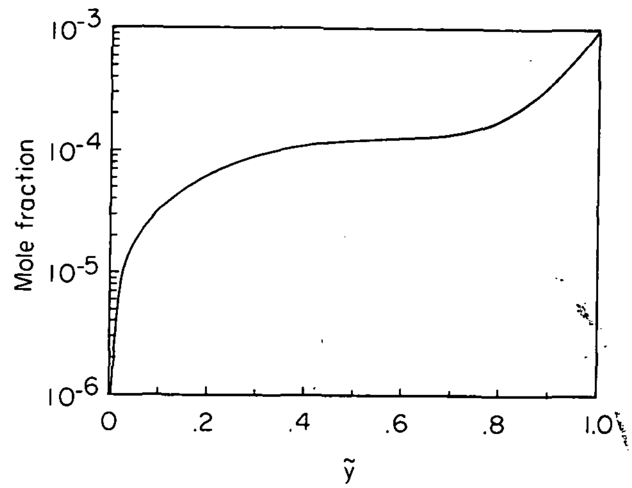


Figure 25.- Electron concentration profiles across shock layer at $\tilde{x} = 2.0$. Case III.

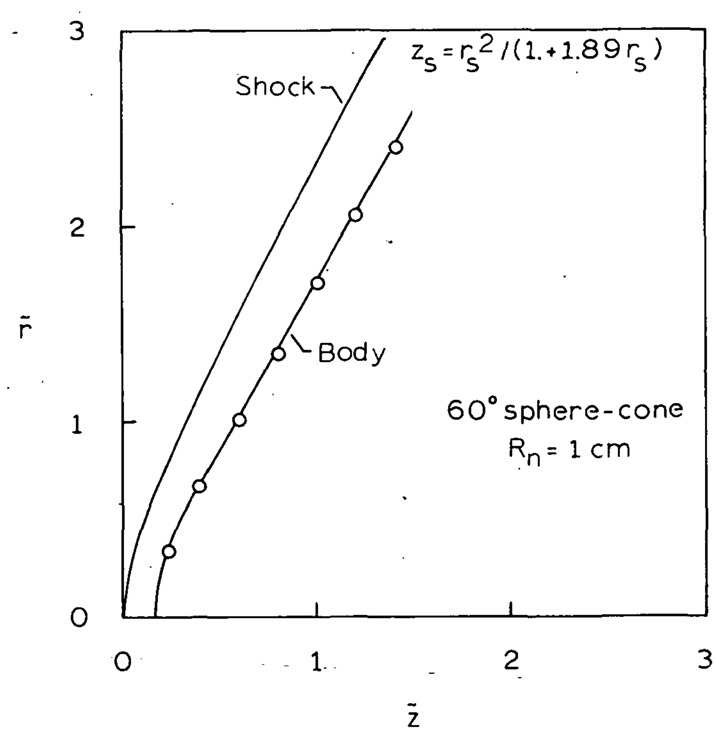


Figure 26.- Assumed shock and computed body shape. Case IV.

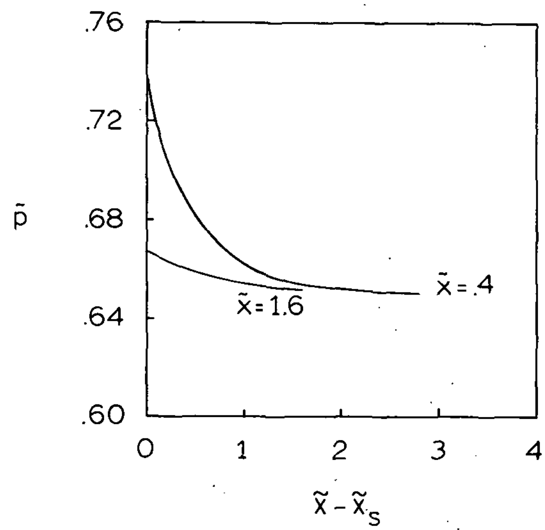


Figure 27.- Pressure variation along streamlines crossing the shock at $\tilde{x}$ = 0.4 and 1.6. Case IV.

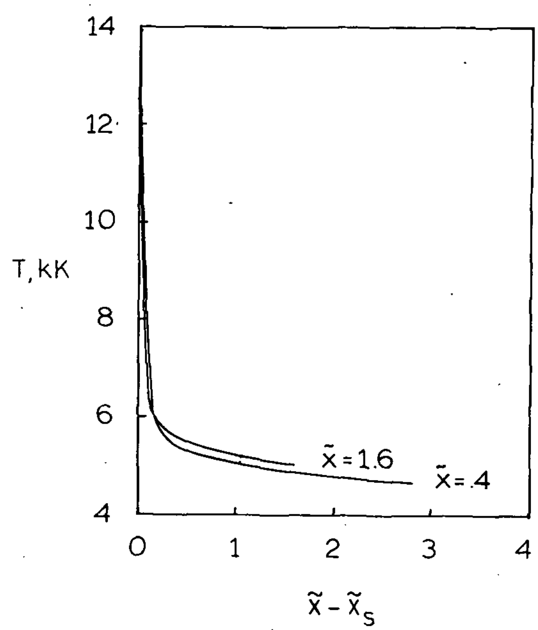
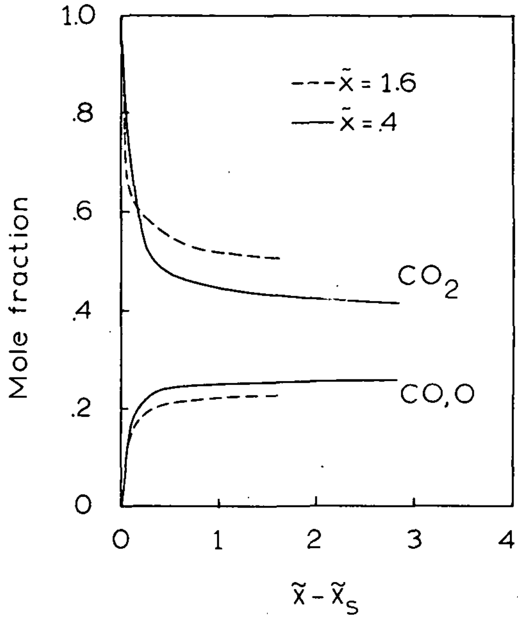
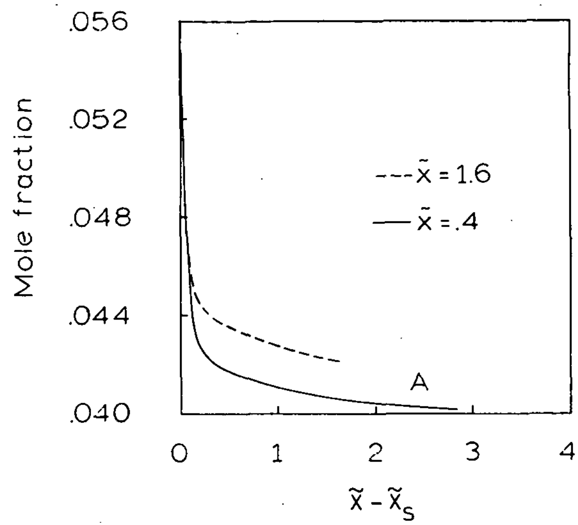


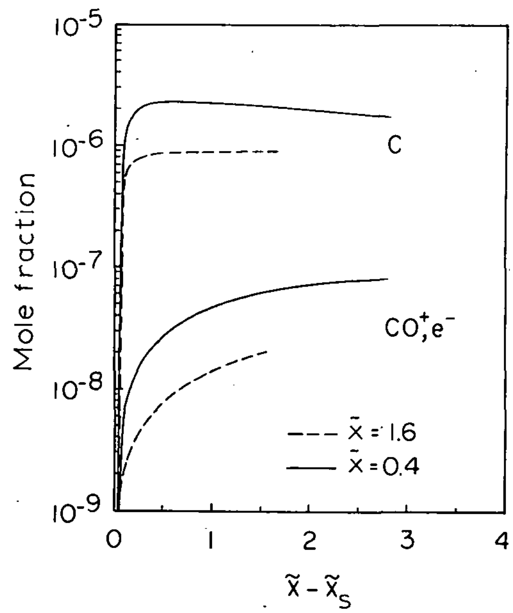
Figure 28.- Temperature variation along streamlines crossing the shock at $\tilde{x}$ = 0.4 and 1.6. Case IV.



(a) CO_2, CO, and O.



(b) A.



(c) C, CO^+, and e^-.

Figure 29.- Species concentrations along streamlines crossing the shock at $\tilde{x} = 0.4$ and $\tilde{x} = 1.6$. Case IV.

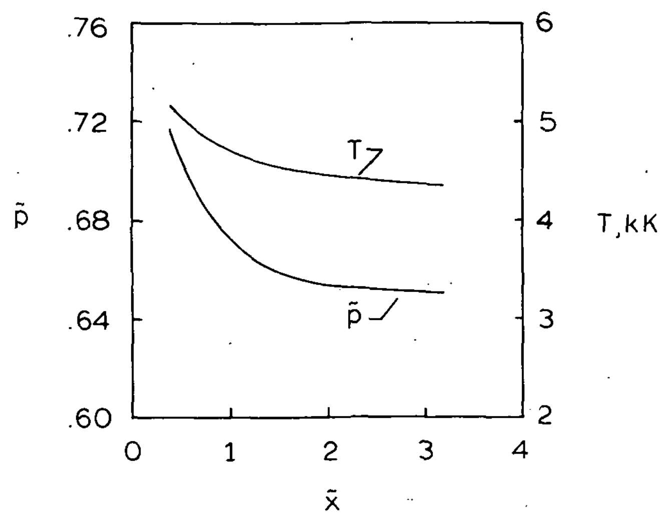
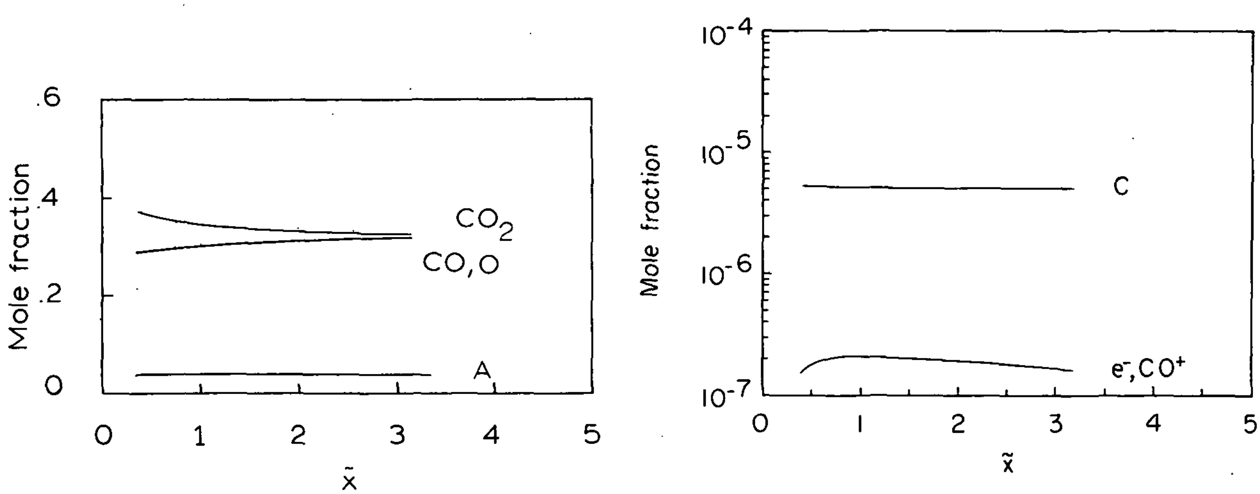


Figure 30.- Pressure and temperature variations along body surface. Case IV.



(a) A, CO, O, and CO_2.

(b) e^-, CO^+, and C.

Figure 31.- Species concentrations along body surface. Case IV.

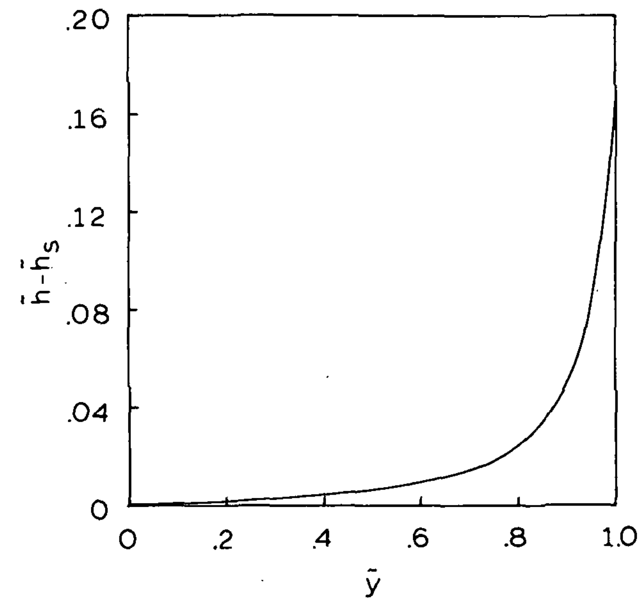


Figure 32.- Static enthalpy profile across shock layer at $\tilde{x} = 1.6$. Case IV.

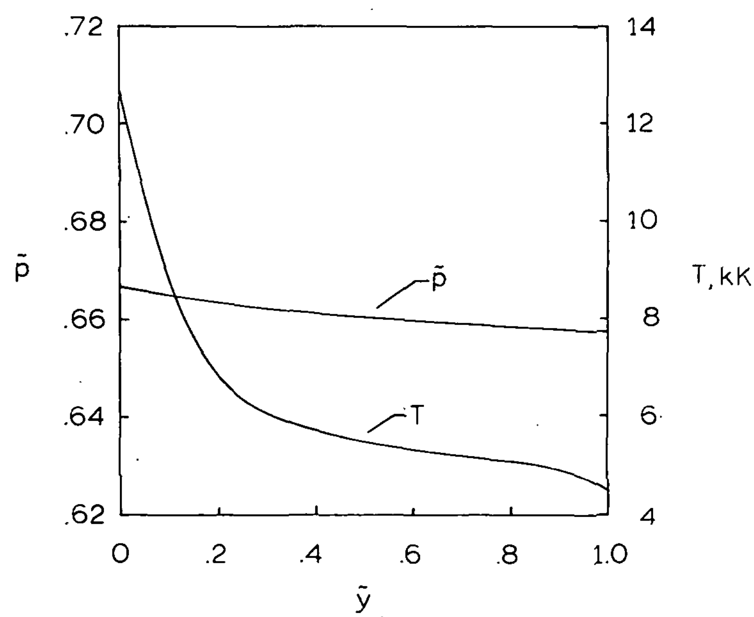


Figure 33.- Pressure and temperature profiles across shock layer at $\tilde{x} = 1.6$. Case IV.

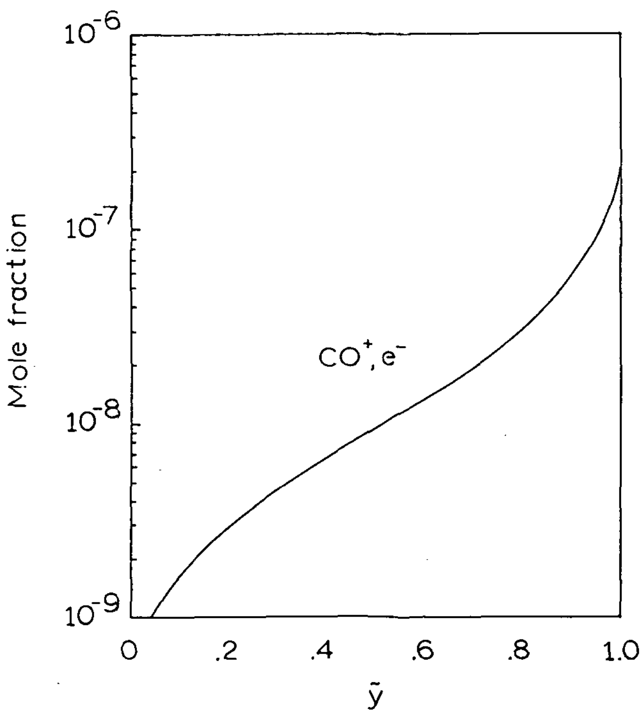


Figure 34.- Electron concentration profile across shock layer at $\tilde{x} = 1.6$. Case IV.

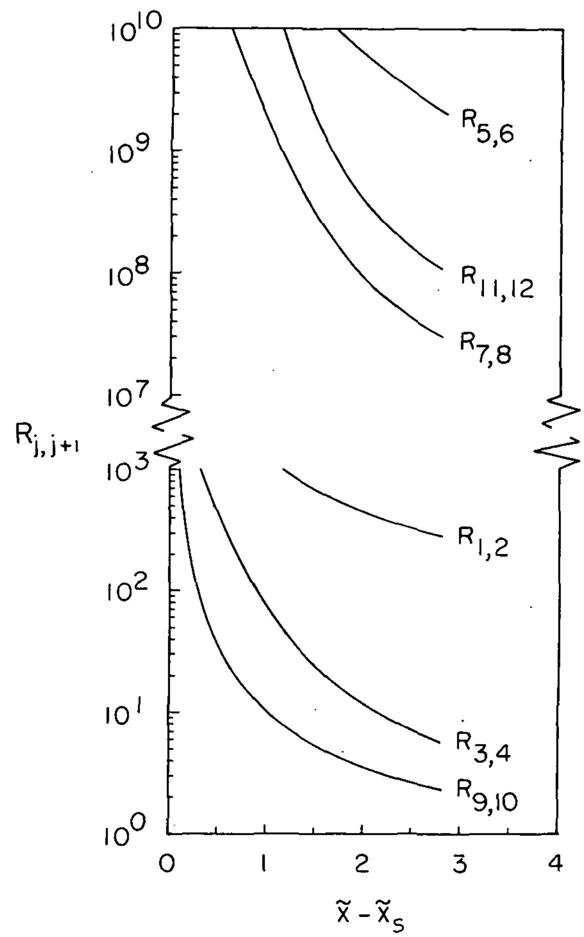


Figure 35.- Ratio of forward reaction rate to reverse reaction rate along inner streamline ($\tilde{x} = 0.4$). Case IV.

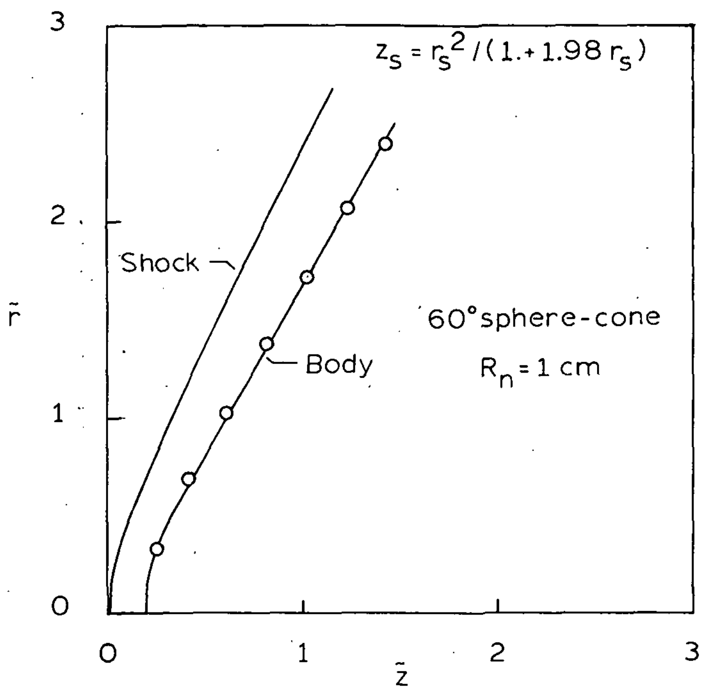


Figure 36.- Assumed shock shape and computed body shape. Case V.

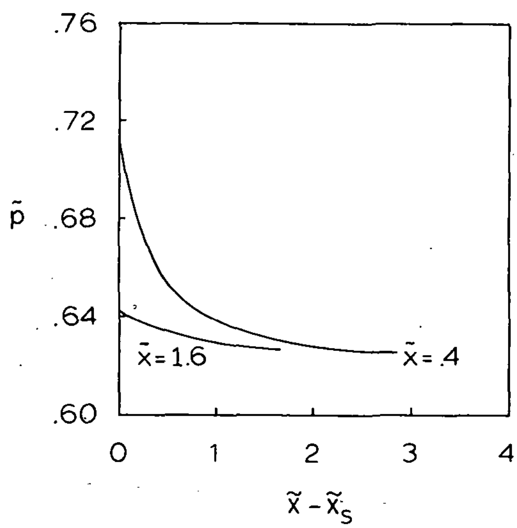


Figure 37.- Pressure variations along streamlines crossing the shock at $\tilde{x}$ = 0.4 and 1.6. Case V.

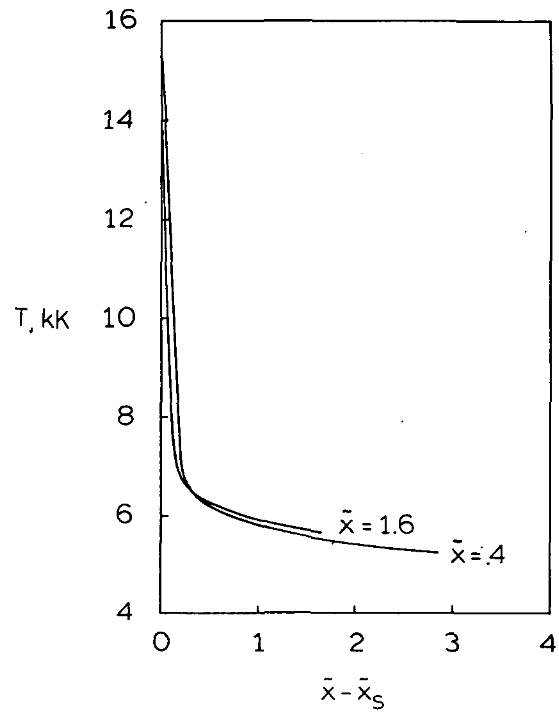
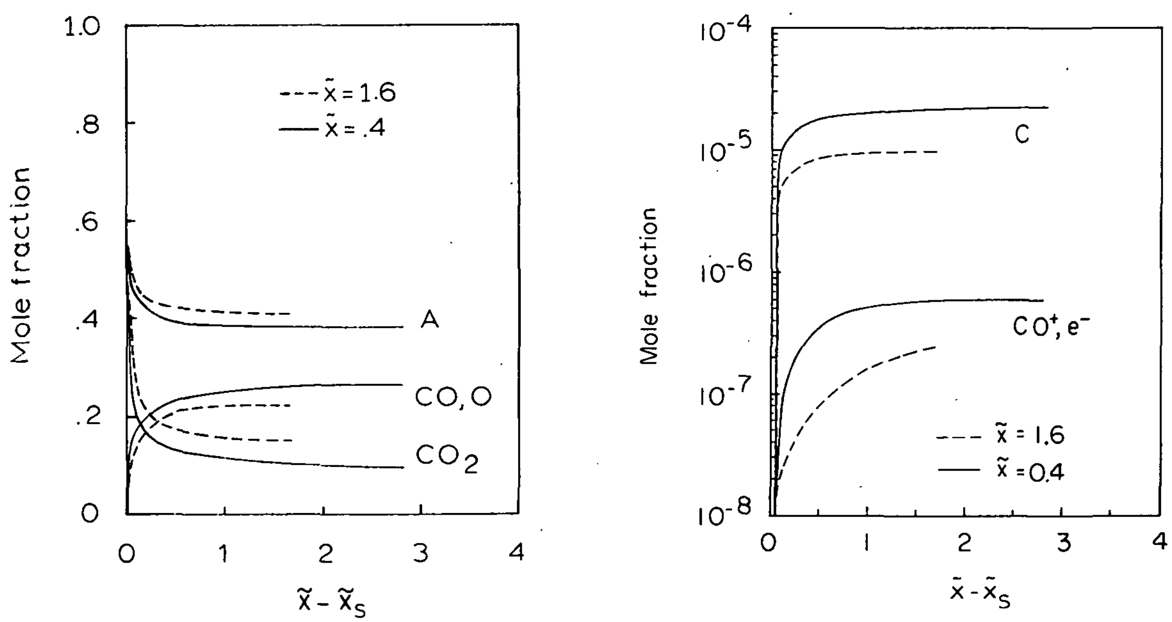


Figure 38.- Temperature variation along streamlines crossing the shock at $\tilde{x} = 0.4$ and 1.6. Case V.



(a) A, CO, O, and CO_2.

(b) C, CO^+, and e^-.

Figure 39.- Species concentrations along streamlines crossing the shock at $\tilde{x} = 0.4$ and 1.6. Case V.

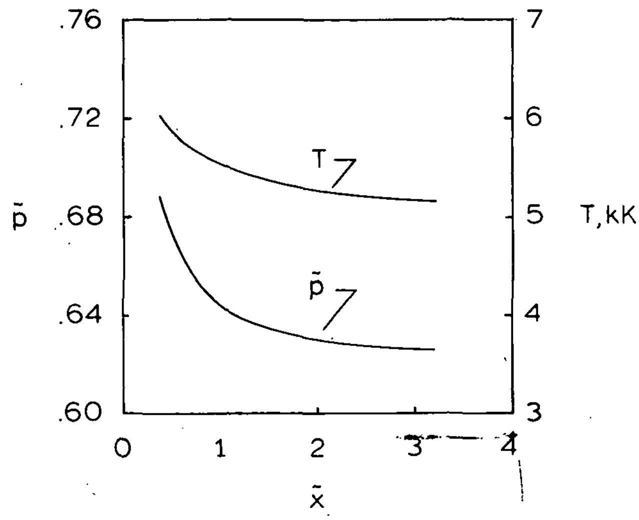
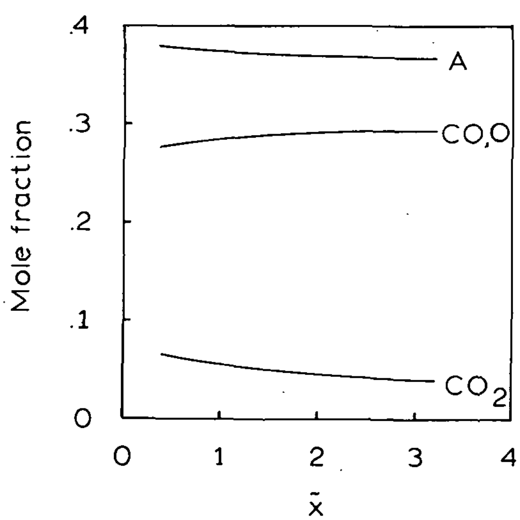
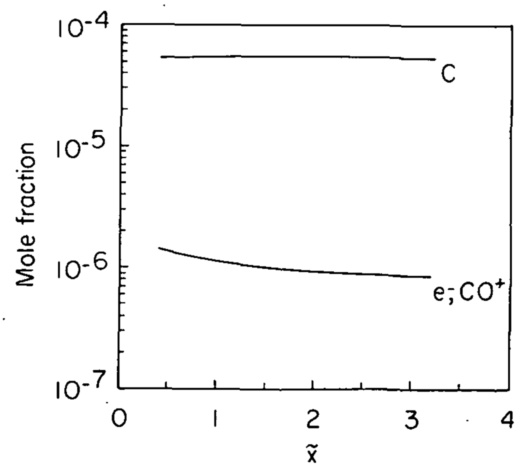


Figure 40.- Pressure and temperature variations along body surface. Case V.



(a) A, CO, O, and CO_2.



(b) C, CO^+, and e^-.

Figure 41.- Species concentrations along body surface. Case V.

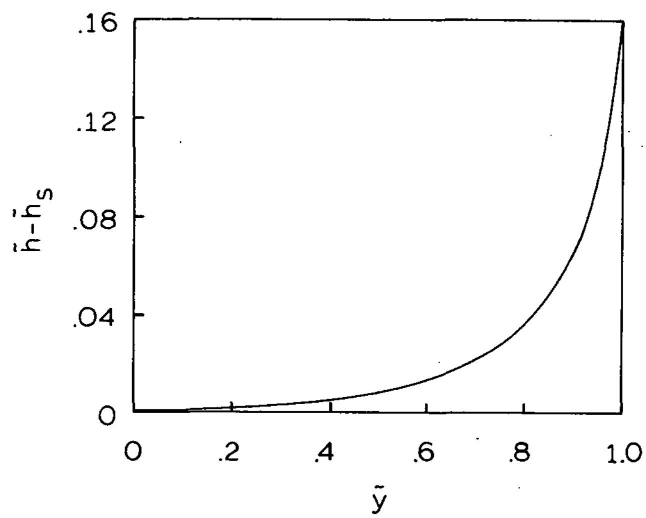


Figure 42.- Static enthalpy profile across shock layer at $\tilde{x} = 1.6$. Case V.

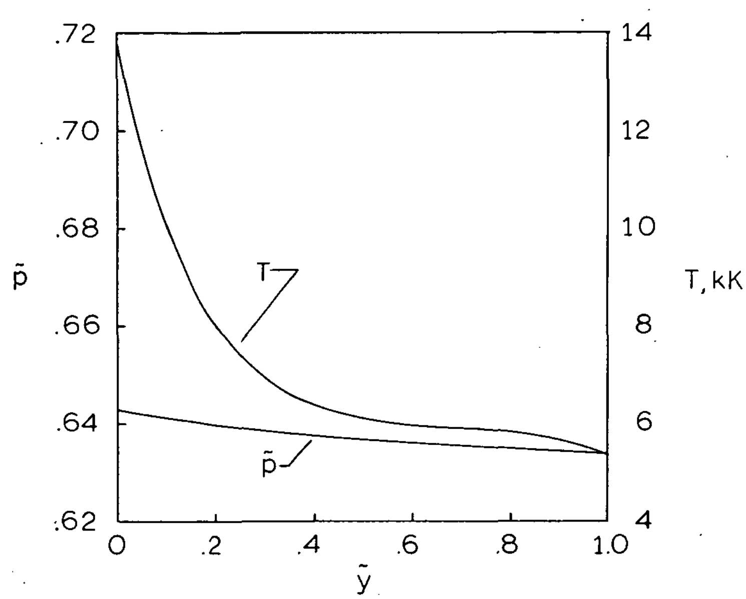


Figure 43.- Pressure and temperature profiles across the shock layer at $\tilde{x} = 1.6$. Case V.

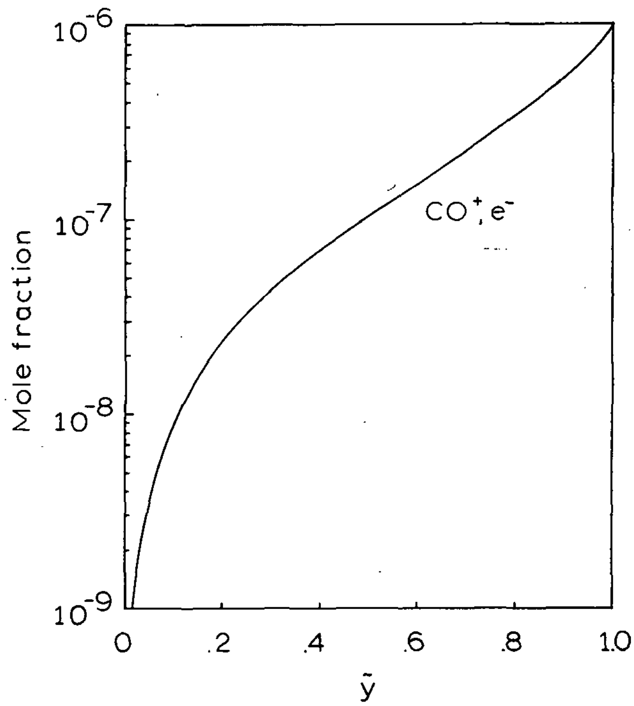


Figure 44.- Electron concentration profile across the shock layer at $\tilde{x} = 1.6$. Case V.

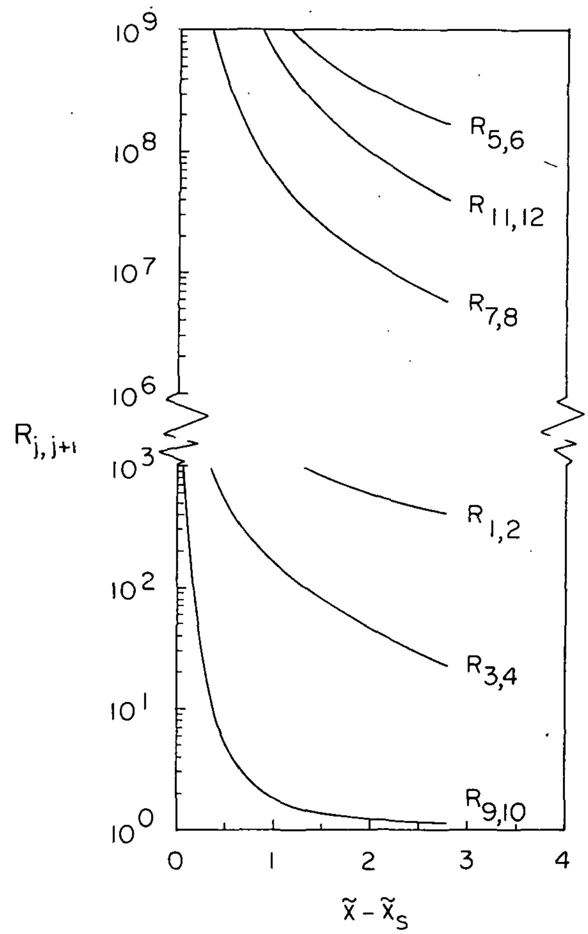


Figure 45.- Ratio of forward reaction rate to reverse reaction rate along inner streamline. ($\tilde{x} = 0.4$). Case V.

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