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A COMPUTER CODE FOR FULLY-COUPLED ROCKET NOZZLE FLOWS (FULLNOZ)

H. S. Pergament, et al

AeroChem Research Laboratories, Incorporated

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H.S. Pergament
R.D. Thorpe

AeroChem Research Laboratories, Inc.
Princeton, New Jersey 08540

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A comprehensive computer code (FULLNOZ) has been developed to perform detailed calculations of rocket nozzle flows downstream of the sonic line. The code uses the streamtube method to integrate the hyperbolic governing equations of steady supersonic flow. The program represents a significant advance in nozzle flow predictions through the coupling of gas/particle nonequilibrium effects, nonequilibrium chemistry, turbulent boundary layers (to determine the effects of wall heat transfer and shear stress) and turbulent mixing across streamtubes.

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This report describes the analytical and numerical techniques employed by the code, presents results of a sample calculation for the Minuteman Stage 2 nozzle and gives complete instructions on the preparation of input data and a full FORTRAN listing.

Conditions of Reproduction

SUMMARY

This report describes the analytical and numerical techniques utilized in the development of a fully-coupled rocket nozzle flow computer code (FULLNOZ). The code uses the streamtube method to integrate the governing equations of steady supersonic flow. The elliptic Navier-Stokes equations are reduced to hyperbolic form by assuming diffusional effects along streamlines are small compared to those across streamlines. Finite difference techniques are then used to solve the hyperbolic equations along and perpendicular to streamlines.

FULLNOZ represents a significant advance in nozzle flow calculations by coupling the effects of nonequilibrium chemistry, gas/particle thermal and dynamic nonequilibrium, turbulent mixing across streamtubes and turbulent boundary layers. Turbulent mixing is treated via a phenomenological eddy viscosity model, while the turbulent boundary layer analysis utilizes the experimental data of Keener and Hopkins (which relates the compressible skin friction coefficient to measured velocity/temperature profiles in flows with favorable pressure gradients), the Van Driest transformations and the momentum integral equation. The operation of FULLNOZ requires the specification of initial gas and particle properties just downstream of the sonic line, the nozzle wall contour and temperature, and a chemical reaction mechanism and rate coefficients. The marching scheme proceeds downstream computing flow properties and composition along surfaces orthogonal to a specified number of streamtubes. A mixed explicit/implicit differencing scheme is used to obtain the most favorable integration step size.

Sample calculations are presented for the Minuteman Stage 2 nozzle. In addition, this report describes the preparation of input data and gives a full FORTRAN listing of the program. Also included is an analysis of heterogeneous electron/ion recombination on particles, although it has not as yet been incorporated into the code.

PREFACE

This is a report on the work performed on Contract F44620-74-C-0006 covering the period 1 September 1973 to 30 April 1975. It is basically a program user's manual for FULLNOZ, although some additional results obtained during this period, e.g. a preliminary study of how to incorporate heterogeneous electron-ion recombination into the code, have also been included.

The authors would like to thank J. T. Kelly for his initial work in the development of FULLNOZ and Capt. L. R. Lawrence, AFOSR Program Manager, for his interest, encouragement and support during the development of FULLNOZ.

This code is available for public use and may be obtained by forwarding a request and a tape to Lt. Robert Sperlein, DYSP, at the Air Force Rocket Propulsion Laboratory, Edwards Air Force Base, CA 93523.

This scientific report has been reviewed and is approved.

LIST OF SYMBOLS

A	streamtube area; also pre-exponential term in rate coefficient equations
$a_{i,jj}$	enthalpy-temperature polynomial coefficients, see Eq. (20)
B	activation energy
C_D	particle drag coefficient
$\bar{C}_D$	normalized drag coefficient, see Eq. (34)
$C_{D_{FM}}$	free molecular drag coefficient
C_{D_I}	high Reynolds number drag coefficient, see Eq. (35)
C_i	mass fraction of ith species
C_F	skin friction coefficient, see Eqs. (54) and (59)
C_p	gas specific heat
C_s	particle specific heat
D	diffusion flux, defined by Eq. (23)
$\bar{D}$	diffusion coefficient
F_i	defined as C_i/M_i
f_p	ratio of actual particle drag coefficient to the drag coefficient for Stokes flow
g_p	ratio of actual particle heat transfer coefficient to heat transfer coefficient for Stokes flow
H	gas stagnation enthalpy
H_{12}	shape factor, defined by Eq. (69)
H_f^o	heat of formation at 298°K
h	gas static enthalpy
h'	particle/gas heat transfer coefficient
I	total number of gas species
J	total number of particle groups
K_p	equilibrium constant
k	thermal (eddy) conductivity
k_f	forward reaction rate coefficient
k_g	molecular thermal conductivity in particle/gas interaction terms

L	total number of species on left or right side of reaction
L_1-L_5	specific heat polynomial coefficients
L_6	enthalpy constant of integration, see Eq. (31)
L_7	entropy constant of integration, see Eq. (32)
Le	turbulent Lewis number, $Le = \frac{C_p \bar{D} \rho}{k}$
M	Mach number
M_i	molecular weight of ith species
$\dot{m}$	streamtube mass flow, defined by Eq. (13)
N	number of reactions
Nu	Nusselt number, $Nu = \frac{h' r_p}{k_g}$
n	distance normal to streamline, also exponent in Eqs. (57) and (58)
Pr	turbulent Prandtl number, $Pr = \frac{\mu C_p}{k}$
Pr_g	laminar Prandtl number
p	static pressure
q	heat flux, defined by Eq. (22)
q_w	wall heat transfer, defined by Eq. (62)
R	universal gas constant, also value of nozzle radius at each x
Re	Reynolds number based on streamtube width
Re_p	particle Reynolds number
Re_x	Reynolds number based on distance along nozzle wall
Re_θ	Reynolds number based on boundary layer momentum thickness
r	radial distance from axis; also recovery factor, Eq. (49)
r_p	particle radius
s	distance along streamline
S	entropy
S_t	Stanton number, defined by Eq. (62)
T	static temperature
T_r	recovery temperature

u	velocity along streamline
U	velocity in boundary layer
U_τ	friction velocity, defined by Eq. (63)
V_p	particle velocity normal to gas streamline
$\dot{W}_i$	production rate of ith species
x	axial distance from nozzle starting line
y	distance from nozzle wall
Y	molar concentration

Greek Letters

α	numerical stability coefficient for marching scheme, see Eq. (29)
γ	ratio of specific heats
ΔG	Gibbs free energy
$\Delta_k(\Phi)$	change in Φ across streamtube
δ	boundary layer thickness
δ^*	displacement thickness
δn	finite difference mesh spacing in n direction
δs	finite difference mesh spacing in s direction
θ	angle between streamline and plume axis; also boundary layer momentum thickness
$\theta_s, \theta_s', \theta_s''$	respectively; final, initial and intermediate streamline radii of curvature
Φ	T/1000, used in Eq. (30)
ν	kinematic viscosity
ν'	stoichiometric coefficient on left hand side of reaction
ν''	stoichiometric coefficient on right hand side of reaction
μ	eddy viscosity
μ_g	molecular viscosity in particle/gas interaction terms
ρ	gas density
ρ_p	particle cloud density
ρ_s	density of liquid or solid particle
τ	shear stress, defined by Eq. (21) and Eq. (60)
Π	multiplication

$\sum$	summation

Subscripts

aw	adiabatic wall
c	compressible
e	wall streamtube
FM	free molecular
g	gas
i	ith species; also, incompressible
j	particle group identification index
k	streamtube index
ℓ	orthogonal surface index; also refers to species on left or right hand side of reaction in Eq. (6)
m	mth reaction
n	differentiation in direction normal to streamlines
o	stagnation value
p	particle
s	differentiation in streamline direction
t	total
w	wall

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I. INTRODUCTION

This report describes a new fully-coupled rocket nozzle code (FULLNOZ) which treats, simultaneously, gas/particle nonequilibrium, nonequilibrium chemistry, diffusion across streamlines, and turbulent boundary layers within axisymmetric and two-dimensional nozzles. Because of its fully-coupled capability FULLNOZ can be applied to a wider range of problems than such existing rocket nozzle codes,† as TDK[1] (which does not account for gas/particle nonequilibrium effects), the nozzle portion of the CONTAM[2] code, the original constant γ gas/particle nonequilibrium code of Nickerson and Kliegel[3] and the recently-developed gas/particle and chemical nonequilibrium code developed at Lockheed/Huntsville.[4] The emphasis in the present code has been on an accurate calculation of nozzle exit plane gas and particle properties (particularly major and minor neutral and charged species concentrations), rather than on the determination of specific impulse, although FULLNOZ is well equipped to calculate I_{sp}.

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† e.g. none of these codes calculate turbulent boundary layers.

1. "ICRPG Two-Dimensional Kinetic (TDK) Nozzle Analysis Computer Program," Dynamic Science Corp., December 1973 (revised version).

2. Hoffman, R.J., English, W.D., Oeding, R.G., and Webber, W.T., "Plume Contamination Effects Prediction: The CONTAM Computer Program," Final Report, Air Force Rocket Propulsion Laboratory, AFRPL-TR-71-109, December 1971.

3. Nickerson, G.R. and Kliegel, J.R., "Axisymmetric Two-Phase Perfect Gas Performance Program," TRW Systems Report No. 02874-6006-R000, Vols. I and II, April 1967.

4. Penny, M.M. and Smith, S.D., "Supersonic Gas-Particle Flows, Including Reacting Chemistry," JANNAF 8th Plume Technology Meeting, Colorado Springs, CO, July 1974.

FULLNOZ is based on the MULTITUBE code developed by Boynton,[5] which incorporates the streamtube method† (described by Boynton and Thomson[6]) to integrate the hyperbolic governing equations of steady supersonic flow. The major routines incorporated into FULLNOZ which are not in MULTITUBE include (1) particle/gas nonequilibrium, (2) nonequilibrium chemistry and (3) turbulent wall boundary layers. Briefly, in the streamtube method the elliptic Navier-Stokes equations‡ are reduced to hyperbolic form by assuming that diffusional effects along streamlines are small compared to diffusion across streamlines. This assumption is very good for rocket nozzle (and plume) flows and enables one to solve an initial value problem (where a marching procedure can be used) rather than the more difficult boundary value problem. The gas flow equations, in finite-difference form, are solved along and perpendicular to streamlines while a full continuum particle cloud system of equations is incorporated for the condensed phase.

The advantages of using the streamtube method over the method of characteristics in calculating rocket nozzle (and plume) flows are:

- Species diffusion, shear, and heat transfer normal to streamlines are easily included.
- Chemical reactions or internal relaxations are easily incorporated since the calculation follows streamlines.
- Bounding surfaces and gradients normal to streamlines are treated without difficulty; and
- A wide variety of boundary conditions including mass transfer, shear and heat transfer can readily be incorporated.

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† In contrast to the abovementioned codes,[1-4] which all use the method of characteristics.

‡ In using the Navier-Stokes equations as a base the technique can readily be extended, with the proper boundary conditions, to low density nozzle flows.

5. Boynton, F.P., "The MULTITUBE Supersonic Flow Computer Code," General Dynamics/Convair GDC-DBB 67-003, February 1967.

6. Boynton, F.P. and Thomson, A., "Numerical Computation of Steady, Supersonic, Two-Dimensional Gas Flow in Natural Coordinates," J. Computational Phys. 3, 379-398 (1969).

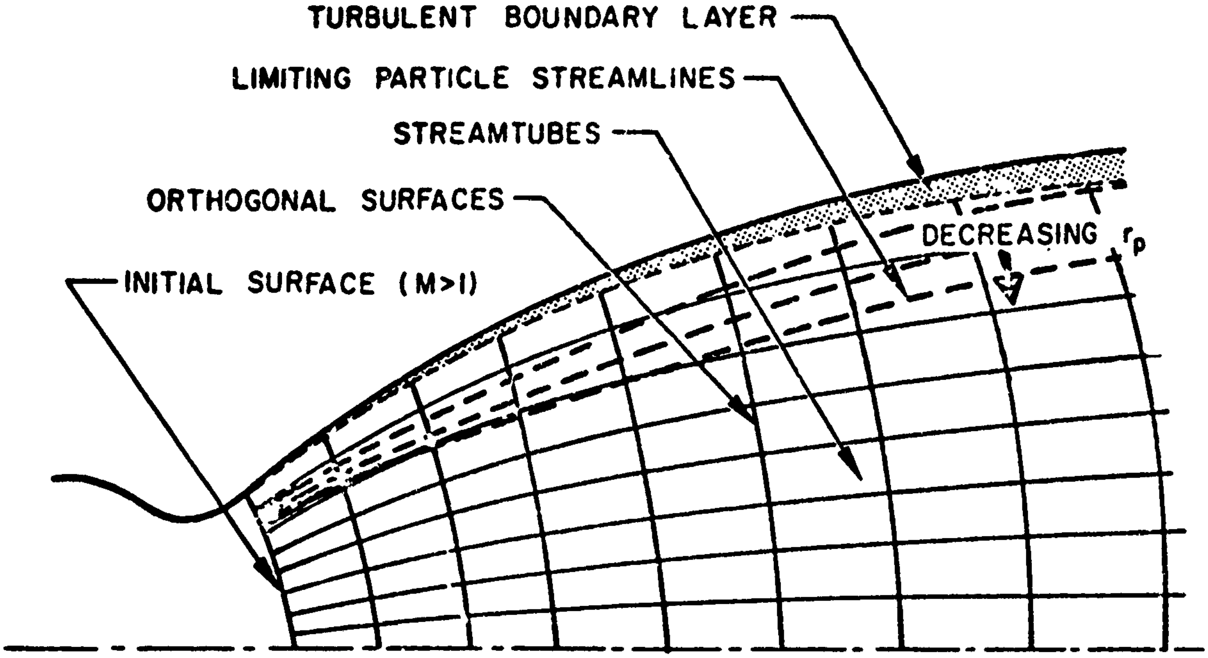

Figure 1. FULLNOZ schematic.

Operation of the code is achieved by specifying (1) initial gas and particle properties in the supersonic region just downstream of the nozzle throat,† (2) the nozzle wall contour, (3) a chemical reaction mechanism and rate coefficients, (4) physical properties of the particles, and (5) the nozzle wall temperature (for the boundary layer calculations). With the above input data the marching scheme steps from one orthogonal surface to the next (Fig. 1) computing gas and particle properties within a specified number of streamtubes. The (essentially) continuous particle size distribution is represented by up to a maximum of 8 discreet particle sizes. All particles cross the gas streamlines, but the lighter particles follow the gas streamlines more closely than the heavy particles. As depicted in Fig. 1, limiting particle streamlines are computed for each particle size. At each orthogonal surface (i.e. each integration

† It would be useful to incorporate an "initializing" scheme which utilizes combustion chamber properties as initial conditions, computes flow properties through the transonic region and establishes an initial supersonic data line. Such a scheme, developed by Nickerson and Kliegel,[3] is contained in the codes of Refs. 1-3, and with additional programming could be inserted into FULLNOZ.

step) the code calculates wall shear stress and heat transfer, boundary layer displacement thickness and velocity and temperature profiles. The shear stress and heat transfer are coupled to the main nozzle flow via their effect on the wall streamtube properties.† The turbulent boundary layer analysis utilizes the Van Driest[7] transformations and the experimental data of Keener and Hopkins,[8] which relates the compressible skin friction coefficient to measured velocity/temperature profiles in flows with favorable pressure gradients (see Section II.C.4). The boundary layer momentum thickness is computed via the momentum integral equation, using the wall streamtube pressure, velocity, etc., as the boundary layer 'edge' conditions. The displacement thickness is then determined from the velocity profile and momentum thickness.

The code will not handle shocks that might originate from the nozzle wall in turning the flow. The flow in the region of the shock will be treated as a strong compression wave.‡

---

† This implicitly assumes that the boundary layer momentum and energy thicknesses are smaller than the wall streamtube thickness. This will generally be true for high Reynolds number nozzle flows. Provision is in the program, however, to transfer momentum, heat and mass across streamtubes, so that if an appropriate transfer coefficient can be defined the boundary layer effects can be "felt" throughout the flow.

‡ Nozzle shocks could be incorporated into FULLNOZ in a manner similar to that employed in the AIPP code[9,10] to detect internal plume shocks, but this would require additional programming.

7. Van Driest, E.R., "Turbulent Boundary Layer in Compressible Fluids," J. Aeron. Sci. 18, 145-160 (1951).

8. Keener, E.R. and Hopkins, E.J., "Van Driest Generalization Applied to Turbulent Skin Friction and Velocity Profiles Measured on the Wall of a Mach 7.4 Wind Tunnel," AIAA J. 11, 1784-1785 (1973).

9. Pergament, H.S. and Kelly, J.T., "A Fully-Coupled Underexpanded Rocket Plume Program. (The AIPP Code). Part I. Analytical and Numerical Techniques," AeroChem TP-302a, AFPRL-TR-74-59, November 1974.

10. Pergament, H.S. and Kelly, J.T., "A Fully-Coupled Underexpanded Rocket Plume Program (The AIPP Code). Part II. Program User's Manual," AeroChem TP- (in preparation).

The code was written for operation on a CDC 6400 computer and requires approximately 122 K (octal) of core storage. For operation on machines with larger core storage the user may want to increase the dimension of some parameters, such as total number of species (25 maximum) and total number of reactions (40 maximum).

This report serves primarily as a program user's manual,† but also contains all the governing equations (Section II) and the results of some preliminary parametric calculations for the Minuteman, second stage nozzle (Section IV.A). The user should be cautioned that, although the code has been formally debugged for several test cases, extensive calculations have not (as of April 1975) been made; therefore some operational problems may be experienced. If these do occur, please contact the authors.

II. GOVERNING EQUATIONS

This section gives the governing differential and finite-difference equations used in the code. Also included are the auxiliary equations for calculating thermodynamic and chemical kinetic properties of the system, gas/particle drag and heat transfer coefficients and turbulent boundary layer properties.

A. Differential Equations

1. Gas Phase

For most high Reynolds number nozzle flows of interest the turbulent transport of mass, momentum and energy throughout the main nozzle flow will be negligible. Thus in the equations that follow all transport terms will be identically zero. In practice this is achieved by setting ITURB (Card 4, Cols. 56-60) equal to zero. If turbulent diffusion across streamtubes is to be included due either to initial non-uniformities or to the propagation of boundary layer effects across the flow, appropriate (constant) values of the eddy transport terms, μ, Pr and Le will have to be input on Card 10. If a suitable expression for eddy viscosity in terms of local properties can be developed for transport across streamtubes within nozzles, this expression can easily be added to the program in subroutine TRANSP.

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† The same numerical integration techniques and similar program logic is incorporated into the AIPP code,[9,10] to which the reader is referred for additional information on program subroutines.

Global Continuity

$$(\rho u)_s + \rho u \frac{\sin\theta}{r} + \rho u \theta_n = 0 \qquad (1)$$

s-Momentum

$$\rho u u_s + p_s = \frac{1}{r}\left[r \mu u_n\right]_n - \sum_{j=1}^{J} \frac{9}{2} \frac{\rho_{p_j} f_{p_j} \mu_g}{\rho_s r_{p_j}^2} \left(u - u_{p_j}\right) \qquad (2)$$

n-Momentum

$$\rho u^2 \theta_s + p_n = \sum_{j=1}^{J} \frac{9}{2} \frac{\mu_g \rho_{p_j} f_{p_j}}{\rho_s r_{p_j}^2} V_{p_j} \qquad (3)$$

Species Continuity†

$$\rho u (C_i)_s = \rho \dot{W}_i + \frac{1}{r}\left[r \mu \frac{Le}{Pr} (C_i)_n\right]_n \qquad (4)$$

Energy

$$\rho u H_s = \frac{1}{r}\left[r \frac{\mu}{Pr} H_n\right]_n + \frac{1}{r}\left[\left(1 - \frac{1}{Pr}\right)\mu \left(\frac{u^2}{2}\right)_n r\right]_n$$

$$+ \frac{1}{r}\left[\sum_{i=1}^{I} \left\{\frac{\mu}{Pr}\left(Le - 1\right) r \, h_i (C_i)_n\right\}\right]_n$$

$$+ \sum_{j=1}^{J} \frac{9}{2} \frac{\mu_g \rho_{p_j} f_{p_j}}{\rho_s r_{p_j}^2} \left\{ V_{p_j}^2 + \left(u - u_{p_j}\right)^2\right.$$

$$\left. + \frac{2}{3} \frac{g_{p_j}}{f_{p_j}} \frac{C_p}{Pr_g} \left(T_{p_j} - T\right) \right\} \qquad (5)$$

---

†In this formulation, $\dot{W}_i$ is expressed in units of sec^{-1}.

The drag (f_{p_j}) and heat transfer (g_{p_j}) factors are defined as, $f_{p_j} = C_D Re_p/24$ and $g_{p_j} = (Nu/2)(T_p - T_r)/(T_p - T)$, where T_r is the recovery temperature based on the relative velocity between the gas and particle.

The following auxiliary expressions are required:

Species Production

$$\dot{W}_i = \frac{M_i}{\rho} \sum_{m=1}^{N} \left(\nu''_{i,m} - \nu'_{i,m}\right) \left[k_{fm} \prod_{\ell=1}^{L} Y_\ell^{\nu'_{\ell,m}} - \frac{k_{fm}}{K_p} \prod_{\ell=1}^{L} Y_\ell^{\nu''_{\ell,m}} \right] \tag{6}$$

Equation of State

$$\rho = \frac{p}{RT \sum_i \frac{C_i}{M_i}} \tag{7}$$

Stagnation Enthalpy

$$H = \frac{u^2}{2} + h(T) \tag{8}$$

2. Particles

For the condensed phases present within the flow a continuum particle cloud assumption is made and therefore field conservation equations for continuity, momentum and energy can be written for the particles. The (essentially) continuous distribution of particle sizes at each point in the flow is modeled by several groups of constant size particles representative of the distribution. For a given group, j, the conservation equations, written in a streamline oriented coordinate system are:

Continuity

$$(r\,\rho_{p_j}\,u_{p_j})_s + (r\,\rho_{p_j}\,V_{p_j})_n + r\,\rho_{p_j}\,u_{p_j}\,\theta_n - r\,\rho_{p_j}\,V_{p_j}\,\theta_s = 0 \qquad (9)$$

s-Momentum

$$u_{p_j}(u_{p_j})_s + V_{p_j}(u_{p_j})_n - V_{p_j}(V_{p_j}\theta_n - u_{p_j}\theta_s) = - \frac{9}{2}\,\frac{\mu_g f_{p_j}}{\rho_s r_{p_j}^{\;2}}\left(u_{p_j} - u\right) \qquad (10)$$

n-Momentum

$$u_{p_j}(V_{p_j})_s + V_{p_j}(V_{p_j})_n + u_{p_j}(V_{p_j}\theta_n + u_{p_j}\theta_s) = - \frac{9}{2}\,\frac{\mu_g f_{p_j}}{\rho_s r_{p_j}^{\;2}}\,V_{p_j} \qquad (11)$$

Energy[†]

$$u_{p_j}(C_s T_{p_j})_s + V_{p_j}(C_s T_{p_j})_n = - \frac{3 k_g g_{p_j}}{r_{p_j}^2 \rho_s}\left(T_{p_j} - T\right) \qquad (12)$$

[†]The effects of chemical reactions on the surface of particles are not included in this analysis.

When the particle undergoes a phase change (liquid to solid) it is kept at the solidification temperature until the total heat of solidification is released (via radiative and convective heat transfer) to the gas.

B. Finite-Difference Equations

A finite difference formulation of the gas phase and particle cloud governing equations is utilized on a grid which lies along and perpendicular to the streamlines.

1. Gas-Phase

The momentum and energy equations (Eqs. (2), (3) and (5)) are solved via an explicit finite-difference marching technique, whereas the species continuity equation (Eq. (4)), utilizes an implicit finite difference formulation developed in an earlier study at AeroChem.[11] This mixed form of the difference equations is necessary for the economical operation of the present code since, for near-equilibrium chemistry, the explicit finite-difference form of Eq. (4) leads to stability-limited (impractically small) integration step sizes. Equations (2), (3) and (5) are left in explicit form since the required integration step sizes for stability are reasonable; an implicit formulation of these equations would unnecessarily complicate the calculations.

To minimize the effects of large tube-to-tube property variations on the calculation of streamline curvature, a Von Mises-type transformation is employed, i.e.

$$\dot{m} = 2\pi \int \rho\, u r\, dn \qquad (13)$$

Using Eq. (13) the finite difference forms of the differential equations become:

Global Continuity

$$\dot{m}_k = \rho_{k,\ell+1} u_{k,\ell+1} A_{k,\ell+1} \qquad (14)$$

---

11. Mikatarian, R.R., Kau, C.J., and Pergament, H.S., "A Fast Computer Program for Nonequilibrium Rocket Plume Predictions," Final Report, AeroChem TP-282, AFRPL-TR-72-94, August 1972.

s-Momentum

$$\dot{m}_k(u_{k,\ell+1} - u_{k,\ell}) + \frac{1}{2}(A_{k,\ell+1} + A_{k,\ell})\,(p_{k,\ell+1} - p_{k,\ell}) =$$

$$\Delta_k(r_k \tau_k\, \delta s_k)\, 2\pi - \frac{1}{2}\left(A_{k,\ell+1} + A_{k,\ell}\right)$$

$$\times \sum_{j=1}^{J} \frac{9}{2}\left(\frac{\rho_{p_j}\, f_{p_j}\, \mu_g}{\rho_s\, r_{p_j}^{\,2}}\right)_{k,\ell}\left(u_{k,\ell} - u_{p_{j\,k,\ell}}\right) \tag{15}$$

n-Momentum

$$\left(\frac{\partial \Theta}{\partial s}\right)_{k,\ell} = - \frac{8\pi\, r_{k,\ell}}{u_{k,\ell} + u_{k+1,\ell}}\left(\frac{p_{k+1,\ell} - p_{k,\ell}}{\dot{m}_k + \dot{m}_{k+1}}\right)$$

$$+ \frac{2}{\left((\rho u^2)_{k+1,\ell} + (\rho u^2)_{k,\ell}\right)}$$

$$\times \sum_{j=1}^{J} \frac{9}{2}\left(\frac{\rho_{p_j}\, f_{p_j}\, \mu_g}{\rho_s\, r_{p_j}^{\,2}}\right)_{k,\ell} V_{p_{j\,k,\ell}} \tag{16}$$

Species Continuity†

$$\dot{m}_k\,(C_{i,k,\ell+1} - C_{i,k,\ell}) = \Delta_k(r_k\, D_{i,k}\, \delta s_k)\, 2\pi + \frac{2\,\dot{m}_k\, \delta s_k}{(u_{k,\ell+1} + u_{k,\ell})}\, \dot{W}_{i_k} \tag{17}$$

---

†The species mass fractions at station $k,\ell+1$ ($C_{i,\,k,\ell+1}$) are determined by linearizing the chemistry terms ($(\dot{W}_i)_k$) and inverting the resulting matrix (see Ref. 11).

Energy

$$\dot{m}_k \left(h_{k,\ell+1} - h_{k,\ell} + \frac{1}{2} u^2_{k,\ell+1} - \frac{1}{2} u^2_{k,\ell}\right) =$$

$$\Delta_k \left(r_k \left[q_k + \left(\frac{1}{2}\left(u_k^2 + u_{k+1}^2\right)\right)^{1/2} \tau_k + \sum_{i=1}^{I} h_{i,k} D_{i,k} \right] \delta s_k \right) 2\pi$$

$$+ \frac{1}{2}\left(A_{k,\ell+1} + A_{k,\ell}\right) \sum_{j=1}^{J} \left(\frac{9}{2} \left(\frac{\rho_{p_j} f_{p_j} \mu_g}{\rho_s \, r_{p_j}^2}\right)_{k,\ell} \left[V_{p_j\,k,\ell}^2 \right.\right.$$

$$\left.\left. + \left(u^2_{k,\ell} - u^2_{p_j\,k,\ell}\right) + \frac{2}{3}\left(\frac{g_{p_j} C_{p_g}}{f_{p_j} Pr}\right)_{k,\ell} \left(T_{p_j\,k,\ell} - T_{k,\ell}\right) \right] \right) \qquad (18)$$

State

$$\rho_{k,\ell} = \frac{P_{k,\ell}}{R\, T_{k,\ell} \sum_i \left(\frac{C_i}{M_i}\right)_{k,\ell}} \qquad (19)$$

Enthalpy

$$H = \frac{u^2_{k,\ell}}{2} + \sum_i \sum_{jj} a_{i,jj} \, T_{k,\ell}^{jj-1} \, C_{i_{k,\ell}} \qquad (20)$$

where in Eqs. (15), (17) and (18),

$$\tau_k = -2\pi \, r_k \, 2\left(u^2_{k+1,\ell} - u^2_{k,\ell}\right) \frac{\left(\rho_{k,\ell}\,\mu_{k,\ell} + \rho_{k+1,\ell}\,\mu_{k+1,\ell}\right)}{\left(\dot{m}_{k+1} + \dot{m}_k\right)} \qquad (21)$$

and

$$q_k = -2\pi \, r_k \, 2(u_{k+1,\ell} + u_{k,\ell}) \times \frac{\left(\rho_{k,\ell}\, k_{k,\ell} + \rho_{k+1,\ell}\, k_{k+1,\ell}\right)\left(T_{k+1,\ell} - T_{k,\ell}\right)}{\left(\dot{m}_{k+1} + \dot{m}_k\right)} \tag{22}$$

and

$$D_{i,k} = - \frac{2\pi \, r_k \, 2\left(u_{k+1,\ell} + u_k\right)\left(\rho^2_{k+1,\ell}\, \overline{D}_{k+1,\ell} + \rho^2_{k,\ell}\, \overline{D}_{k,\ell}\right)\left(C_{i,k+1,\ell} - \left(C_{i,k,\ell}\right)\right)}{\left(\dot{m}_{k+1} + \dot{m}_k\right)} \tag{23}$$

2. Particles

The finite difference forms of Eqs. (9-12) are:

Continuity

$$(r\rho_{p_j} u_{p_j})_{k,\ell+1} - (r\rho_{p_j} u_{p_j})_{k,\ell} + \left((r\rho_{p_j} V_{p_j})_{k+1,\ell} - (r\rho_{p_j} V_{p_j})_{k,\ell} \right) \frac{\delta s_k}{\delta n_k}$$

$$+ \delta s_k (r\rho_{p_j} u_{p_j})_{k,\ell} \, \theta_{n_{k,\ell}} - \delta s_k (r\rho_{p_j} V_{p_j})_{k,\ell} \, \theta_{s_{k,\ell}} = 0 \tag{24}$$

s-Momentum

$$u_{p_{jk\ell}}\left(u_{p_{jk\ell+1}} - u_{p_{jk\ell}}\right) + V_{p_{jk\ell}}\left(u_{p_{jk+1\ell}} - u_{p_{jk\ell}}\right)\frac{\delta s_k}{\delta n_k}$$

$$- \delta s_k V_{p_{jk\ell}}\left(V_{p_j}\theta_n - u_{p_j}\theta_s\right)_{k\ell} =$$

$$- \frac{9}{2}\left(\frac{f_{p_j}\mu_g}{\rho_s r_{p_j}^{2}}\right)_{k\ell}\left(u_{p_{jk\ell}} - u_{k\ell}\right)\delta s_k$$

(25)

n-Momentum

$$u_{p_{jk\ell}}\left(V_{p_{jk\ell+1}} - V_{p_{jk\ell}}\right) + V_{p_{jk\ell}}\left(V_{p_{jk+1\ell}} - V_{p_{jk\ell}}\right)\frac{\delta s_k}{\delta n_k}$$

$$+ u_{p_{jk\ell}}\left(V_{p_j}\theta_n + u_{p_j}\theta_s\right)_{k\ell}\delta s_k =$$

$$- \frac{9}{2}\left(\frac{\mu_g f_{p_j}}{\rho_s r_{p_j}^{2}}\right)_{k\ell} V_{p_{jk\ell}}\delta s_k$$

(26)

Energy

$$u_{p_{jk\ell}} C_s\left(T_{p_{jk\ell+1}} - T_{p_{jk\ell}}\right) + V_{p_{jk\ell}} C_s\left(T_{p_{jk+1\ell}} - T_{p_{jk\ell}}\right)\frac{\delta s_k}{\delta n_k} =$$

$$- \frac{3\epsilon\sigma}{r_{p_{jk\ell}}\rho_s} T_{p_{jk\ell}}^{4}\delta s_k - 3\left(\frac{k_g g_{p_j}}{r_{p_j}^{2}\rho_s}\right)_{k\ell}$$

$$\times \left(T_{p_{jk\ell}} - T_{k\ell}\right)\delta s_k$$

(27)

3. Integration Step Size

The integration step size must be limited in order to perform a stable calculation. The stability of the explicit finite difference scheme for solving the gas dynamic equations is discussed by Boynton and Thomson,[6] who show that the stable step size for laminar flow is determined from,

$$\delta s \leq \frac{\delta n}{2} \left[\frac{1}{Re} + \frac{1}{(M^2 - 1)^{1/2}} \right]^{-1} \tag{28}$$

For turbulent flow the eddy viscosity replaces the laminar viscosity in the expression for Re.† The step size determined from Eq. (28) may not be sufficiently small if the chemistry is very "fast". Thus, an additional "chemistry" control has been incorporated into the code: at each integration step (orthogonal surface) the species mass fractions are tested for sign. If any C_i goes negative the integration step size is halved and the calculations are repeated until the C_i in question becomes positive or the step size becomes less than the minimum allowable step size. In the latter case the program terminates.

The particle cloud system of equations (Eqs. (9-12)) contains derivatives related only to the convection of mass, momentum and energy. In the momentum and energy equations, the convection terms are equal to the particle/gas interaction terms. Unlike the gas flow equations the particle equations have no wave or diffusive nature. Consequently when these equations are solved explicitly there is no stability limitation on the integration step size and the step size can be determined from Eq. (28).

4. Solution Procedure

The gas phase and particle cloud finite difference equations are solved on a grid consisting of the streamtubes and the surfaces orthogonal to them, as illustrated in Fig. 1. All gas and particle flow properties, streamline positions and angles must be known along the initial orthogonal surface downstream of the throat ($M > 1$). Starting with the first streamtube (adjacent to the axis) the streamtubes are extended a distance δs to a downstream surface, utilizing the radius of curvature, $(\Theta_s)'$ obtained from the normal momentum equation (Eq. (16)) and the known initial pressure distribution along the

† Eq. (28) is not, of course, valid in the limit, $Re \to 0$. In that case (i.e. the situation for most practical nozzle flows), $\delta s \leq \frac{\delta n}{2} [M^2-1]^{1/2}$.

surface. The resulting streamtube areas are then used to determine all the necessary gas properties at the downstream surface from Eqs. (14), (15), and (17)-(23). The transfer of mass, momentum and energy into or out of each streamtube is arranged such that what is lost from a given streamtube is gained by the adjacent tube. Thereby mass, momentum and energy are automatically conserved.

In order to render this marching scheme conditionally stable a single iteration on the radius of curvature calculation is required,[6] with the new value, $(\Theta_s)''$, determined using the downstream surface properties. $(\Theta_s)''$ is then combined with $(\Theta_s)'_k$ in the following expression,[6]

$$(\Theta_s) = (1 - \alpha)(\Theta_s)' + \alpha(\Theta_s)'' \quad (29)$$

This new value for the radius of curvature is then used in the calculation. A value for α of 0.55 is used in the present code. (The scheme is conditionally stable for $\alpha \geq 1/2$).

After the gas phase equations have been solved for the first streamtube the particle properties are determined by sequentially applying the particle momentum, continuity and energy equations. The calculation of gas and particle properties then moves outward to the next streamtube and the procedure is repeated up to the last streamtube† where boundary conditions must be applied.

C. Auxiliary Calculations

1. Thermodynamic Input Data

The thermodynamic data are input via curve fits of specific heats[12] of individual species in the JANNAF tables.[13] These curve fits have the form,

$$C_{p_i} = L_{1_i} + L_{2_i}\Phi + L_{3_i}\Phi^2 + L_{4_i}\Phi^3 + L_{5_i}\Phi^{-2} \text{ cal/mole-}^\circ\text{K} \quad (30)$$

† In general the limiting particle streamlines for each particle size will not extend to the last streamtube.

12. Cruise, D.R., "Information Manual for the Theoretical Propellant Evaluation Program," Naval Weapons Center PEP NOTE TN-U-1 (plus additions), December 1964.

13. JANNAF Thermochemical Tables (Dow Chemical Company, Midland, Mich.), continuously updated.

where $\Phi = T(^{o}K)/1000$. The enthalpy is then expressed as,

$$h_i = \int_0^T C_{p_i} \, dT + L_{6_i} \qquad \text{kcal/mole} \qquad (31)$$

where $L_{6_i} = H_f^0 - \int_0^{298} C_{p_i} \, dT$; H_f^0 being the heat of formation at $298^{o}K$. The entropy is expressed as,

$$S_i = \int_0^T C_{p_i} \frac{dT}{T} + L_{7_i} \qquad \text{cal/mole-}^{o}\text{K} \qquad (32)$$

where L_{7_i} is the entropy integration constant. The coefficients L_1 - L_7 are input on Card group 8.

2. Chemical Kinetic Input Data

Ten possible reaction types are included in the program:

Reaction Type

(1)	$A + B \rightleftarrows C + D$
(2)	$A + B + M \rightleftarrows C + M$
(3)	$A + B \rightleftarrows C + D + E$
(4)	$A + B \rightleftarrows C$
(5)	$A + M \rightleftarrows C + D + M$
(6)	$A + B \rightarrow C + D$
(7)	$A + B + M \rightarrow C + M$
(8)	$A + B \rightarrow C + D + E$
(9)	$A + B \rightarrow C$
(10)	$A + M \rightarrow C + D + M$

Reaction types (6)-(10) correspond to reaction types (1)-(5), but proceed in the forward direction only. In Reactions (2), (5), (7) and (10), M is an arbitrary third body. In this program, all species are assumed to have equal third body efficiencies.

The forward rate coefficient, k_f, is input to the code as one of the following 8 types

Rate Coefficient Type†

(1) $k_f = A$

(2) $k_f = AT^{-1}$

(3) $k_f = AT^{-2}$

(4) $k_f = AT^{-\frac{1}{2}}$

(5) $k_f = A \exp(B/RT)$

(6) $k_f = AT^{-1} \exp(B/RT)$

(7) $k_f = AT^{-\frac{3}{2}}$

(8) $k_f = AT^{N} \exp(B/RT)$

The equilibrium constant, K_p, is determined from

$$\ln K_p = - \Delta G/RT \tag{33}$$

where the Gibbs free energy, ΔG, for individual reactions is computed from the input thermodynamic data.

† Rate coefficient data for typical rocket nozzle and plume reactions may be found, e.g., in Ref. 14.

14. Jensen, D.E. and Jones, G.A., "Gas-Phase Reaction Rate Coefficients for Rocketry Applications," Rocket Propulsion Establishment Technical Report No. 71/9, October 1971.

3. Particle/Gas Drag and Heat Transfer Coefficients

The momentum and energy exchange (via convective heat transfer) between the small diameter particles and the combustion products in the nozzle cannot adequately be described by simple theoretical expressions (e.g. Stokes law).[15] Empirical correlations of drag and heat transfer coefficients developed by Crowe[16] have therefore been incorporated in the particle/gas interaction terms (see, e.g. Eqs. (2), (3), and (5)).

a. Drag Coefficient - The drag coefficient has been correlated by Crowe[16] in terms of a normalized value,

$$\bar{C}_D = (C_D - C_{D_I})/(C_{D_{FM}} - C_{D_I}) \tag{34}$$

where C_{D_I} is the drag coefficient at very large Reynolds number and $C_{D_{FM}}$ is the free molecular drag coefficient. Note that for $Re_p << 1$, $\bar{C}_D \to 1$, while for $Re_p >> 1$, $\bar{C}_D \to 0$.

The expressions needed to evaluate C_D from Eq. (32) are:

$$C_{D_I} = 0.66 + 0.26\,[\exp(4\ \ln M_p) - 1] + 0.17\,\exp[-2.5(\ln M_p/1.4)^2] \tag{35}$$

$$C_{D_{FM}} = \frac{\exp(-S_1^2/2)}{\sqrt{\pi}\, S_1^3}(1 + 2S_1^2) + \frac{4(S_1^4 + S_1^2) - 1}{2S_1^4}\,\mathrm{erf}(S_1) + \frac{2}{3}\,\frac{\sqrt{\pi}}{\sqrt{T/T_p}} \tag{36}$$

where,

$$S_1 = \sqrt{\gamma/2}\, M_p \tag{37}$$

$$\bar{C}_D = G(Kn)\, D(Kn, Re_p) \tag{38}$$

$$G(Kn) = \frac{Kn^{0.4}\exp(1.2\ Kn^{0.5})}{1 + Kn^{0.4}\exp(1.2\ Kn^{0.5})} \tag{39}$$

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15. Soo, S.L., Fluid Dynamics of Multiphase Systems (Blaisdell Publ. Co, Waltham, Mass., 1967).

16. Crowe, C.T., "On the Momentum and Heat Transfer Equations for Two-Phase Plumes," Washington State Univ., March 1971.

and

$$D(Kn, Re_p) = 1 - \exp\left[-\frac{Re_p}{8} Kn^{0.6} \exp(Kn)\left(C_{D_o} - 0.4\right)\right] \quad (40)$$

$$Kn = 1.26\sqrt{\gamma}\ \frac{M_p}{Re_p} \quad (41)$$

and, $$C_{D_o} = 24/Re_p \quad (42)$$

The expression used in the particle/gas interaction terms is then,

$$f_p = FFF\ \frac{C_D}{C_{D_o}} \quad (43)$$

where FFF is a factor (input on Card 15, Cols. 1-10) used to arbitrarily vary C_D to account for uncertainties in the above analysis.

b. Heat Transfer Coefficient - Heat transfer from the particle to the gas is expressed in terms of a Nusselt number as,

$$q = 2\pi\ r_p\ Nu\ k(T_p - T_r) \quad (44)$$

where T_r is the recovery temperature. From Crowe[16] we get the following expression,

$$Nu = Nu_{KD} + \frac{\gamma + 1}{\gamma}\ Re_p Pr_g \exp(-Re_p/2M_p) \quad (45)$$

$$Nu_{KD} = Nu_o/\left(1 + \frac{5\gamma^{1.5}}{\gamma + 1}(M_p/Re_p Pr_g)\ Nu_o\right) \quad (46)$$

Nu_o is the Nusselt number in incompressible flow, expressed as

$$Nu_o = 2.0 + 0.459\ Re_p^{0.55}\ Pr_g^{0.33} \quad (47)$$

The recovery temperature is defined as,

$$Tr = T + r\left((u - u_p)^2 + V_p^2 \right)/2C_p \tag{48}$$

where the recovery factor r is[16];

$$r = 0.9 + (r_{FM} - 0.9) \exp(-Re_p/2M_p) \tag{49}$$

and

$$r_{FM} = \frac{\gamma}{\gamma+1} \left(2 + 0.67 \exp(-M^2/3) \right) \tag{50}$$

The expression used in the particle/gas interaction term is,

$$g_p = FFG \frac{Nu}{2} \frac{T_p - T_r}{T_p - T} \tag{51}$$

where FFG is a factor (input on Card 15, Cols. 11-20) used to arbitrarily vary g_p to account for uncertainties in the above analysis.

D. Turbulent Boundary Layer Equations†

The turbulent compressible boundary layer analysis is initiated by calculating the corresponding adiabatic flat plate, zero pressure gradient, incompressible boundary layer properties, based on a 1/7 power law[17]

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† The "free stream" properties (subscript "e") for the boundary layer analysis are taken to be the properties in the last (wall) streamtube. It is implicitly assumed that the boundary layer displacement thickness is smaller than the width of the wall streamtube.

17. Schlicting, H., Boundary Layer Theory, 6th Ed. (McGraw-Hill, New York, 1968), p. 599.

velocity profile.† Expressions for the incompressible momentum and boundary layer thickness are,

$$\theta_i(x) = 0.036/Re_x^{0.2} \tag{52}$$

$$\delta_i(x) = 10.286\,\theta_i(x) \tag{53}$$

The incompressible skin friction coefficient is evaluated from the Karman-Schoenherr relation.[20]

$$C_{F_i} = [17.08\,(\log_{10} Re_{\theta_i})^2 + 25.11\,\log_{10} Re_{\theta_i} + 6.012]^{-1} \tag{54}$$

Transformation from the compressible to the incompressible boundary layer is accomplished via the Van Driest equations,[7] which relate the velocity and temperature profiles as follows,

$$\bar{T}_t = \frac{T_e - T_w}{T_{t_e} - T_w} = f\left(\frac{U}{U_e}\right) \tag{55}$$

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† It was originally anticipated that the complete boundary layer equations including nonequilibrium chemistry would be solved by finite differences and coupled to the nozzle flow solution. A number of boundary layer codes are available, including those of Herring and Mellor[18] and the Aerotherm BLIMP code,[19] which would be very useful for this purpose. However, initial attempts to incorporate the BLIMP code into FULLNOZ showed that it would take more effort than was warranted at this time. Consequently, a more simplified analysis was incorporated into the present code.

18. Herring, H.J. and Mellor, G.L., "A Method of Calculating Compressible Turbulent Boundary Layers," NASA CR-1144, September 1968.

19. Tong, H., Buckingham, A.C., and Morse, H.L., "Nonequilibrium Chemistry Boundary Layer Integral Matrix Procedure," Aerotherm Final Report No. 73-67, July 1973.

20. Hopkins, E.J., Keener, E.R., and Louie, P.T., "Direct Measurements of Turbulent Skin Friction on a Nonadiabatic Flat Plate at Mach Number 6.5 and Comparisons with Eight Theories," NASA TN D-5675, February 1970.

The general functional relation used in the analysis is

$$\bar{T}_t = \left(\frac{U}{U_e}\right)^n \tag{56}$$

Equation (56) becomes the Crocco relation for n = 1 and the quadratic for n = 2.

A general expression between T/T_e and U/U_e can then be written

$$\frac{T}{T_e} = A\left(\frac{U}{U_e}\right)^2 + B\left(\frac{U}{U_e}\right)^n + C \tag{57}$$

where

$$A = \left(\frac{T_{t_e}}{T_e} - 1\right);\ B = \left(\frac{T_{t_e}}{T_e} - \frac{T_w}{T_e}\right);\ C = \frac{T_w}{T_e}$$

From Back and Cuffel,[21] wall cooling ($T_w < T_{aw}$) tends to make the exponent n closer to 1.0, while wall heating causes n to approach 2 or more. The value of n selected here was 1.2. It was determined by fitting recent data of Keener and Hopkins[8] for which, $T_w/T_{aw} = 0.32$. (This corresponds to a wall temperature of 1000-1300 K.) Equation (57) was used to generate a table of T/T_e vs. U/U_e, which is then used to determine the compressible skin friction coefficient via the Van Driest transformation

$$\frac{C_{f_c}}{C_{f_i}} = \left\{\int_0^1 \left(\frac{T_e}{T}\right)^{1/2} d\left(\frac{U}{U_e}\right)\right\}^2 \tag{58}$$

The Stanton number was determined from the relation

$$S_t = 0.35\, C_{f_c} \tag{59}$$

which is supported by the experimental data of Back and Cuffel[21] for accelerating flows.

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21. Back, L.H. and Cuffel, R.F., "Relationship Between Temperature and Velocity Profiles in a Turbulent Boundary Layer along a Supersonic Nozzle with Heat Transfer," AIAA J. 8, 2066-2069 (1970).

Wall shear stress and heat transfer are then calculated from

$$\tau_w = \frac{1}{2} \rho_e U_e^2 C_{f_c} \tag{60}$$

$$\dot{q}_w = -S_t \rho_e U_e C_p (T_{t_e} - T_w) \tag{61}$$

In order to obtain the velocity profiles the friction velocity profile, $(U/U_\tau)_i = f(U/U_e)$ is first determined from another Van Driest transformation,[7]

$$\left(\frac{U}{U_\tau}\right)_i = \left(\frac{2}{C_{f_c}}\right)^{1/2} \int_0^{U/U_e} \left(\frac{T_e}{T}\right)^{1/2} d\left(\frac{U}{U_e}\right) \tag{62}$$

where the friction velocity is defined as,

$$U_{\tau_i} = \left(\rho_e U_e^2 C_{f_i}/2\rho_w\right)^{1/2} \tag{63}$$

$(y/\delta)_i$ is then obtained from the standard incompressible boundary layer profiles[22] †

$$\frac{yU_\tau}{\nu} = \frac{U}{U_\tau}; \qquad \frac{U}{U_\tau} < 5 \tag{64}$$

$$\frac{yU_\tau}{\nu} = \exp\left\{\frac{U/U_\tau + 3.05}{2.5}\right\}; \qquad 5 \le \frac{U}{U_\tau} \le 13.96 \tag{65}$$

$$\frac{yU_\tau}{\nu} = \exp\left\{\frac{U/U_\tau - 5.05}{2.5}\right\}; \qquad \frac{U}{U_\tau} > 13.96 \tag{66}$$

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† The values of yU_τ/ν are normalized by $\exp\{[U/U_{\tau\,max} - 5.05]/2.5\}$ to avoid the calculation of the ν profile in the boundary layer.

22. Kays, W.M., Convective Heat and Mass Transfer (McGraw-Hill, New York, 1966).

Another Van Driest transformation yields $(y/\delta)_c = (y/\delta)_i$. Once the compressible profiles are known, Θ/δ, δ^*/δ, and the shape factor are determined from

$$\Theta/\delta = \int_0^1 \left(\frac{U}{U_e}\right)\left(1 - \frac{U}{U_e}\right) d\left(\frac{y}{\delta}\right) \tag{67}$$

$$\delta^*/\delta = \int_0^1 \left(1 - \frac{U}{U_e}\right) d\left(\frac{y}{\delta}\right) \tag{68}$$

$$H_{12} = \frac{\delta^*/\delta}{\Theta/\delta} \tag{69}$$

The variation of momentum thickness along the nozzle is determined via integration of the momentum integral equation,

$$\frac{C_{f_c}}{2} = \frac{d\Theta}{dx} + [H_{12} + 2]\Theta \frac{1}{U_e} \frac{dU_e}{dx} + \frac{\Theta}{\rho_e} \frac{d\rho_e}{dx} + \frac{\Theta}{R} \frac{dR}{dx} \tag{70}$$

by the use of backward differences.† δ and δ^* are then evaluated from Eqs. (67) and (68).

III. PREPARATION OF INPUT DATA

All necessary information for preparing input data is given below; Fig. 2 defines some of the input for a sample case. Many of the input parameters that are left blank are used in the companion rocket plume code[10] (AIPP), but not in FULLNOZ.

† This requires that a throat value of 0 be assumed.

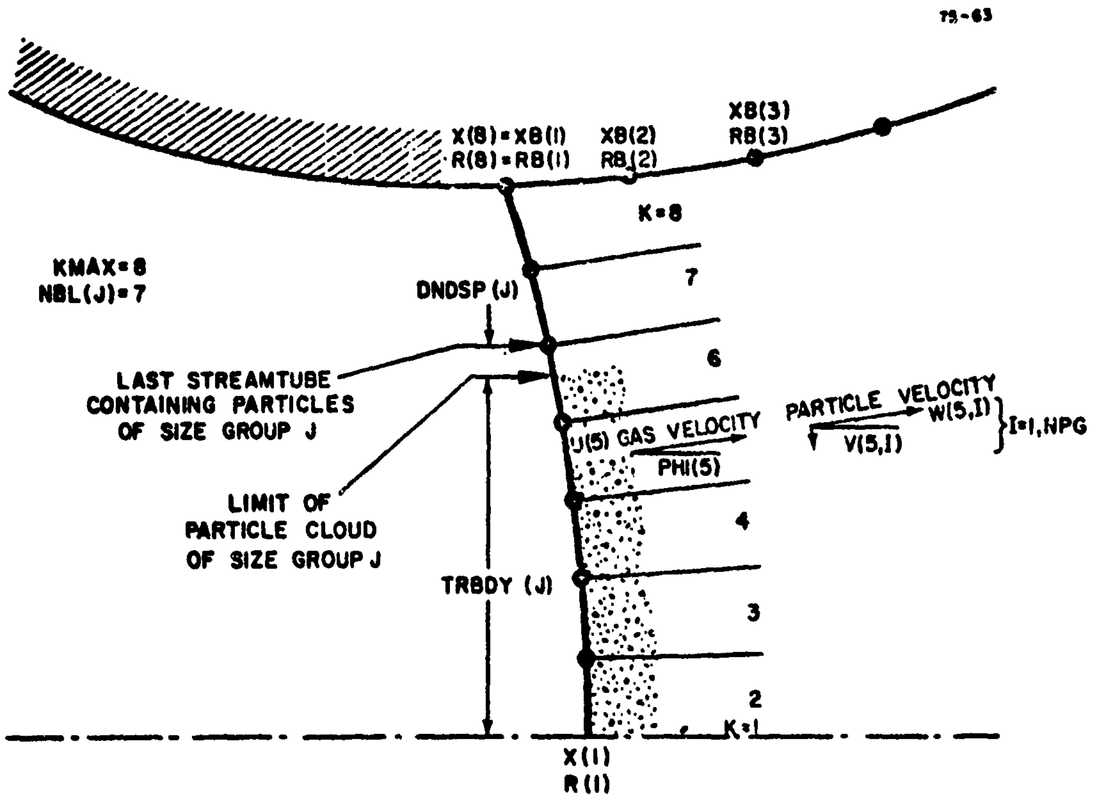

Figure 2. Input data definitions.

Card No.	Cols.	Fortran Name	Description	Format
1	1-10	NDATA	Number of data sets; in present version of code data sets cannot be stacked; therefore NDATA = 1	I.10
2	1-80	ID	Run identification	20A4
3	1-10	NSEC	Maximum run time (sec); when run time reaches NSEC nozzle properties at last orthogonal surface are punched and can be used to continue the calculation. (Not operational in present version of code)	I.10
	11-22	DXLSS	Approximate distance (cm) along axis between orthogonal surface print stations. For control of print increment by number of integration steps (KP, Card 5, Cols. 11-15) instead of axial distance, make DXLSS larger than XLMAX (below)	E12.5

Card No.	Cols.	Fortran Name	Description	Format
3	23-34	XLMAX	Maximum distance (cm) along axis for which calculations will be made. XLMAX should be set somewhat larger than axial distance to nozzle exit plane in order to complete calculation at last wall point	E12.5
4	1- 5	ITYPE	Inner boundary condition (nozzle axis) Set ITYPE = 1	I5
	6-10	IKIND	Outer boundary condition; set IKIND = 1 for wall boundary condition	
	11-15		Not used; leave blank	
	16-20		Not used; leave blank	
	21-25		Not used; leave blank	
	26-30	IBUGSH	Debug printout index; 0 - No debug printout 1 - Extensive printout for debugging	I5
	31-35		Not used; leave blank	
	36-40		Not used; leave blank	
	41-45		Not used; leave blank	
	46-50	IPART	Particle indicator; 0 - No particles 1 - Particles in flow	I5
	51-55		Not used; leave blank	
	56-60	ITURB	Turbulent flow indicator; 0 - Inviscid 3 - Constant values of turbulent mixing parameters, μ, Pr and Le are input on Card 10	I5
5	1- 5	KMAX	Initial number of streamtubes plus one (axis is counted as K = 1; maximum is 40)	I5
	6-10	NN	Number of terms for C_p polynomial curve fit plus one; for curve fits supplied with program,[12] NN = 6. If fewer coefficients are used for a given species NN is left at 6 and zeroes are input for the missing coefficients (see Card 8)	

Card No.	Cols.	Fortran Name	Description	Format
5	11-15	KP	Output control; number of orthogonal surfaces between print stations. To control print via axial distance (DXLSS, Card 3, Cols. 11-22) instead of orthogonal surfaces set KP larger than LPLANE (Card 5, Cols. 36-40)	
	16-20	MMAX	Number of points needed to describe shape of inner boundary; always set equal to 2 for axis boundary	I5
	21-25	NMAX	Number of points required to define nozzle wall contour (50 maximum)	I5
	26-30	NDS	Total number of gas species in flow (25 maximum)	I5
	31-35	NITER	Maximum number of iterations allowed for iterative solutions (e.g. calculation of streamtube properties for variable γ) Recommended value: NITER = 50	I5
	36-40	LPLANE	Maximum number of integration steps for entire calculation	I5
	41-45	IKINE	Number of chemical reactions (40 maximum)	I5

NOTE: IF NO BOUNDARY LAYER CALCULATIONS ARE TO BE MADE CARD 6 MAY BE LEFT BLANK, BUT MUST BE INCLUDED

Card No.	Cols.	Fortran Name	Description	Format
6	1- 5	TWALL	Nozzle wall temperature (^{o}K) (assumed constant)	F5.0
	8	IBLFLG	Boundary layer property printout indicator; 0 - Print Re, δ_i, θ_i, C_{f_i}, U_T, δ_c, δ_c^*, θ_c, C_{f_c}/C_{f_i}, H_{12}, q_w, T_w 1 - Print above plus velocity and temperature profiles	I1

Card No.	Cols.	Fortran Name	Description	Format
6	11	IBL	Boundary layer calculation indicator; 0 - Do not calculate boundary layer 1 - Calculate boundary layer	I1
7	1- 9	ALPHAH	Factor that multiplies maximum stable step size (see Eq. (28)); Recommended value: ALPHAH = 0.8	F9.4
	10-18	EPSLON	Amount by which streamtube Mach numbers must exceed one in order for the calculation to continue. Recommended value: EPSLON = 0.01	F9.4
	19-27	TOL	Convergence tolerance for iterative solutions; Recommended value: TOL = 1×10^{-4}	F9.4
	28-36	DELTA	Metric exponent†; 0 - Two-dimensional flow 1 - Axially symmetric flow	F9.4
	37-45	ATOL	Maximum allowable fractional change in streamtube area per step. Recommended value: ATOL = 0.1	F9.4

NOTE: CARD GROUP 8 DEFINES THE THERMODYNAMIC DATA FOR EACH SPECIES. THERE ARE 2 CARDS PER SPECIES AND NDS SPECIES

Card No.	Cols.	Fortran Name		Description	Format
8.1.1	1-13	A(1)	L_1	Specific heat polynomial constants for first species, see Section II.C.1 (cal/mole °K)	E13.5
	14-26	A(2)	L_2		
	27-39	A(3)	L_3		
	40-52	A(4)	L_4		

† The particle conservation equations are written only for axially symmetric flow. Thus two-dimensional solutions can only be obtained for flows without particles.

Card No.	Cols.	Fortran Name	Description	Format
8.1.2	1-13	A(5)	L_5, Specific heat polynomial constant for first species	E13.5
	14-26	A(6)	L_6, Enthalpy constant of integration for first species $\left(\Delta H_f^o - \int_0^{298} C_p \, dT \right)$ (kcal/mole)	E13.5
	27-39	CS(1)	L_7, entropy constant of integration for first species (cal/mole ^oK)	
⋮				
8.NDS.1 8.NDS.2			Repeat thermodynamic data for NDS species	

NOTE: CARD GROUP 9 IDENTIFIES EACH SPECIES AND SPECIFIES VARIOUS TRANSPORT PROPERTIES. MUST BE IN SAME ORDER AS CARD GROUP 8

Card No.	Cols.	Fortran Name	Description	Format
9.1	1- 4	IDENT(1)	Species name; first species (the remaining data on Card 9.1 also apply to the first species)	A4
	13-24	MUO(1)	Viscosity at reference temperature† (g/cm-sec); only used when flow contains particles. FOR IPART = 0, MUO MUST = 0 FOR ALL SPECIES	E12.4
	25-36	TO(1)	Reference temperature for viscosity (^oK)	E12.4
	37-48	OMEGA(1)	Exponent describing viscosity/temperature relation; $\mu \propto T^{\omega}$	E12.4
	49-60	PR(1)	Reciprocal of species Prandtl number	E12.4
	61-72	SC(1)	Reciprocal of species Schmidt number	E12.4
	73-80	MW(1)	Species molecular weight	E8.2
⋮				

† Values for common gases can be found in most physics and chemistry handbooks.

Card No.	Cols.	Fortran Name	Description	Format
9.NDS			Repeat for each species	
	NOTE:	CARD 10 IS NOT NEEDED IF ITURB = 0 (CARD 4, COLS. 56-60)		
10	1-10	TLE	Turbulent Lewis number (constant)	
	11-20	TPR	Turbulent Prandtl number (constant)	
	21-30	EDDYK	Eddy viscosity, g/cm-sec (constant)	
	NOTE:	CARD GROUPS 11 AND 12 DEFINE THE LOCATION OF THE INITIAL ORTHOGONAL SURFACE, AND THE FLOW ANGLE, PRESSURE, TEMPERATURE, VELOCITY AND SPECIES MASS FRACTIONS WITHIN EACH STREAMTUBE		
11	1-12	X(1)	Initial axial position on inner boundary (cm)	E12.4
	13-24	R(1)	Initial radial position on inner boundary (cm); usually equal to 0 for axis boundary	E12.4
	25-36	PHI(1)	Initial flow angle† on inner boundary (radians); usually equal to 0 for axis boundary	E12.4
12.1.1	1-12	X(2)	Axial position at outer boundary of first streamtube (cm)	E12.4
	13-24	R(2)	Radial position at outer boundary of first streamtube (cm)	E12.4
	25-36	PHI(2)	Flow angle at outer boundary of first streamtube (radians)	E12.4
	37-48	P(2)	Average pressure in first streamtube (atm)	E12.4
	49-60	T(2)	Average temperature in first streamtube (^{o}K)	E12.4
	61-72	U(2)	Average velocity in first streamtube (cm/sec)	E12.4
12.1.2	1-10	C(1,2)	Average mass fraction of first species in first streamtube	E10.3

† Flow angle is defined as the angle between the flow velocity vector and the axis.

Card No.	Cols.	Fortran Name	Description	Format
12.1.2	11-20	C(2,2)	Average mass fraction of second species in first streamtube	E10.3
	•		•	•
	•		•	•
	71-80	C(8,2)	Average mass fraction of eighth species in first streamtube	E10.3
•				
•				
12.1.I($\frac{NDS}{8}$)				

NOTE: I($\frac{NDS}{8}$) DENOTES THE NEXT INTEGER LARGER THAN ($\frac{NDS}{8}$). REPEAT CARD 12.1.2 TO INCLUDE NDS SPECIES, 8 SPECIES/CARD

Card No.	Cols.	Fortran Name	Description	Format
12.2.1	1-12	X(3)	Axial position at outer boundary of second streamtube (cm)	E12.4
	•		•	
	•		•	
	61-72	U(3)	Average velocity in second streamtube (cm/sec)	E12.4
12.2.2	1-10	C(1,3)		E10.3
	•			•
	•			•
	71-80	C(8,3)		•
•				•
•				•
12.2.I($\frac{NDS}{8}$)		C(NDS,3)	Average mass fraction of last species in second streamtube	E10.3
•				
•				
12.(KMAX-1).1	1-12	X(KMAX)	Axial position at outer boundary of last (KMAX-1) streamtube (cm)	E12.4
•				
•				
•				
12.(KMAX-1).I($\frac{NDS}{8}$)		C(NDS, KMAX)	Average mass fraction of last species in last streamtube	E10.3

NOTE: CARD 13 DEFINES THE POSITION OF THE INNER BOUNDARY

Card No.	Cols.	Fortran Name	Description	Format
13.1	1-12	XW(1)	Initial axial position (cm); repeat of X(1) on Card 10	E12.4
	13-24	RW(1)	Initial radial position (cm); repeat of R(1) on Card 10	E12.4

Card No.	Cols.	Fortran Name	Description	Format
13.1	25-36	PHIW(1)	Leave rest of card blank; program will determine these inner boundary properties	E12.4
	37-48	PW(1)		E12.4
	49-60	SW(1)		E12.4
13.2	1-12	XW(2)	Axial distance greater than XLMAX (Card 3, Cols. 23-34)(cm). Since the inner boundary is an axis the program will interpolate linearly between XW(1) and XW(2) to get axial locations of orthogonal surfaces. Therefore, set XW(2) = 1×10^{10}	E12.4
	13-24	RW(2)	Final radial position of inner boundary (cm); since inner boundary is an axis set RW(2) equal to R(1) on Card 11	E12.4
	25-36	PHIW(2)	Leave rest of card blank; program will determine these inner boundary properties	E12.4
	37-48	PW(2)		E12.4
	49-60	SW(2)		E12.4

NOTE: CARD GROUP 14 DEFINES THE POSITION OF THE OUTER BOUNDARY (NOZZLE WALL CONTOUR)

Card No.	Cols.	Fortran Name	Description	Format
14.1	1-12	XB(1)	Initial axial position of nozzle wall (cm); equal to X(KMAX) on Card 12.(KMAX-1).1	E12.4
	13-24	RB(1)	Initial radial position of nozzle wall (cm); equal to R,KMAX) on Card 12.(KMAX-1).1	E12.4
14.2	1-12	XB(2)	Axial position (cm) of second point along nozzle wall	E12.4
	13-24	RB(2)	Radial position (cm) of second point along nozzle wall	E12.4
•				
•				
14.NMAX	1-12	XB(NMAX)	Final axial position (cm) of nozzle wall	E12.4
	13-24	RB(NMAX)	Final radial position (cm) of nozzle wall	E12.4

NOTE: CARD GROUPS 15-19 AND 20-24 (OR 25-32) ARE INCLUDED ONLY IF PARTICLES ARE IN FLOW, i.e. IPART = 1 (CARD 4, COLS. 46-50)

Card No.	Cols.	Fortran Name	Description	Format
15	1-10	FFF	Factor which multiplies particle/gas drag coefficient (see Section II.C.3)	E10.3

Card No.	Cols.	Fortran Name	Description	Format
15.	11-20	FFG	Factor which multiplies particle/gas heat transfer coefficient (see Section II.C.3)	E10.3
	21-30	CL	Liquid particle specific heat (cal/g-^{o}K)	E10.3
	31-40	CS	Solid particle specific heat (cal/g-^{o}K)	E10.3
	41-50	HTRAN	Particle heat of solidification (cal/g)	E10.3
	51-60	WT	Particle molecular weight	E10.3
16	1-10	RHSS	Particle density (g/cm^3)	E10.3
	11-20		Not used; leave blank	
	21-30		Not used; leave blank	
	31-40	TPS	Particle solidification temperature (^{o}K)	E10.3
17	1- 5	NPG	Number of particle groups (8 maximum)	I5
	6-10	NC	Index noting whether particle properties are constant or variable along initial orthogonal surface 0 - constant 1 - variable	I5

NOTE: NBL( ) INDICATES RADIAL EXTENT OF EACH PARTICLE GROUP ALONG INITIAL ORTHOGONAL SURFACE (SEE FIG. 2); DEFINED AS LAST STREAMTUBE NUMBER CONTAINING PARTICLES PLUS 2. FOR EXAMPLE, IF THE FIRST PARTICLE GROUP EXTENDS TO STREAMTUBE NO. 12, NBL(1) = 14

Card No.	Cols.	Fortran Name	Description	Format
18	1- 5	NBL(1)	Last streamtube containing first particle group along initial orthogonal surface (streamtube number + 2)	I5
	•			
	•			
		NBL(NPG)	Last streamtube containing NPG particle group (streamtube number + 2)	I5
19	1-10	RP(1)	Radius of first particle group (cm)	8E10.3
	•	•		
	•	•		
		RP(NPG)	Radius of NPG particle group (cm)	

Card No.	Cols.	Fortran Name	Description	Format
	NOTE:	IF PARTICLE PROPERTIES ALONG INITIAL ORTHOGONAL SURFACE ARE CONSTANT (NC = 0) CARDS 20-24 ARE INPUT; IF NC = 1 THE NEXT CARD GROUP IS NO. 25		
20	1-10	WI(1)	Velocity of first particle group in streamline direction (cm/sec)	E10.3
	11-20	WI(2)	Velocity of second particle group in streamline direction (cm/sec)	E10.3
	•	•		•
	•	•	•	•
		WI(NPG)	Velocity of NPG particle group in streamline direction (cm/sec)	E10.3
21	1-10	VI(1)	Velocity of first particle group normal to streamline (cm/sec)	E10.3
	11-20	VI(2)	Velocity of second particle group normal to streamline (cm/sec)	E10.3
	•	•		•
	•	•	•	•
		VI(NPG)	Velocity of NPG particle group normal to streamline (cm/sec)	E10.3
22	1-10	TPI(1)	Temperature of first particle group (°K)	E10.3
	11-20	TPI(2)	Temperature of second particle group (°K) •	E10.3
	•	•		•
	•	•	•	•
		TPI(NPG)	Temperature of NPG particle group (°K)	E10.3
23	1-10	RHP(1)	Particle cloud density of second particle group (g/cm³)	E10.3
	11-20	RHPI(2)	Particle cloud density of second particle group (g/cm³)	E10.3
	•	•		•
	•	•	•	•
		RHPI(NPG)	Particle cloud density of NPG particle group (g/cm³)	E10.3

Card No.	Cols.	Fortran Name	Description	Format
	NOTE:	IF A PARTICLE GROUP IS AT THE SOLIDIFICATION TEMPERATURE THE AMOUNT OF HEAT WHICH HAS BEEN TRANSFERRED FROM THE LIQUID PARTICLES (i.e. SOME FRACTION OF THE TOTAL HEAT OF SOLIDIFICATION) IS INPUT ON CARD 24. IF THE PARTICLE TEMPERATURE IS ABOVE OR BELOW THE SOLIDIFICATION TEMPERATURE, DENGI(J) = 0 (J = 1, NPG)		
24	1-10	DENGI(1)	Heat transferred from first particle group at solidification temperature (cal)	E10.3
	11-20	DENGI(2)	Heat transferred from second particle group at solidification temperature (cal)	E10.3
	•	•	•	•
	•	•	•	•
		DENGI(NPG)	Heat transferred from NPG particle group at solidification temperature (cal)	E10.3
	NOTE:	IF PARTICLE PROPERTIES ALONG INITIAL ORTHOGONAL SURFACE ARE VARIABLE (NC = 1) CARDS 25-32 ARE INPUT (SEE FIG. 2)		
25.1	1-10	W(1,1)	Streamwise velocity of first particle group at r = 0 (cm/sec)	E10.3
	11-20	W(1,2)	Streamwise velocity of second particle group at r = 0 (cm/sec)	E10.3
	•	•	•	•
	•	•	•	•
		W(1,NPG)	Streamwise velocity of NPG particle group at r = 0 (cm/sec)	E10.3
26.1	1-10	V(1,1)	Normal velocity of first particle group at r = 0 (cm/sec); generally = 0	E10.3
	11-20	V(1,2)	Normal velocity of second particle group at r = 0 (cm/sec); generally = 0	E10.3
	•	•	•	•
	•	•	•	•
	•	•	•	•
		V(1,NPG)	Normal velocity of NPG particle group at r = 0 (cm/sec); generally = 0	E10.3

Card No.	Cols.	Fortran Name	Description	Format
27.1	1-10	TP(1, 1)	Temperature of first particle group at r = 0 (°K)	E10.3
	11-20	TP(1, 2)	Temperature of second particle group at r = 0 (°K)	E10.3
	•	•		
	•	•		
		TP(1,NPG)	Temperature of NPG particle group at r = 0 (°K)	E10.3
28.1	1-10	RHP(1, 1)	Particle cloud density of first particle group at r = 0 (g/cm^3)	E10.3
	11-20	RHP(1, 2)	Particle cloud density of second particle group at r = 0 (g/cm^3)	E10.3
	•	•		•
	•	•		•
		RHP(1, NPG)	Particle cloud density of NPG particle group at r = 0 (g/cm^3)	E10.3
29.1	1 -5	ICOND(1,1)	Index which indicates whether first particle group is at solidification temperature at r = 0 ICOND = 0; No = 1; Yes	I5
	6 -10	ICOND(1, 2)	Same as above for second particle group	I5
	•	•	•	
	•	•	•	
		ICOND(1,NPG)	Same as above for NPG particle group	I5
30.1	1-10	DENG(1, 1)	Heat transferred from first particle group at r = 0 at solidification temperature (cal) (See NOTE on page)	E10.3
	11-20	DENG(1, 2)	Same as above for second particle group	E10.3
	•	•	•	
	•	•	•	
		DENG(1,NPG)	Same as above for NPG particle group	E10.3
25.2 26.2 27.2 28.2 29.2 30.2			Same as 25.1, 26.1, 27.1, 28.1, 29.1, and 30.1, except for first streamtube • •	

Card No.	Cols.	Fortran Name	Description	Format
25.(NBL-1)			•	
26.(NBL-1)			•	
27.(NBL-1)				
28.(NBL-1)			Same as above except for last stream-tube containing particles	
29.(NBL-1)				
30.(NBL-1)				

NOTE: CARDS 31 AND 32 LOCATE THE INITIAL BOUNDARY OF EACH PARTICLE GROUP

Card No.	Cols.	Fortran Name	Description	Format
31	1-10	TRBDY(1)	Distance from axis, along initial orthogonal surface, to boundary of first particle group (cm) (see Fig. 2)	E10.3
	11-20	TRBDY(2)	Same as above for second particle group	E10.3
	•	•		•
	•	•		•
		TRBDY(NPG)	Same as above for NPG particle group	E10.3
32	1-10	DNDSP(1)	Distance from outer boundary of last streamtube containing particle to boundary of first particle group at initial orthogonal surface (cm) (see Fig. 2)	E10.3
	11-20	DNDSP(2)	Same as above for boundary of second particle group	E10.3
	•	•	•	•
	•	•	•	•
		DNDSP(NPG)	Same as above for boundary of NPG particle group	

NOTE: THE FOLLOWING CARDS CONTAIN THE REACTION MECHANISM AND RATE COEFFICIENTS. USE ONLY IF IKINE (CARD 5, COLS. 41-45) IS GREATER THAN 0. (SEE SECTION II.C.2 FOR REACTION AND RATE COEFFICIENT TYPES)

Card No.	Cols.	Fortran Name	Description	Format
33.1	1- 4	IZD(1)	Species A	A4
	7		+ sign	
	8-11	IZD(2)	Species B	A4
	14		+ sign	
	15-20		Blank or M	A4

Card No.	Cols.	Fortran Name	Description	Format
33.1	21		= sign	
	22-25	IZD(3)	Species C	A4
	28		+ sign (if needed)	
	29-32	IZD(4)	Species D	A4
	35		+ sign (if needed)	
	36-39	IZD(5)	Species E	A4
	49-50	IRR	Reaction type (1 to 10)	I2
	51	IRT	Rate coefficient type (1 to 8)	I1
	52-59	RC(1)	Pre-exponential factor, A (cm-molecule-sec units)	E8.2
	60-63	RC(2)	Temperature exponent, N	F4.1
	64-72	RC(3)	Activation energy, B (cal/mole)	F9.1
•				
•				
•				
33.IKINE			Same as above for IKINE reaction	

IV. PRELIMINARY RESULTS

This section gives the results of several sample calculations made with FULLNOZ and an analysis performed to determine heterogeneous electron-ion recombination rates in solid propellant nozzle flows.

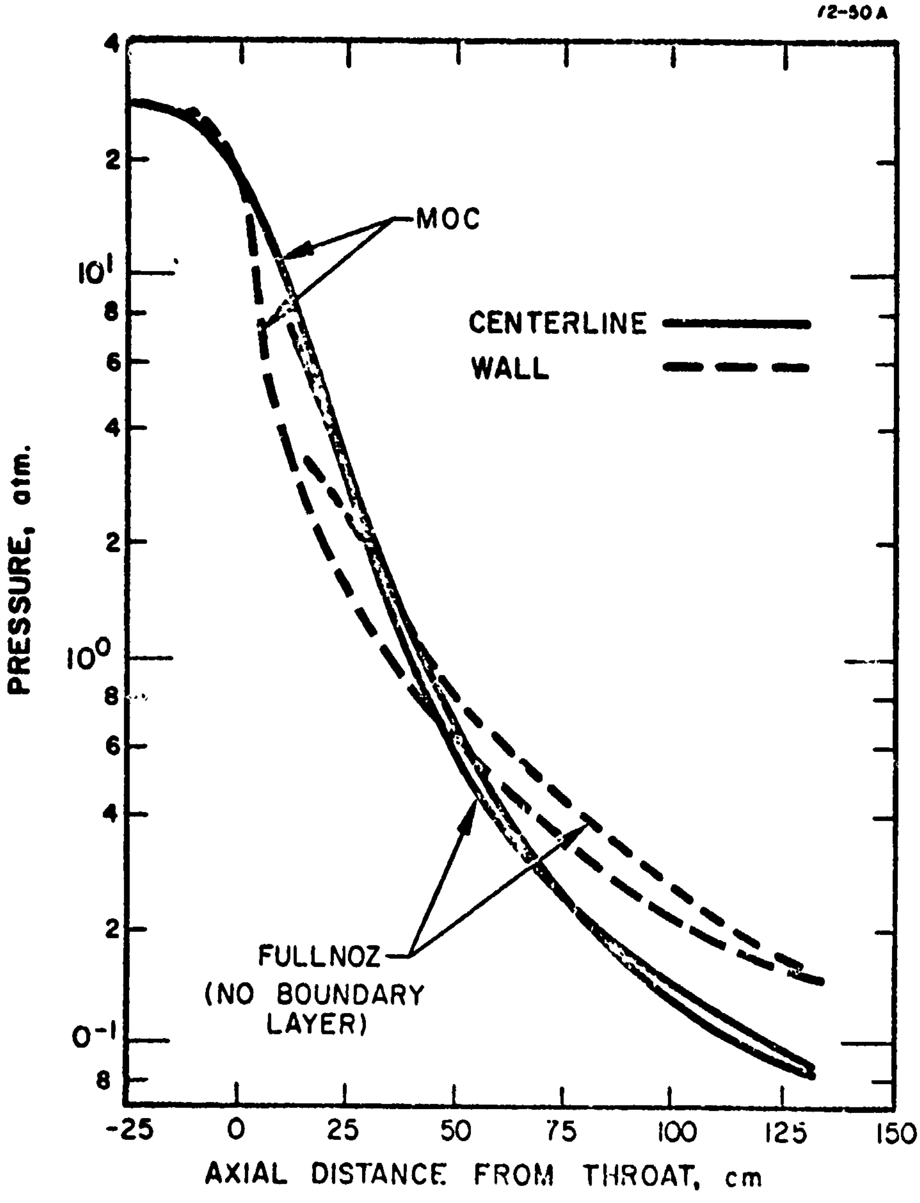

Figure 3. Comparison between Method of Characteristics (MOC) and FULLNOZ calculations of MM-Stage 2 nozzle pressure distributions.

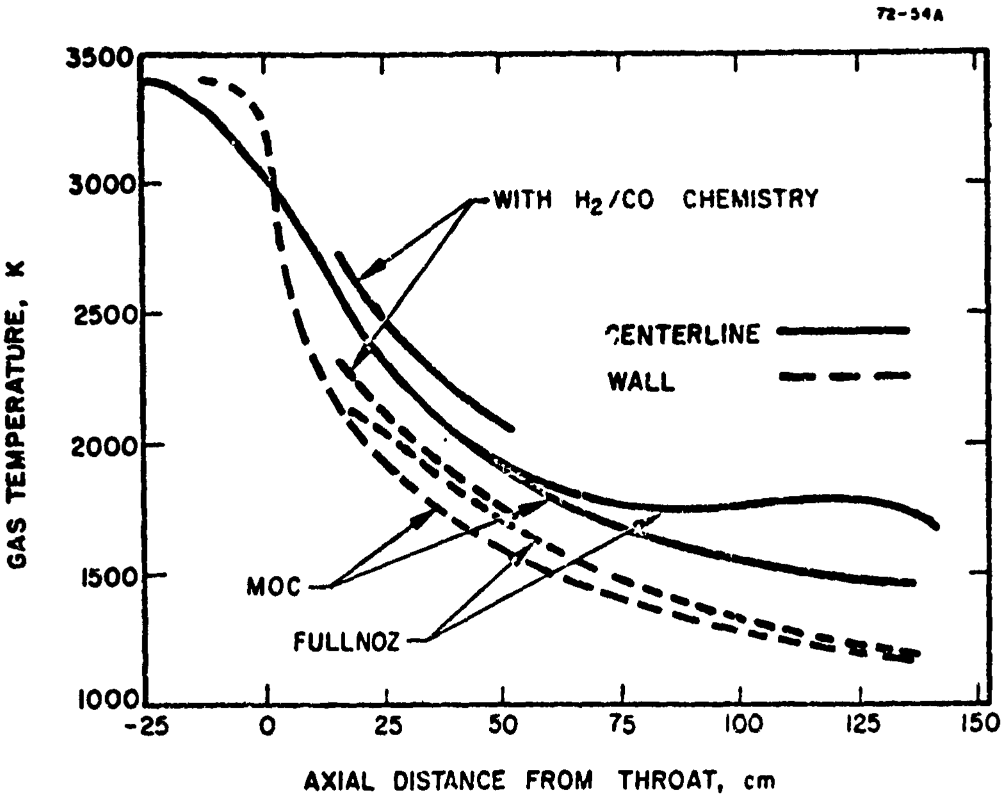

Figure 4. Comparison between Method of Characteristics (MOC) and FULLNOZ calculations of MM-Stage 2 nozzle gas temperature distributions.

A. Sample Calculations

Initial calculations with FULLNOZ were compared with calculations for the Minuteman, Stage 2 nozzle using a two-phase constant γ method of characteristics (MOC) code.[3] The purpose of this comparison was to check the numerical accuracy of the code. Input data for the calculations are given in Ref. 23.

Figures 3 and 4 show the pressure and temperature distributions along the centerline and wall (with no boundary layer effects). The pressure distributions compare very well, but FULLNOZ temperatures are slightly higher than those calculated via the MOC code. The centerline gas temperature calculated with FULLNOZ shows a more pronounced effect of gas/parti-

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23. Pergament, H.S. and Mikatarian, R.R., "Predictions of Minuteman Exhaust Plume Electrical Properties," AeroChem TP-281, July 1972.

cle interactions than was demonstrated by the MOC code. The results of a short run with FULLNOZ, including a set of 10 reactions involving H_2/CO chemistry, (see Ref. 23 for the reaction mechanism and rate coefficients) are also shown on Fig. 4.

Figures 5 and 6 show the influence of boundary layer heat transfer and shear stress on the temperature and velocity within the wall streamtube. The largest effects are observed for the cold (500°K) wall; when the wall is near the adiabatic wall temperature (≈ 3000°K) the results are similar to those for no boundary layer.

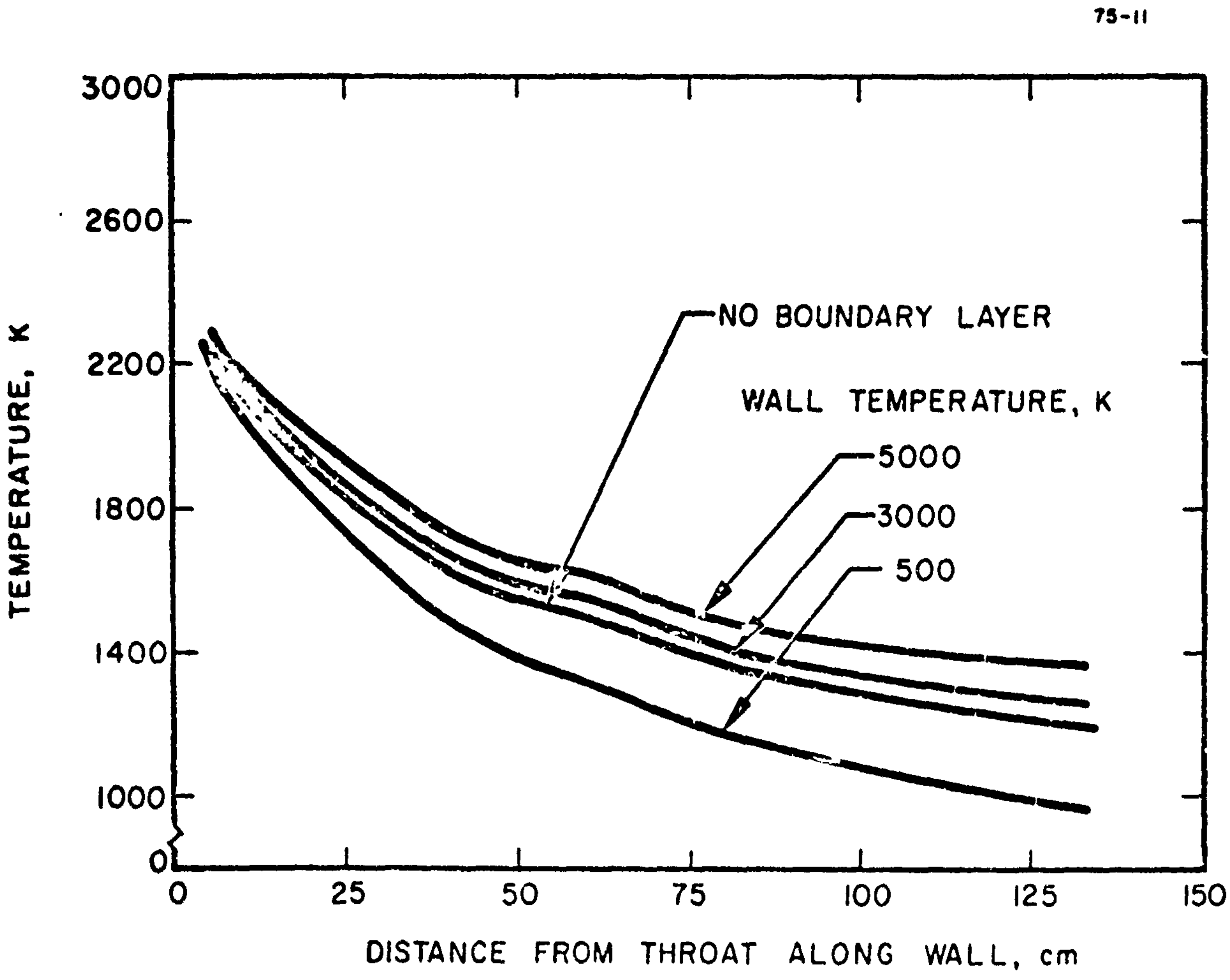

Figure 5. Influence of nozzle boundary layer on wall streamtube temperature.

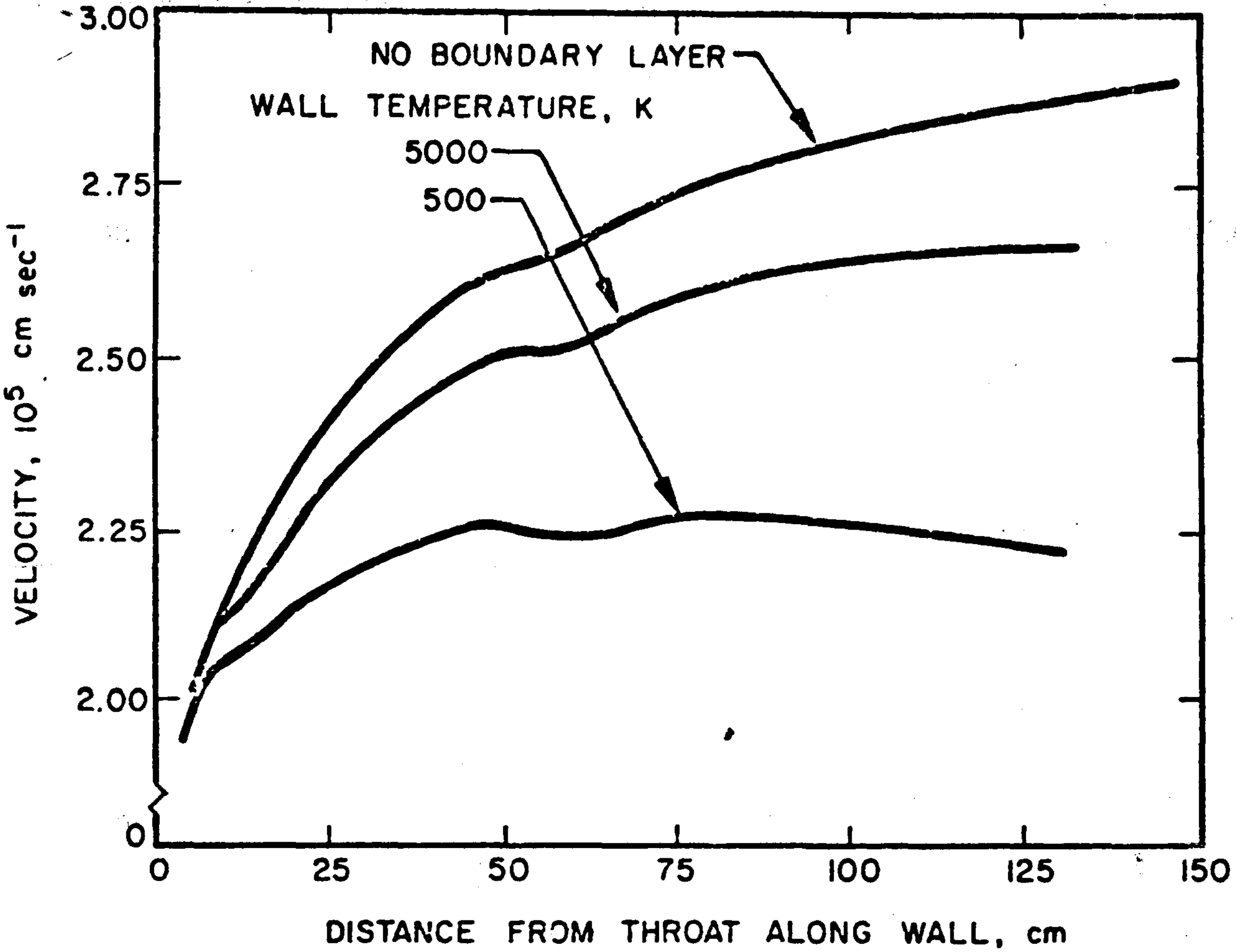

Figure 6. Influence of nozzle boundary layer on wall streamtube velocity.

Figure 7 shows the boundary layer velocity and temperature profile at the nozzle exit plane; Table 1 demonstrates that the boundary layer displacement and momentum thicknesses are much less than the wall streamtube thickness, i.e. all boundary layer effects are confined to the wall streamtube.

Figures 8 and 9 show the results of a parametric series of calculations in which the gas/particle drag and heat transfer coefficients were arbitrarily varied (via the factors FFF and FFG on Card 15) over their approximate ranges of uncertainty to test the effect on exit plane and particle properties. Figure 8 shows that varying FFF and FFG can have significant effects on gas temperatures and velocities. Figure 9 demonstrates that the 4μ diameter particles can be either at the solidification temperature or completely solidified, depending on the value chosen for FFG.

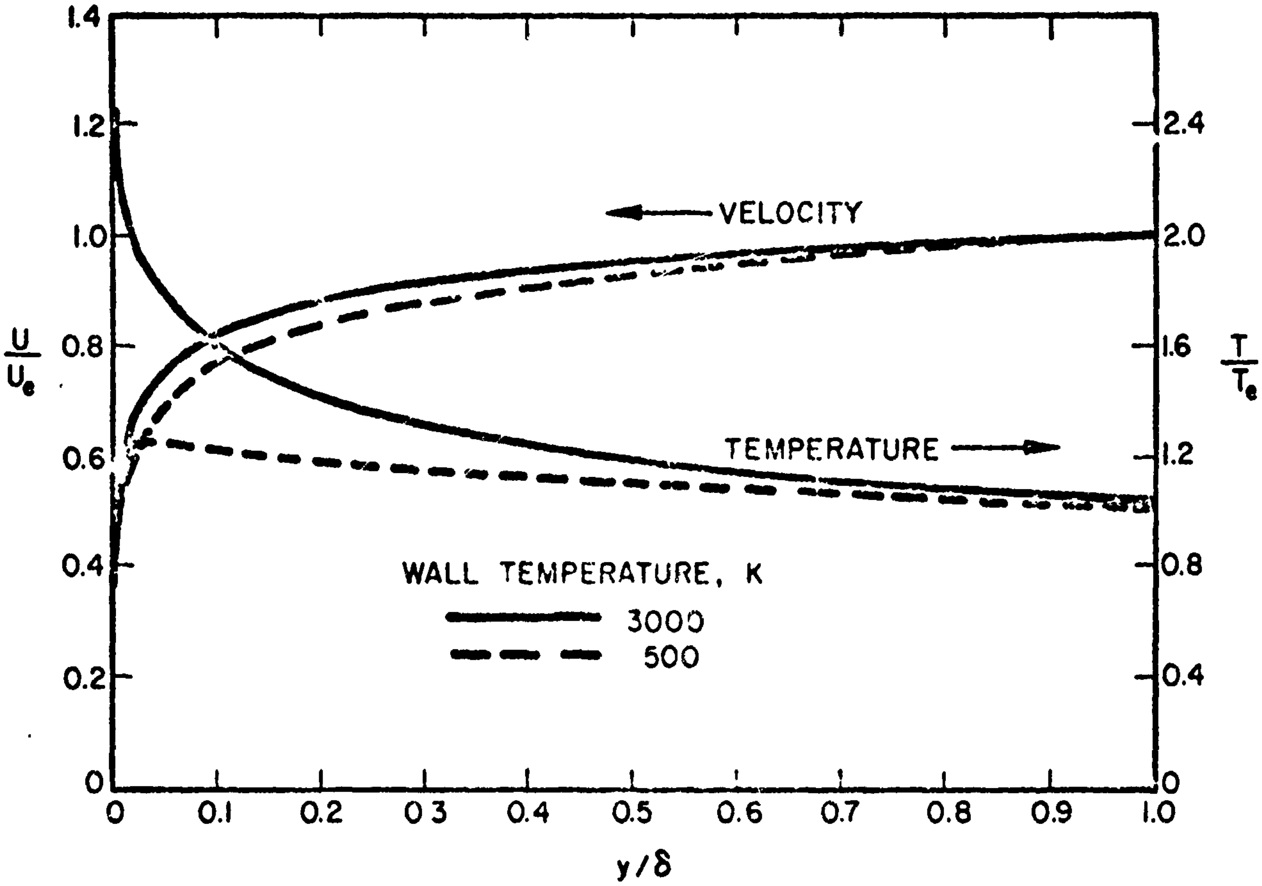

Figure 7. Boundary layer profiles at MM-Stage 2 nozzle exit plane.

TABLE 1

NOZZLE EXIT PLANE BOUNDARY LAYER PARAMETERS

MM-Stage 2 (Ref. 23)

Nozzle Exit Radius = 60.9 cm
Axial Distance From Throat = 134 cm

	Wall Temperature, °K	
	500	3000
Wall Streamtube Width, cm	1.24	1.38
Boundary Layer Thickness, cm	4.45	2.50
Displacement Thickness, cm	0.451	0.196
Momentum Thickness, cm	0.355	0.161

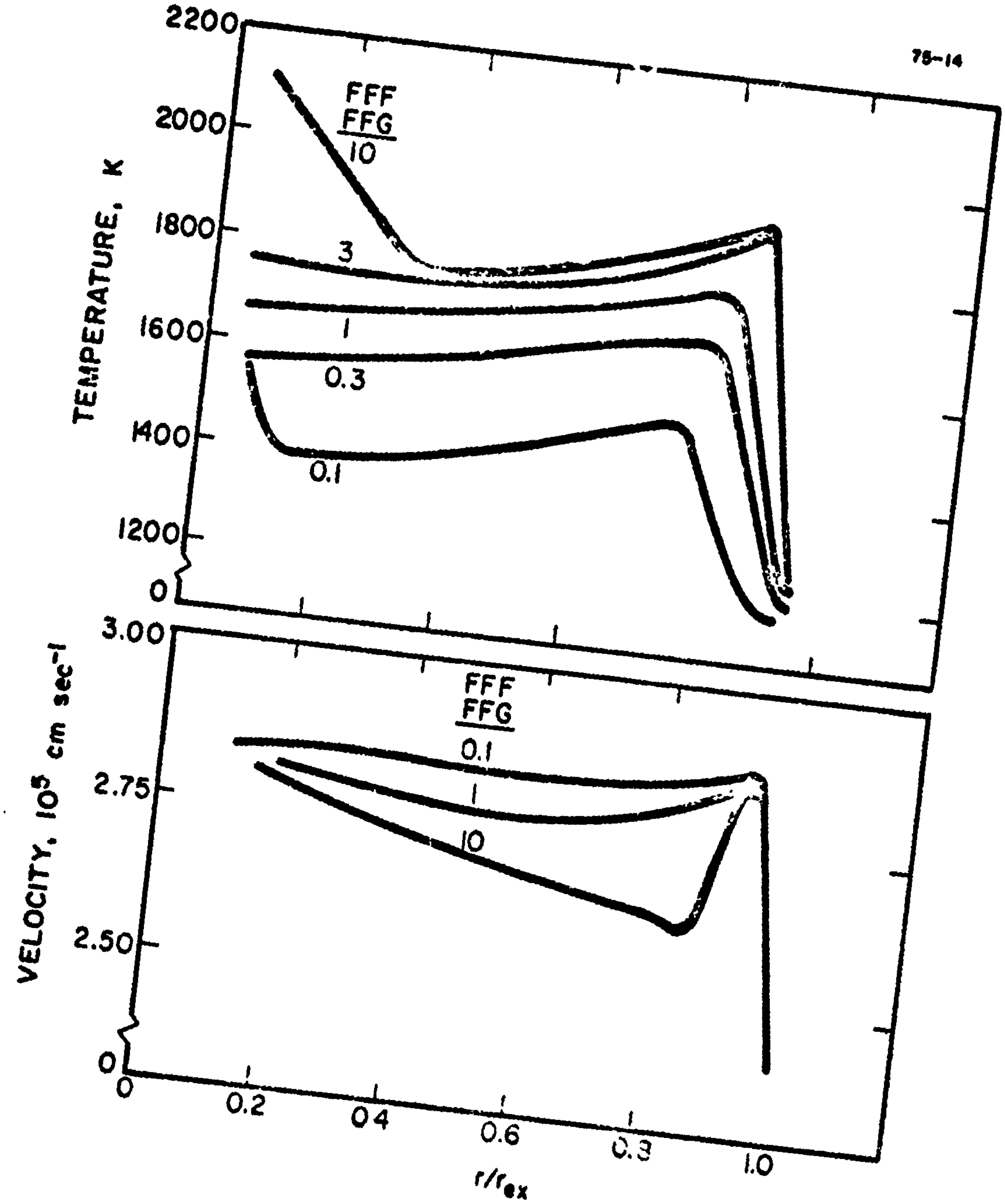

Figure 8. Influence of particle drag and heat transfer coefficients on exit plane gas properties.

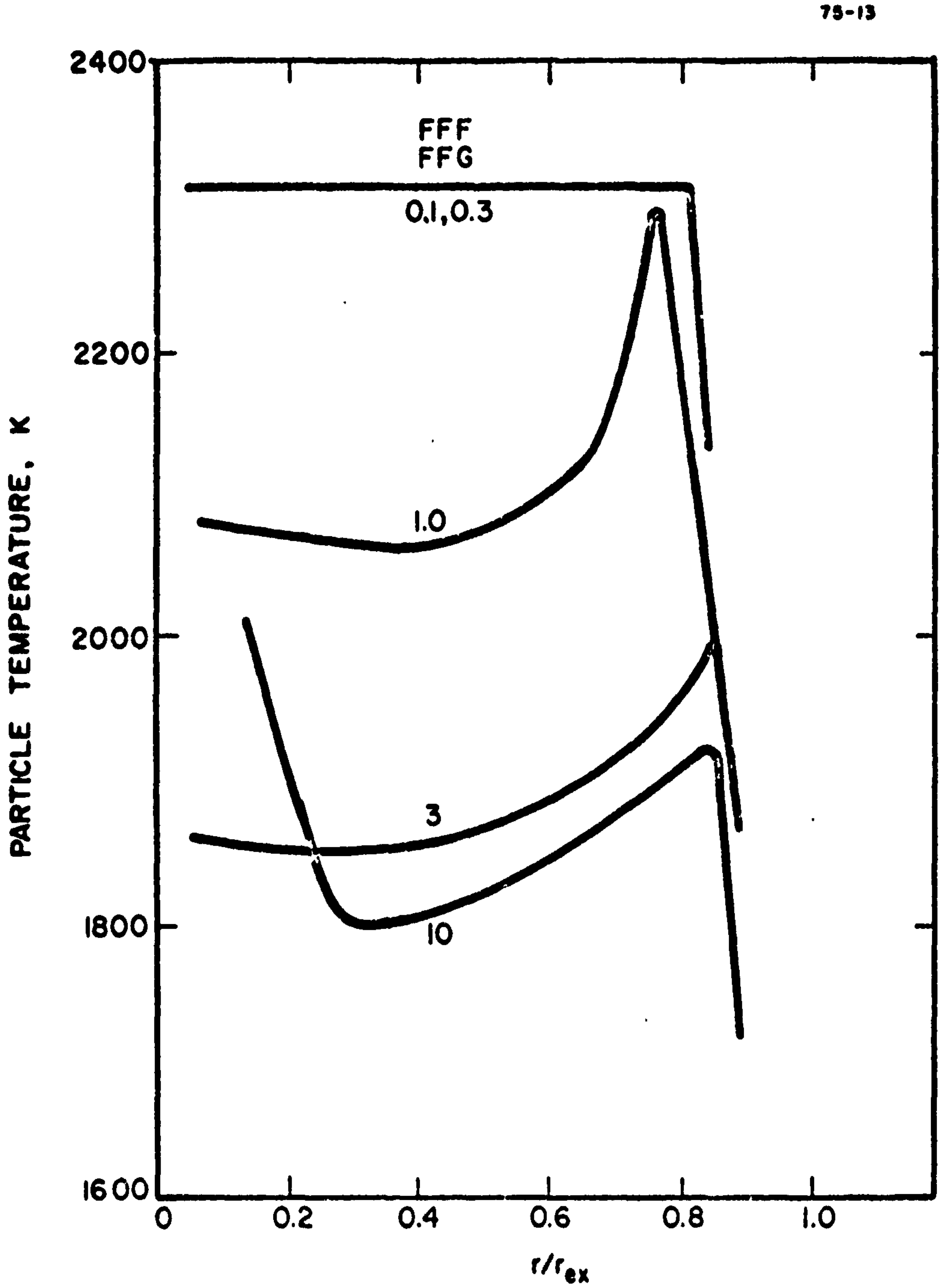

Figure 9. Influence of particle drag and heat transfer coefficients on exit plane particle temperatures.

B. Heterogeneous Electron Ion Recombination

One of the unanswered questions in determining nozzle exit plane electron mole fractions is the extent to which heterogeneous electron/ion recombination on the surface of solid particles can enhance homogeneous electron/ion recombination rates. Towards this end we have adopted a model developed at AeroChem by Calcote, Kurzius and Silla[24] in which a negatively charged particle (particles are negatively charged because the electrons will reach the surface more rapidly than positive ions) is neutralized by positive ions striking the surface. Thus, instead of requiring a three-body collision for recombination, only a two-body collision between the solid particle and positive ion need occur. To a first approximation the particle electron recombination rate can be equated to the rate at which positive ions strike the solid particles. However, if negative ions are present (for typical solid propellants mole fractions of Cl^- are from 2 to 3 orders of magnitude greater than electron mole fractions) the electron recombination rate will decrease, since some of the positive ions will react with negative ions rather than electrons.

The solid particle electron recombination coefficient, α_{p_e}, is defined from

$$\left(\frac{dn_e}{dt}\right)_p = -\alpha_{p_e} n_+ n_p \tag{71}$$

where n_e is electron density, t is time, n_+ is positive ion density and n_p is the particle number density. If particle diameters are small compared to the gas mean free path† (free molecular flow) and the electron densities are sufficiently high that the particles remain negatively charged, α_{p_e} is essentially the random ion flux to the particle (with a correction factor for negative ions),

$$\alpha_{p_e} = \pi r^2 \left(\frac{8kT}{\pi m_+}\right)^{1/2} \left[1 + \left(\frac{n_-}{n_e}\right)\left(\frac{m_e}{m_-}\right)^{1/2}\right]^{-1} \tag{72}$$

---

† If particle diameters are not small compared to the mean free path corrections will have to be made to the expression for α_{p_e}.

24. Calcote, H.F., Kurzius, S.C., and Silla, H., "Solid Propellant Flame Ionization and the Effect of Chemical Additives," Third Radar Attenuation Symposium, CPIA Publ. No. 46 (Applied Physics Lab., Johns Hopkins Univ., Silver Spring, 1964), pp. 17-40.

where r is the particle radius, k is the Boltzmann constant, T is the gas temperature, m_+, m_e, and m_- are the masses of positive ions, electrons and negative ions, respectively, and n_- is the negative ion density.

Equations (71) and (72) represent the formal method for incorporating heterogeneous electron/ion recombination into FULLNOZ. However, we must also account for the possibility that, at the high temperatures near the nozzle throat, the particle is emitting electrons via thermionic emission. Under these conditions a steady state is achieved by balancing the random current density to the particle (from the plasma) by thermionic emission. Equating these electron currents results in a "critical" electron density for which the net current flow to the particle is zero and an initially neutral particle will remain neutral. This critical electron density is defined by,

$$(n_e)_{cr} = B \left(\frac{T_p}{T_g} \right) T_g^{3/2} \exp\left[-11,605\, E_w/T_p \right] \tag{73}$$

where B is the thermionic emission constant, T_p is the particle temperature, T_g is the gas temperature and E_w is the effective work function of the particle in volts. Thus, heterogeneous electron/ion recombination is only of potential importance for $n_e > (n_e)_{cr}$.

The technique adopted to incorporate the above equations into FULLNOZ is:

1. At each integration step determine whether the local electron density is greater than the critical electron density. (During the initial stages of the expansion process, where particle temperatures are very high it is likely that $n_e < (n_e)_{cr}$.)

2. If $n_e < (n_e)_{cr}$ then electron/ion recombination will not be significant and Eqs. (71) and (72) will not be employed.

3. If $n_e > (n_e)_{cr}$ Eqs. (71) and (72) will be incorporated directly into the general kinetic scheme (with possible corrections to Eq. (72) due to non-free molecular flow effects).

The above procedure has not as yet been incorporated into the code.

V. REFERENCES

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2. Hoffman, R.J., English, W.D., Oeding, R.G., and Webber, W.T., "Plume Contamination Effects Prediction: The CONTAM Computer Program," Final Report, Air Force Rocket Propulsion Laboratory, AFRPL-TR-71-109, December 1971.

3. Nickerson, G.R. and Kliegel, J.R., "Axisymmetric Two-Phase Perfect Gas Performance Program," TRW Systems Report No. 02874-6006-R000, Vols. I and II, April 1967.

4. Penn, M.M. and Smith, S.D., "Supersonic Gas-Particle Flows, Including Reacting Chemistry," JANNAF 8th Plume Technology Meeting, Colorado Springs, CO, July 1974.

5. Boynton, F.P., "The MULTITUBE Supersonic Flow Computer Code," General Dynamics/Convair GDC-DBB 67-003, February 1967.

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APPENDIX A

SAMPLE INPUT DATA

AeroChem

FULLNOZ 1 14

```
CARD
NO

1     1
2 *** FULLY COUPLED NOZZLE FLOW PROGRAM - FULLNOZ  -  SAMPLE TEST CASE 9/75 ***
3    7200    2.000E+2    1.524E+2
4   1   1            0                  1            0
5   25   6   10   2   22   10   50   900   10
6 1000.  1  1
7      0.8     0.01    1.0E-4      1.0      0.1
811.64408562 E+1.18575287 E+1-.44865856E+0.36280951 E-1          CO 1
 2-.5981864 E-2-.28443584E+2.54410327 E+2                         CO 2

821.58741331E+1.13592404E+02 -.86056609E1 .21500497E+1            CO2 1
 2-.30567063E+1-.96439872E+2 .54321459E+2                         CO2 2

831.49683629 E+1-.23301268E-3.59667528 E-4-.51872545E-5           H 1
 2-.18467323E-4.50618655 E+2.33404654 E+2                         H 2

841.60596451 E+1.13412152 E+1-.16508752E+0.88760457 E-2           H2 1
 2.46616242 E-1-.17005029E+1.38443271 E+2                         H2 2

851.58818265 E+1.17395375 E+1-.32536218E+0.22313547 E-1           OH 1
 2.75177541 E-1.79212009 E+1.50938996 E+2                         OH 2

861.60311014 E+1.47049758 E+1-.96291245E+0.69087996 E-1           H2O 1
 2.60421152 E-1-.59593534E+2.51387265 E+2                         H2O 2
```

AeroChem

FULLNOZ 2 14

```
CARD
NO
871.62643469 E+1.19328092 E+1-.46158274E+0.37083135 E-1           N2 1
 2.91852768 E-2-.19242408E+1.52824774 E+2                         N2 2

881.50617760 E+1-.11736656E+0.39405358 E-1-.20531577E-2           O 1
 2.18127099 E-1.58115304 E+2.44728172 E+2                         O 2

891.72417589 E+1.12398122 E+1-.18448469E+0.10507580 E-1           O2 1
 2-.59604067E-1-.24219968E+1.57031740 E+2                         O2 2

8101.48485464 E+1.32006164 E+0-.28545471E+0.83218696 E-1          K 1
 2.43725018 E-2.19867370 E+2.44106314 E+2                         K 2

91CO        139.  E-6    300.    0.75    1.4    1.4    28.
 2CO2       139.  E-6    300.    0.75    1.4    1.4    44.
 3H         83.5  E-6    300.    0.75    1.4    1.4    1.
 4H2        83.5  E-6    300     0.75    1.4    1.4    2.
 5OH       125.5  E-6    300.    0.75    1.4    1.4    17.
 6H2O      125.5  E-6    300.    0.75    1.4    1.4    18.
 7N2        160.  E-6    300     0.75    1.4    1.4    28.
 8O         166.  E-6    300.    0.75    1.4    1.4    16.
 9O2        189.  E-6    300.    0.75    1.4    1.4    32.
10K        129.7  E-6    300.    0.75    1.4    1.4    39.1
```

~NOTE~ CARD 10 OMITTED FOR ITURB=0(CARD 4, COL. 56-60)

FORTRAN Coding Form

FULLNOZ — 3 14

CARD NO								
11	12.668	0.0	0.0					
12.1.1	12.663	0.6053	0.01804	8.500	2761.	1.534E+5		
.2	3.0E-1	6.0E-2	6.3E-4	2.4E-2	2.6E-3	1.9E-1	4.2E-1	7.8E-5
3	5.6E-5	1.1E-6						
12.2.1	12.646	1.2110	0.03607	8.473	2759.	1.534E+5		
.2	NOTE – CARDS 12.2.2 TO 12.24.2 ARE IDENTICAL TO CARD 12.1.2							
.3	CARDS 12.2.3 TO 12.24.3 ARE IDENTICAL TO CARD 12.1.3							
12.3.1	12.619	1.8158	0.05411	8.443	2758.	1.534E+5		
.2	SEE NOTE							
.3								
12.4.1	12.581	2.4199	0.07214	8.400	2757.	1.536E+5		
2	SEE NOTE							
3								
12.5.1	12.532	3.0238	0.09018	8.343	2755.	1.538E+5		
2	SEE NOTE							
3								
12.6.1	12.472	3.6262	0.10821	8.273	2751.	1.541E+5		
.2	SEE NOTE							
3								

FORTRAN Coding Form

FULLNOZ — 4 14

CARD NO						
12.7.1	12.401	4.2274	0.12625	8.193	2745.	1.545E+5
	SEE NOTE					
.3						
12.8.1	12.319	4.8278	0.14428	8.103	2739.	1.550E+5
2	SEE NOTE					
3						
12.9.1	12.227	5.4260	0.16232	8.003	2732.	1.556E+5
.2	SEE NOTE					
3						
12.10.1	12.123	6.0225	0.18035	7.895	2726.	1.562E+5
2	SEE NOTE					
3						
12.11.1	12.009	6.6176	0.19839	7.775	2719.	1.570E+5
2	SEE NOTE					
3						
12.12.1	11.885	7.2100	0.21642	7.643	2712.	1.578E+5
2	SEE NOTE					
3						

AeroChem FORTRAN Coding Form

FULLNOZ 5 14

CARD NO							
12131	11.749	7.8000	0.23446	7.498	2708.	1.588E+5
.2	SEE NOTE					
.3						
12141	11.603	8.3880	0.25249	7.328	2700.	1.600E+5
2	SEE NOTE					
3						
12151	11.447	8.9728	0.27053	7.138	2688.	1.613E+5
.2	SEE NOTE					
.3						
12161	11.280	9.5546	0.28856	6.935	2671.	1.629E+5
.2	SEE NOTE					
3						
12171	11.102	10.1340	0.30660	6.715	2648.	1.647E+5
.2	SEE NOTE					
3						
12181	10.914	10.7090	0.32463	6.480	2624.	1.670E+5
.2	SEE NOTE					
.3						

AeroChem FORTRAN Coding Form

FULLNOZ 6 14

CARD NO						
12191	10.716	11.2810	0.34267	6.225	2594.	1.676E+5
2	SEE NOTE					
3						
12201	10.507	11.8500	0.36070	5.950	2563.	1.725E+5
.2	SEE NOTE					
.3						
12211	10.289	12.4150	0.37874	5.680	2550.	1.761E+5
2	SEE NOTE					
3						
12221	10.060	12.9750	0.39677	5.390	2533.	1.798E+5
2	SEE NOTE					
3						
12231	9.8205	[illegible]	0.41481	5.065	2502.	1.847E+5
.2	SEE NOTE					
3						
12241	9.5715	14.0840	0.43284	4.602	2401.	1.904E+5
2	SEE NOTE					
3						

FORTRAN Coding Form

FULLNOZ 7 14

CARD NO		
13.1	12.668	0.0
.2	1.0E+10	0.0
14.1	9.5715	14.084
.2	9.957	14.275
.3	10.312	14.503
.4	11.582	15.215
.5	12.852	15.850
.6	14.122	16.434
.7	16.662	17.729
.8	19.202	18.999
.9	21.742	20.218
.10	26.822	22.606
.11	31.902	24.994
.12	36.982	27.305
.13	44.602	30.683
.14	52.222	33.985
.15	59.842	37.084
.16	73.914	42.062
.17	87.173	46.838
.18	99.035	50.749
.19	111.150	54.508
.20	123.490	58.039
.21	134.420	60.909
.22	152.400	65.634

FORTRAN Coding Form

FULLNOZ 8 14

CARD NO							
15.1	1.0	1.0	0.339	0.323	255.	102.	
16.1	4.0			2320.			
17.1	4	1					
18.1	19	19	19	19			
19.1	1.0E-4	2.0E-4	3.0E-4	4.0E-4			

NC (CARD 17, COL. 10) = 1, THEREFORE CARD NO 25 IS NEXT

CARD NO				
25.1	0.147 E+6	0.139 E+6	0.131 E+6	0.124 E+6
26.1	-0.276 E+3	-0.559 E+3	-0.768 E+3	-0.101 E+4
27.1	2813.	2893.	2913.	2973.
28.1	0.279 E-4	0.143 E-3	0.182 E-3	0.554 E-4
29.1	0.	0.	0.	0.
30.1	0.0	0.0	0.0	0.0
25.2	0.147 E+6	0.139 E+6	0.132 E+6	0.125 E+6
26.2	-0.292 E+3	-0.592 E+3	-0.814 E+3	-0.107 E+4
27.2	2813.	2893.	2913.	2973.
28.2	0.279 E-4	0.143 E-3	0.182 E-3	0.554 E-4

29.2 / 30.2 — NOTE: CARDS 29.2 TO 29.18 ARE IDENTICAL TO 29.1; CARDS 30.2 TO 30.18 ARE IDENTICAL TO 30.1

CARD NO				
25.3	0.148 E+6	0.139 E+6	0.132 E+6	0.125 E+6
26.3	0.310 E+3	-0.625 E+3	-0.864 E+3	-0.114 E+4

FORTRAN Coding Form

FULLNOZ — 9 14

FORTRAN STATEMENT

CARD NO								
27.3	2813.		2893.		2913.		2973.	
28.3	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.3								
30.3								
25.4	0.148	E+6	0.139	E+6	0.132	E+6	0.125	E+6
26.4	-0.331	E+3	-0.671	E+3	-0.922	E+3	-0.121	E+4
27.4	2813.		2893.		2913.		2973.	
28.4	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.4								
30.4								
25.5	0.148	E+6	0.140	E+6	0.132	E+6	0.125	E+6
26.5	-0.356	E+3	-0.719	E+3	-0.988	E+3	-0.130	E+4
27.5	2813.		2893.		2913.		2973.	
28.5	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.5								
30.5								
25.6	0.148	E+6	0.140	E+6	0.132	E+6	0.125	E+6
26.6	-0.382	E+3	-0.775	E+3	-0.106	E+4	-0.140	E+4
27.6	2813.		2893.		2913.		2973.	
28.6	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.6								

FORTRAN Coding Form

FULLNOZ — 10 14

FORTRAN STATEMENT

CARD NO								
30.6								
25.7	0.149	E+6	0.140	E+6	0.132	E+6	0.125	E+6
26.7	-0.414	E+3	-0.839	E+3	-0.115	E+4	-0.151	E+4
27.7	2803.		2883.		2913.		2963.	
28.7	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.7								
30.7								
25.8	0.149	E+6	0.141	E+6	0.133	E+6	0.126	E+6
26.8	-0.451	E+3	0.915	E+3	-0.126	E+4	-0.165	E+4
27.8	2803.		2883.		2913.		2963.	
28.8	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.8								
30.8								
25								
25.9	0.150	E+6	0.141	E+6	0.133	E+6	0.126	E+6
26.9	-0.497	E+3	-0.101	E+4	-0.138	E+4	-0.182	E+4
27.9	2803.		2883.		2913.		2963.	
28.9	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.9								
30.9								

FORTRAN Coding Form

FULLNOZ — 11 14

CARD NO								
25.10	0·150	E+6	0·142	E+6	0·134	E+6	0·126	E+6
26.10	-0·552	E+3	-0·112	E+4	-0·154	E+4	-0·202	E+4
27.10	2793·		2873·		2903·		2933·	
28.10	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.10								
30.10								
25.11	0·151	E+6	0·143	E+6	0·134	E+6	0 [illegible]7	E+6
26.11	-0·621	E+3	0·126	E+4	-0·173	E+4	-[illegible]27	E+[illegible]
27.11	2793·		2873·		2903·		[illegible]	
28.11	0·279	E-4	0·143	E-3	0·182	[illegible]	[illegible]·554	E-4
29.11								
30.11								
25.12	0·152	E+6	0·143	E+6	0·135	E+6	0·127	E+6
26.12	-0·709	E+3	-0·144	E+4	-0·198	E+4	-0·260	E+4
27.12	2783·		2873·		2893·		2943·	
28.12	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.12								
30.12								
25.13	0·153	E+6	0·144	E+6	0·136	E+6	0·128	E+6
26.13	-0·828	E+3	-0·168	E+4	-0·231	E+4	-0·303	E+4
27.13	2783·		2873·		2893·		2943·	

FORTRAN Coding Form

FULLNOZ — 12 14

CARD NO								
28.13	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.13								
30.13								
25.14	0·154	E+6	0·145	E+6	0·136	E+6	0·128	E+6
26.14	-0·993	E+3	-0·201	E+4	-0·277	E+4	-0·363	E+4
27.14	2763·		2853·		2883·		2933·	
28.14	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.14								
30.14								
25.15	0·155	E+6	0·146	E+6	0·137	E+6	0·129	E+6
26.15	-0·124	E+4	-0·252	E+4	-0·346	E+4	-0·454	E+4
27.15	2763·		2853·		2883·		2933·	
28.15	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.15								
30.15								
25.16	0·156	E+6	0·147	E+6	0·138	E+6	0·130	E+6
26.16	-0·166	E+4	-0·336	E+4	-0·461	E+4	-0·606	E+4
27.16	2743·		2823·		2873·		2923·	
28.16	0·279	E-4	0·143	E-3	0·182	E-3	0·554	E-4
29.16								
30.16								

FORTRAN Coding Form

FULLNOZ 13 14

CARD NO								
25.17	0.158	E+6	0.149	E+6	0.139	E+6	0.131	E+6
26.17	-0.218	E+4	-0.504	E+4	-0.692	E+4	-0.909	E+4
27.17	2763.		2823.		2873.		2923.	
28.17	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.17								
30.17								
25.18	0.159	E+6	0.150	E+6	0.140	E+6	0.132	E+6
26.18	-0.497	E+4	-0.101	E+5	-0.138	E+5	-0.182	E+5
27.18	2713.		2793.		2853.		2903.	
28.18	0.279	E-4	0.143	E-3	0.182	E-3	0.554	E-4
29.18								
30.18								
31		10.7		10.7		10.7		10.7
32		0.0		0.0		0.0		0.0

FORTRAN Coding Form

FULLNOZ 14 14

CARD NO									
33.1	O	+O	+M	=O2	+M	21	1 0E-29	.0	
.2	O	+H	+M	=OH	+M	22	1 0E-29	1.0	
.3	H	+H	+M	=H2	+M	22	5 0E-29	1.0	
.4	H	+OH	+M	=H2O	+M	22	2 0E-28	1.0	
.5	CO	+O	+M	=CO2	+M	26	1.0E-29	1.0	-2500
.6	OH	+OH		=OH2	+O	15	1 0E-11		-780.
.7	OH	+H2		=H2O	+H	15	3.6E-11		-5200.
.8	O	+H2		=OH	+H	15	2.9E-11		-9460.
.9	H	+O2		=OH	+O	15	3.7E-10		-16800.
.10	CO	+OH		=CO2	+H	15	9 0E-13		-1080

APPENDIX B

SAMPLE OUTPUT

FULLY COUPLED NOZZLE FLOW PROGRAM

AEROCHEM RESEARCH LABORATORIES, INC.
PRINCETON, NEW JERSEY 08540

*** FULLY COUPLED NOZZLE FLOW PROGRAM - FULLNOZ - SAMPLE TEST CASE 9/75 ***

NO. OF DATA SETS 1

NSECT= 7200 DALSS= 2.000E+02 ALPHAS= 1.524E+02 ALHUDD=0. IPUN =0 NNTB =0

NMAX	NW	NP	IP	ITYPE	IKIND	MMAX	NMAX	NUS	IPO	NITER	IDIFF	LPLANE
25	6	10	0	1	1	2	22	10	-0	50	0	900
IPTOL	IPCM	ISHOCK	IBUGSH	IIO	ICSM	ITAPES	IAINE	IPANT	IKI	ITUMB	IPTO	
-0	-0	-0	0	-0	-0	-0	10	1	-0	0	-0	

NETAP	HO	HLIM
1.015E+00	4.182E+07	1.967E+00

ALPHAN	EPSLON	TOL	DELTA	ATOL	FSTEP	GRAD	FRAC	FRACTN
.800	.010	.100E-03	1.0	.140	-0.00	-0.00	-0.00	-0.00

IDENT	MUO	TO	OMEGA	PR	SC	WM
CO	1.590E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	2.800E+01
CO2	1.590E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	4.400E+01
H	8.350E-05	3.000E+02	7.500E-01	1.400E+00	1.400E+00	1.000E+00
H2	8.350E-05	3.000E+02	7.500E-01	1.400E+00	1.400E+00	2.000E+00
OH	1.255E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	1.700E+01
H2O	1.255E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	1.800E+01
N2	1.600E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	2.800E+01
O	1.660E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	1.600E+01
O2	1.690E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	3.200E+01
K	1.297E-04	3.000E+02	7.500E-01	1.400E+00	1.400E+00	4.000E+01

K	X	W	PHI	P	T	H
1	1.267E+01	0.	0.			
2	1.266E+01	6.053E-01	1.604E-02	8.500E+00	2.761E+03	1.534E+05
3	1.265E+01	1.211E+00	3.607E-02	8.473E+00	2.759E+03	1.534E+05
4	1.262E+01	1.816E+00	5.411E-02	8.443E+00	2.758E+03	1.535E+05
5	1.258E+01	2.428E+00	7.214E-02	8.400E+00	2.757E+03	1.537E+05
6	1.253E+01	3.028E+00	9.018E-02	8.345E+00	2.755E+03	1.539E+05
7	1.247E+01	3.626E+00	1.082E-01	8.273E+00	2.751E+03	1.541E+05
8	1.240E+01	4.227E+00	1.263E-01	8.193E+00	2.745E+03	1.546E+05
9	1.232E+01	4.828E+00	1.443E-01	8.103E+00	2.739E+03	1.551E+05
10	1.223E+01	5.426E+00	1.623E-01	8.003E+00	2.732E+03	1.556E+05
11	1.212E+01	6.023E+00	1.804E-01	7.895E+00	2.726E+03	1.563E+05
12	1.201E+01	6.618E+00	1.984E-01	7.775E+00	2.719E+03	1.571E+05
13	1.189E+01	7.210E+00	2.164E-01	7.643E+00	2.712E+03	1.579E+05
14	1.175E+01	7.800E+00	2.345E-01	7.498E+00	2.708E+03	1.588E+05
15	1.160E+01	8.388E+00	2.525E-01	7.328E+00	2.700E+03	1.600E+05
16	1.145E+01	8.973E+00	2.705E-01	7.138E+00	2.688E+03	1.614E+05
17	1.128E+01	9.555E+00	2.886E-01	6.935E+00	2.671E+03	1.630E+05
18	1.110E+01	1.013E+01	3.066E-01	6.715E+00	2.648E+03	1.648E+05
19	1.091E+01	1.071E+01	3.246E-01	6.480E+00	2.624E+03	1.671E+05
20	1.072E+01	1.128E+01	3.427E-01	6.225E+00	2.594E+03	1.676E+05
21	1.051E+01	1.185E+01	3.607E-01	5.950E+00	2.563E+03	1.726E+05
22	1.029E+01	1.242E+01	3.787E-01	5.680E+00	2.550E+03	1.762E+05
23	1.006E+01	1.298E+01	3.968E-01	5.390E+00	2.533E+03	1.798E+05
24	9.821E+00	1.353E+01	4.148E-01	5.065E+00	2.502E+03	1.847E+05
25	9.572E+00	1.408E+01	4.328E-01	4.602E+00	2.401E+03	1.908E+05

I	XP	WP	PHIP	PP	SP
1	1.267E+01	0.	0.	-0.	-0.
2	1.000E+10	-0.	-0.	-0.	-0.

N	XO	WO	PHIO	PO	SO
1	9.572E+00	1.408E+01	-0.	-0.	-0.
2	9.957E+00	1.428E+01	-0.	-0.	-0.
3	1.031E+01	1.450E+01	-0.	-0.	-0.
4	1.150E+01	1.522E+01	-0.	-0.	-0.
5	1.285E+01	1.585E+01	-0.	-0.	-0.
6	1.412E+01	1.643E+01	-0.	-0.	-0.
7	1.660E+01	1.773E+01	-0.	-0.	-0.
8	1.920E+01	1.900E+01	-0.	-0.	-0.
9	2.174E+01	2.022E+01	-0.	-0.	-0.
10	2.662E+01	2.201E+01	-0.	-0.	-0.
11	3.190E+01	2.494E+01	-0.	-0.	-0.
12	3.698E+01	2.731E+01	-0.	-0.	-0.
13	4.400E+01	3.068E+01	-0.	-0.	-0.
14	5.222E+01	3.390E+01	-0.	-0.	-0.
15	5.984E+01	3.708E+01	-0.	-0.	-0.
16	7.391E+01	4.208E+01	-0.	-0.	-0.
17	8.717E+01	4.684E+01	-0.	-0.	-0.
18	9.903E+01	5.075E+01	-0.	-0.	-0.
19	1.112E+02	5.451E+01	-0.	-0.	-0.
20	1.235E+02	5.804E+01	-0.	-0.	-0.
21	1.344E+02	6.091E+01	-0.	-0.	-0.
22	1.524E+02	6.563E+01	-0.	-0.	-0.

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-1      X= 0.               MA= 0.             PHINO 0.

  2     X= 1.2005E+01       M= 6.0530E-01      PHI= 1.0040E-02  T= 2.7610E+03   P= 8.5000E+00   U= 1.5340E+05
        MA=  .1277E+01      DELTS=  .6053E+00 MW=  .1047E+03    HT=  .3880E+03  TAMB 0.         UB 0.
        PT=  .1714E+02      RHO=  .7443E-03  SX= 0.             SUMDOT=  .1316E+03

        SPECIE  CO          C=  .3000E+00    X=  .2125E+00    NDOT= 0.
        SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    NDOT= 0.
        SPECIE  H           C=  .6300E-03    X=  .1249E-01    NDOT= 0.
        SPECIE  H2          C=  .2400E-01    X=  .2380E+00    NDOT= 0.
        SPECIE  OH          C=  .2600E-02    X=  .3033E-02    NDOT= 0.
        SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    NDOT= 0.
        SPECIE  N2          C=  .4200E+00    X=  .2975E+00    NDOT= 0.
        SPECIE  O           C=  .7800E-04    X=  .9668E-04    NDOT= 0.
        SPECIE  O2          C=  .5600E-04    X=  .3471E-04    NDOT= 0.
        SPECIE  N           C=  .1100E-05    X=  .5454E-06    NDOT= 0.

  3     X= 1.2040E+01       M= 1.2110E+00      PHI= 3.0070E-02  T= 2.7590E+03   P= 8.0730E+00   U= 1.5342E+05
        MA=  .1278E+01      DELTS=  .6050E+00 MW=  .1057E+03    HT=  .3871E+03  TAMB 0.         UB 0.
        PT=  .1710E+02      RHO=  .7424E-03  SX= 0.             SUMDOT=  .5253E+03

        SPECIE  CO          C=  .3000E+00    X=  .2125E+00    NDOT= 0.
        SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    NDOT= 0.
        SPECIE  H           C=  .6300E-03    X=  .1249E-01    NDOT= 0.
        SPECIE  H2          C=  .2400E-01    X=  .2380E+00    NDOT= 0.
        SPECIE  OH          C=  .2600E-02    X=  .3033E-02    NDOT= 0.
        SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    NDOT= 0.
        SPECIE  N2          C=  .4200E+00    X=  .2975E+00    NDOT= 0.
        SPECIE  O           C=  .7800E-04    X=  .9668E-04    NDOT= 0.
        SPECIE  O2          C=  .5600E-04    X=  .3471E-04    NDOT= 0.
        SPECIE  N           C=  .1100E-05    X=  .5454E-06    NDOT= 0.

  4     X= 1.2019E+01       M= 1.8150E+00      PHI= 5.0110E-02  T= 2.7580E+03   P= 8.6050E+00   U= 1.5508E+05
        MA=  .1279E+01      DELTS=  .6054E+00 MW=  .1052E+03    HT=  .3806E+03  TAMB 0.         UB 0.
        PT=  .1705E+02      RHO=  .7401E-03  SX= 0.             SUMDOT=  .1179E+00

        SPECIE  CO          C=  .3000E+00    X=  .2125E+00    NDOT= 0.
        SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    NDOT= 0.
        SPECIE  H           C=  .6300E-03    X=  .1249E-01    NDOT= 0.
        SPECIE  H2          C=  .2400E-01    X=  .2380E+00    NDOT= 0.
        SPECIE  OH          C=  .2600E-02    X=  .3033E-02    NDOT= 0.
        SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    NDOT= 0.
        SPECIE  N2          C=  .4200E+00    X=  .2975E+00    NDOT= 0.
        SPECIE  O           C=  .7800E-04    X=  .9668E-04    NDOT= 0.
        SPECIE  O2          C=  .5600E-04    X=  .3471E-04    NDOT= 0.
        SPECIE  N           C=  .1100E-05    X=  .5454E-06    NDOT= 0.

  5     X= 1.2581E+01       M= 2.4199E+00      PHI= 7.2140E-02  T= 2.7570E+03   P= 8.6000E+00   U= 1.5365E+05
        MA=  .1280E+01      DELTS=  .6053E+00 MW=  .1047E+03    HT=  .3869E+03  TAMB 0.         UB 0.
        PT=  .1698E+02      RHO=  .7388E-03  SX= 0.             SUMDOT=  .2091E+00

        SPECIE  CO          C=  .3000E+00    X=  .2125E+00    NDOT= 0.
        SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    NDOT= 0.
        SPECIE  H           C=  .6300E-03    X=  .1249E-01    NDOT= 0.
        SPECIE  H2          C=  .2400E-01    X=  .2380E+00    NDOT= 0.
        SPECIE  OH          C=  .2600E-02    X=  .3033E-02    NDOT= 0.
        SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    NDOT= 0.
        SPECIE  N2          C=  .4200E+00    X=  .2975E+00    NDOT= 0.
        SPECIE  O           C=  .7800E-04    X=  .9668E-04    NDOT= 0.
        SPECIE  O2          C=  .5600E-04    X=  .3471E-04    NDOT= 0.
        SPECIE  N           C=  .1100E-05    X=  .5454E-06    NDOT= 0.

  6     X= 1.2532E+01       M= 3.0238E+00      PHI= 9.0180E-02  T= 2.7550E+03   P= 8.5430E+00   U= 1.5387E+05
        MA=  .1283E+01      DELTS=  .6059E+00 MW=  .1037E+03    HT=  .3867E+03  TAMB 0.         UB 0.
        PT=  .1690E+02      RHO=  .7321E-03  SX= 0.             SUMDOT=  .3250E+00

        SPECIE  CO          C=  .3000E+00    X=  .2125E+00    NDOT= 0.
        SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    NDOT= 0.
        SPECIE  H           C=  .6300E-03    X=  .1249E-01    NDOT= 0.
        SPECIE  H2          C=  .2400E-01    X=  .2380E+00    NDOT= 0.
        SPECIE  OH          C=  .2600E-02    X=  .3033E-02    NDOT= 0.
        SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    NDOT= 0.
        SPECIE  N2          C=  .4200E+00    X=  .2975E+00    NDOT= 0.
        SPECIE  O           C=  .7800E-04    X=  .9668E-04    NDOT= 0.
        SPECIE  O2          C=  .5600E-04    X=  .3471E-04    NDOT= 0.
        SPECIE  N           C=  .1100E-05    X=  .5454E-06    NDOT= 0.

  7     X= 1.2472E+01       M= 3.6262E+00      PHI= 1.0821E-01  T= 2.7510E+03   P= 8.2730E+00   U= 1.5413E+05
        MA=  .1288E+01      DELTS=  .6054E+00 MW=  .1018E+03    HT=  .3857E+03  TAMB 0.         UB 0.
        PT=  .1680E+02      RHO=  .7270E-03  SX= 0.             SUMDOT=  .4675E+00

        SPECIE  CO          C=  .3000E+00    X=  .2125E+00    NDOT= 0.
        SPECIE  CO2         C=  .6000E-01    X=  .2704E-01    NDOT= 0.
        SPECIE  H           C=  .6300E-03    X=  .1249E-01    NDOT= 0.
        SPECIE  H2          C=  .2400E-01    X=  .2380E+00    NDOT= 0.
        SPECIE  OH          C=  .2600E-02    X=  .3033E-02    NDOT= 0.
        SPECIE  H2O         C=  .1900E+00    X=  .2093E+00    NDOT= 0.
        SPECIE  N2          C=  .4200E+00    X=  .2975E+00    NDOT= 0.
        SPECIE  O           C=  .7800E-04    X=  .9668E-04    NDOT= 0.
        SPECIE  O2          C=  .5600E-04    X=  .3471E-04    NDOT= 0.
        SPECIE  N           C=  .1100E-05    X=  .5454E-06    NDOT= 0.
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8    X= 1.2401E+01     M= 6.2270E+00     PHI= 1.2625E-01  T= 2.7050E+03    P= 8.1930E+00     U= 1.5456E+05
     MAS=  .1291E+01   DELTA=  .6050E+00 H=  .9860E+02    HT=  .3882E+03   TAMB 0.           Q= 0.
     HIS=  .1670E+02   RHOE=  .7210E-03  SX= 0.           SUMDOTS=  .6341E+04

     SPECIE  CO       C=  .3000E+00    X=  .2125E+00    WDOT= 0.
     SPECIE  CO2      C=  .6000E-01    X=  .2704E-01    WDOT= 0.
     SPECIE  H        C=  .6300E-03    X=  .1249E-01    WDOT= 0.
     SPECIE  H2       C=  .2400E-01    X=  .2380E+00    WDOT= 0.
     SPECIE  OH       C=  .2600E-02    X=  .3033E-02    WDOT= 0.
     SPECIE  H2O      C=  .1900E+00    X=  .2093E+00    WDOT= 0.
     SPECIE  N2       C=  .4200E+00    X=  .2975E+00    WDOT= 0.
     SPECIE  O        C=  .7800E-04    X=  .9668E-04    WDOT= 0.
     SPECIE  O2       C=  .5600E-04    X=  .3471E-04    WDOT= 0.
     SPECIE  N        C=  .1100E-05    X=  .5454E-06    WDOT= 0.

9    X= 1.2519E+01     M= 6.4278E+00     PHI= 1.4420E-01  T= 2.7390E+03    P= 8.1030E+00     U= 1.5505E+05
     MAS=  .1290E+01   DELTA=  .6060E+00 H=  .9550E+02    HT=  .3830E+03   TAMB 0.           Q= 0.
     HIS=  .1659E+02   RHOE=  .7152E-03  SX= 0.           SUMDOTS=  .8253E+04

     SPECIE  CO       C=  .3000E+00    X=  .2125E+00    WDOT= 0.
     SPECIE  CO2      C=  .6000E-01    X=  .2704E-01    WDOT= 0.
     SPECIE  H        C=  .6300E-03    X=  .1249E-01    WDOT= 0.
     SPECIE  H2       C=  .2400E-01    X=  .2380E+00    WDOT= 0.
     SPECIE  OH       C=  .2600E-02    X=  .3033E-02    WDOT= 0.
     SPECIE  H2O      C=  .1900E+00    X=  .2093E+00    WDOT= 0.
     SPECIE  N2       C=  .4200E+00    X=  .2975E+00    WDOT= 0.
     SPECIE  O        C=  .7800E-04    X=  .9668E-04    WDOT= 0.
     SPECIE  O2       C=  .5600E-04    X=  .3471E-04    WDOT= 0.
     SPECIE  N        C=  .1100E-05    X=  .5454E-06    WDOT= 0.

10   X= 1.2227E+01     M= 5.8260E+00     PHI= 1.6232E-01  T= 2.7320E+03    P= 8.0030E+00     U= 1.5561E+05
     MAS=  .1302E+01   DELTA=  .6052E+00 H=  .9202E+02    HT=  .3815E+03   TAMB 0.           Q= 0.
     HIS=  .1647E+02   RHOE=  .7062E-03  SX= 0.           SUMDOTS=  .1040E+05

     SPECIE  CO       C=  .3000E+00    X=  .2125E+00    WDOT= 0.
     SPECIE  CO2      C=  .6000E-01    X=  .2704E-01    WDOT= 0.
     SPECIE  H        C=  .6300E-03    X=  .1249E-01    WDOT= 0.
     SPECIE  H2       C=  .2400E-01    X=  .2380E+00    WDOT= 0.
     SPECIE  OH       C=  .2600E-02    X=  .3033E-02    WDOT= 0.
     SPECIE  H2O      C=  .1900E+00    X=  .2093E+00    WDOT= 0.
     SPECIE  N2       C=  .4200E+00    X=  .2975E+00    WDOT= 0.
     SPECIE  O        C=  .7800E-04    X=  .9668E-04    WDOT= 0.
     SPECIE  O2       C=  .5600E-04    X=  .3471E-04    WDOT= 0.
     SPECIE  N        C=  .1100E-05    X=  .5454E-06    WDOT= 0.

11   X= 1.2123E+01     M= 6.0225E+00     PHI= 1.8035E-01  T= 2.7260E+03    P= 7.8950E+00     U= 1.5629E+05
     MAS=  .1309E+01   DELTA=  .6055E+00 H=  .8899E+02    HT=  .3810E+03   TAMB 0.           Q= 0.
     HIS=  .1634E+02   RHOE=  .7002E-03  SX= 0.           SUMDOTS=  .1278E+05

     SPECIE  CO       C=  .3000E+00    X=  .2125E+00    WDOT= 0.
     SPECIE  CO2      C=  .6000E-01    X=  .2704E-01    WDOT= 0.
     SPECIE  H        C=  .6300E-03    X=  .1249E-01    WDOT= 0.
     SPECIE  H2       C=  .2400E-01    X=  .2380E+00    WDOT= 0.
     SPECIE  OH       C=  .2600E-02    X=  .3033E-02    WDOT= 0.
     SPECIE  H2O      C=  .1900E+00    X=  .2093E+00    WDOT= 0.
     SPECIE  N2       C=  .4200E+00    X=  .2975E+00    WDOT= 0.
     SPECIE  O        C=  .7800E-04    X=  .9668E-04    WDOT= 0.
     SPECIE  O2       C=  .5600E-04    X=  .3471E-04    WDOT= 0.
     SPECIE  N        C=  .1100E-05    X=  .5454E-06    WDOT= 0.

12   X= 1.2009E+01     M= 6.6176E+00     PHI= 1.9834E-01  T= 2.7190E+03    P= 7.7750E+00     U= 1.5707E+05
     MAS=  .1318E+01   DELTA=  .6059E+00 H=  .8545E+02    HT=  .3804E+03   TAMB 0.           Q= 0.
     HIS=  .1619E+02   RHOE=  .6913E-03  SX= 0.           SUMDOTS=  .1540E+05

     SPECIE  CO       C=  .3000E+00    X=  .2125E+00    WDOT= 0.
     SPECIE  CO2      C=  .6000E-01    X=  .2704E-01    WDOT= 0.
     SPECIE  H        C=  .6300E-03    X=  .1249E-01    WDOT= 0.
     SPECIE  H2       C=  .2400E-01    X=  .2380E+00    WDOT= 0.
     SPECIE  OH       C=  .2600E-02    X=  .3033E-02    WDOT= 0.
     SPECIE  H2O      C=  .1900E+00    X=  .2093E+00    WDOT= 0.
     SPECIE  N2       C=  .4200E+00    X=  .2975E+00    WDOT= 0.
     SPECIE  O        C=  .7800E-04    X=  .9668E-04    WDOT= 0.
     SPECIE  O2       C=  .5600E-04    X=  .3471E-04    WDOT= 0.
     SPECIE  N        C=  .1100E-05    X=  .5454E-06    WDOT= 0.

13   X= 1.1885E+01     M= 7.2100E+00     PHI= 2.1042E-01  T= 2.7120E+03    P= 7.6650E+00     U= 1.5789E+05
     MAS=  .1326E+01   DELTA=  .6052E+00 H=  .8192E+02    HT=  .3800E+03   TAMB 0.           Q= 0.
     HIS=  .1606E+02   RHOE=  .6813E-03  SX= 0.           SUMDOTS=  .1823E+05

     SPECIE  CO       C=  .3000E+00    X=  .2125E+00    WDOT= 0.
     SPECIE  CO2      C=  .6000E-01    X=  .2704E-01    WDOT= 0.
     SPECIE  H        C=  .6300E-03    X=  .1249E-01    WDOT= 0.
     SPECIE  H2       C=  .2400E-01    X=  .2380E+00    WDOT= 0.
     SPECIE  OH       C=  .2600E-02    X=  .3033E-02    WDOT= 0.
     SPECIE  H2O      C=  .1900E+00    X=  .2093E+00    WDOT= 0.
     SPECIE  N2       C=  .4200E+00    X=  .2975E+00    WDOT= 0.
     SPECIE  O        C=  .7800E-04    X=  .9668E-04    WDOT= 0.
     SPECIE  O2       C=  .5600E-04    X=  .3471E-04    WDOT= 0.
     SPECIE  N        C=  .1100E-05    X=  .5454E-06    WDOT= 0.
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14   X= 1.1749E+01     M= 7.0000E+00     PHI= 2.3000E-01  T= 2.7000E+03    P= 7.0900E+00     U= 1.5000E+05
     MA=  .1335E+01    DELTX=  .6059E+00 MW=  .7990E+02    HT=  .3814E+03   TAU= 0.           W= 0.
     PI=  .1503E+02    RHO=  .6094E-03  S= 0.            SUMDOT=  .2126E+05

     SPECIE  CO        C=  .3000E+00     X=  .2125E+00     MDOT= 0.
     SPECIE  CO2       C=  .6000E-01     X=  .2704E-01     MDOT= 0.
     SPECIE  H         C=  .6300E-03     X=  .1249E-01     MDOT= 0.
     SPECIE  H2        C=  .2400E-01     X=  .2300E+00     MDOT= 0.
     SPECIE  OH        C=  .2600E-02     X=  .3033E-02     MDOT= 0.
     SPECIE  H2O       C=  .1900E+00     X=  .2093E+00     MDOT= 0.
     SPECIE  N2        C=  .4200E+00     X=  .2975E+00     MDOT= 0.
     SPECIE  O         C=  .7800E-04     X=  .9666E-04     MDOT= 0.
     SPECIE  O2        C=  .5600E-04     X=  .3471E-04     MDOT= 0.
     SPECIE  A         C=  .1100E-05     X=  .5454E-06     MDOT= 0.

15   X= 1.1603E+01     M= 8.3000E+00     PHI= 2.5200E-01  T= 2.7000E+03    P= 7.1200E+00     U= 1.6001E+05
     MA=  .1347E+01    DELTX=  .6059E+00 MW=  .7500E+02    HT=  .3820E+03   TAU= 0.           W= 0.
     PI=  .1502E+02    RHO=  .6501E-03  S= 0.            SUMDOT=  .2050E+05

     SPECIE  CO        C=  .3000E+00     X=  .2125E+00     MDOT= 0.
     SPECIE  CO2       C=  .6000E-01     X=  .2704E-01     MDOT= 0.
     SPECIE  H         C=  .6300E-03     X=  .1249E-01     MDOT= 0.
     SPECIE  H2        C=  .2400E-01     X=  .2300E+00     MDOT= 0.
     SPECIE  OH        C=  .2600E-02     X=  .3033E-02     MDOT= 0.
     SPECIE  H2O       C=  .1900E+00     X=  .2093E+00     MDOT= 0.
     SPECIE  N2        C=  .4200E+00     X=  .2975E+00     MDOT= 0.
     SPECIE  O         C=  .7800E-04     X=  .9666E-04     MDOT= 0.
     SPECIE  O2        C=  .5600E-04     X=  .3471E-04     MDOT= 0.
     SPECIE  A         C=  .1100E-05     X=  .5454E-06     MDOT= 0.

16   X= 1.1447E+01     M= 8.9720E+00     PHI= 2.7053E-01  T= 2.6800E+03    P= 7.1300E+00     U= 1.6137E+05
     MA=  .1361E+01    DELTX=  .6053E+00 MW=  .6942E+02    HT=  .3012E+03   TAU= 0.           W= 0.
     PI=  .1539E+02    RHO=  .6420E-03  S= 0.            SUMDOT=  .2793E+05

     SPECIE  CO        C=  .3000E+00     X=  .2125E+00     MDOT= 0.
     SPECIE  CO2       C=  .6000E-01     X=  .2704E-01     MDOT= 0.
     SPECIE  H         C=  .6300E-03     X=  .1249E-01     MDOT= 0.
     SPECIE  H2        C=  .2400E-01     X=  .2300E+00     MDOT= 0.
     SPECIE  OH        C=  .2600E-02     X=  .3033E-02     MDOT= 0.
     SPECIE  H2O       C=  .1900E+00     X=  .2093E+00     MDOT= 0.
     SPECIE  N2        C=  .4200E+00     X=  .2975E+00     MDOT= 0.
     SPECIE  O         C=  .7800E-04     X=  .9666E-04     MDOT= 0.
     SPECIE  O2        C=  .5600E-04     X=  .3471E-04     MDOT= 0.
     SPECIE  A         C=  .1100E-05     X=  .5454E-06     MDOT= 0.

17   X= 1.1290E+01     M= 9.5540E+00     PHI= 2.8050E-01  T= 2.6710E+03    P= 6.9350E+00     U= 1.6290E+05
     MA=  .1379E+01    DELTX=  .6053E+00 MW=  .6124E+02    HT=  .3700E+03   TAU= 0.           W= 0.
     PI=  .1518E+02    RHO=  .6277E-03  S= 0.            SUMDOT=  .3152E+05

     SPECIE  CO        C=  .3000E+00     X=  .2125E+00     MDOT= 0.
     SPECIE  CO2       C=  .6000E-01     X=  .2704E-01     MDOT= 0.
     SPECIE  H         C=  .6300E-03     X=  .1249E-01     MDOT= 0.
     SPECIE  H2        C=  .2400E-01     X=  .2300E+00     MDOT= 0.
     SPECIE  OH        C=  .2600E-02     X=  .3033E-02     MDOT= 0.
     SPECIE  H2O       C=  .1900E+00     X=  .2093E+00     MDOT= 0.
     SPECIE  N2        C=  .4200E+00     X=  .2975E+00     MDOT= 0.
     SPECIE  O         C=  .7800E-04     X=  .9666E-04     MDOT= 0.
     SPECIE  O2        C=  .5600E-04     X=  .3471E-04     MDOT= 0.
     SPECIE  A         C=  .1100E-05     X=  .5454E-06     MDOT= 0.

18   X= 1.1102E+01     M= 1.0134E+01     PHI= 3.0000E-01  T= 2.6400E+03    P= 6.7150E+00     U= 1.6470E+05
     MA=  .1400E+01    DELTX=  .6001E+00 MW=  .4971E+02    HT=  .3743E+03   TAU= 0.           W= 0.
     PI=  .1493E+02    RHO=  .6131E-03  S= 0.            SUMDOT=  .3531E+05

     SPECIE  CO        C=  .3000E+00     X=  .2125E+00     MDOT= 0.
     SPECIE  CO2       C=  .6000E-01     X=  .2704E-01     MDOT= 0.
     SPECIE  H         C=  .6300E-03     X=  .1249E-01     MDOT= 0.
     SPECIE  H2        C=  .2400E-01     X=  .2300E+00     MDOT= 0.
     SPECIE  OH        C=  .2600E-02     X=  .3033E-02     MDOT= 0.
     SPECIE  H2O       C=  .1900E+00     X=  .2093E+00     MDOT= 0.
     SPECIE  N2        C=  .4200E+00     X=  .2975E+00     MDOT= 0.
     SPECIE  O         C=  .7800E-04     X=  .9666E-04     MDOT= 0.
     SPECIE  O2        C=  .5600E-04     X=  .3471E-04     MDOT= 0.
     SPECIE  A         C=  .1100E-05     X=  .5454E-06     MDOT= 0.

19   X= 1.0918E+01     M= 1.0704E+01     PHI= 3.2005E-01  T= 2.6240E+03    P= 6.6800E+00     U= 1.6705E+05
     MA=  .1425E+01    DELTX=  .6050E+00 MW=  .3767E+02    HT=  .3713E+03   TAU= 0.           W= 0.
     PI=  .1470E+02    RHO=  .5970E-03  S= 0.            SUMDOT=  .3020E+05

     SPECIE  CO        C=  .3000E+00     X=  .2125E+00     MDOT= 0.
     SPECIE  CO2       C=  .6000E-01     X=  .2704E-01     MDOT= 0.
     SPECIE  H         C=  .6300E-03     X=  .1249E-01     MDOT= 0.
     SPECIE  H2        C=  .2400E-01     X=  .2300E+00     MDOT= 0.
     SPECIE  OH        C=  .2600E-02     X=  .3033E-02     MDOT= 0.
     SPECIE  H2O       C=  .1900E+00     X=  .2093E+00     MDOT= 0.
     SPECIE  N2        C=  .4200E+00     X=  .2975E+00     MDOT= 0.
     SPECIE  O         C=  .7800E-04     X=  .9666E-04     MDOT= 0.
     SPECIE  O2        C=  .5600E-04     X=  .3471E-04     MDOT= 0.
     SPECIE  A         C=  .1100E-05     X=  .5454E-06     MDOT= 0.
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20   X= 1.0710E+01    M= 1.1201E+01    PHI= 3.6207E-01  T= 2.5900E+03   P= 6.2050E+00    U= 1.6763E+05
     MA=  .1438E+01   DELTA=  .0053E+00 H=  .2267E+02   HT=  .3506E+03  TANG 0.          Q= 0.
     PT=  .1627E+02   RHO=  .5002E-03  S= 0.            SUMDOTS=  .0338E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00   ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01   ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01   ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2300E+00   ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02   ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00   ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00   ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04   ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04   ADOT= 0.
     SPECIE  N         C=  .1100E-05    X=  .5454E-06   ADOT= 0.

21   X= 1.0507E+01    M= 1.1050E+01    PHI= 3.0070E-01  T= 2.5650E+03   P= 5.9500E+00    U= 1.7250E+05
     MA=  .1480E+01   DELTA=  .0062E+00 H=  .7201E+01   HT=  .3632E+03  TANG 0.          Q= 0.
     PT=  .1620E+02   RHO=  .5012E-03  S= 0.            SUMDOTS=  .4790E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00   ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01   ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01   ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2300E+00   ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02   ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00   ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00   ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04   ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04   ADOT= 0.
     SPECIE  N         C=  .1100E-05    X=  .5454E-06   ADOT= 0.

22   X= 1.0289E+01    M= 1.2815E+01    PHI= 3.7874E-01  T= 2.5500E+03   P= 5.6000E+00    U= 1.7616E+05
     MA=  .1527E+01   DELTA=  .0058E+00 H=  .7283E+00   HT=  .3710E+03  TANG 0.          Q= 0.
     PT=  .1593E+02   RHO=  .5305E-03  S= 0.            SUMDOTS= .5197E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00   ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01   ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01   ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2300E+00   ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02   ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00   ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00   ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04   ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04   ADOT= 0.
     SPECIE  N         C=  .1100E-05    X=  .5454E-06   ADOT= 0.

23   X= 1.0080E+01    M= 1.2975E+01    PHI= 3.9677E-01  T= 2.5330E+03   P= 5.3000E+00    U= 1.7901E+05
     MA=  .1559E+01   DELTA=  .0050E+00 H= -.7725E+01   HT=  .3780E+03  TANG 0.          Q= 0.
     PT=  .1360E+02   RHO=  .5144E-03  S= 0.            SUMDOTS=  .5663E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00   ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01   ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01   ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2300E+00   ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02   ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00   ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00   ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04   ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04   ADOT= 0.
     SPECIE  N         C=  .1100E-05    X=  .5454E-06   ADOT= 0.

24   X= 9.8205E+00    M= 1.3532E+01    PHI= 4.1401E-01  T= 2.5020E+03   P= 5.0050E+00    U= 1.8472E+05
     MA=  .1611E+01   DELTA=  .0063E+00 H= -.2311E+02   HT=  .3849E+03  TANG 0.          Q= 0.
     PT=  .1331E+02   RHO=  .4894E-03  S= 0.            SUMDOTS=  .6100E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00   ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01   ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01   ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2300E+00   ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02   ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00   ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00   ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04   ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04   ADOT= 0.
     SPECIE  N         C=  .1100E-05    X=  .5454E-06   ADOT= 0.

25   X= 9.5715E+00    M= 1.4184E+01    PHI= 4.3284E-01  T= 2.4410E+03   P= 4.8020E+00    U= 1.9043E+05
     MA=  .1694E+01   DELTA=  .0058E+00 H= -.7243E+02   HT=  .3908E+03  TANG 0.          Q= 0.
     PT=  .1290E+02   RHO=  .4834E-03  S= 0.            SUMDOTS=  .6563E+05

     SPECIE  CO        C=  .3000E+00    X=  .2125E+00   ADOT= 0.
     SPECIE  CO2       C=  .6000E-01    X=  .2704E-01   ADOT= 0.
     SPECIE  H         C=  .6300E-03    X=  .1249E-01   ADOT= 0.
     SPECIE  H2        C=  .2400E-01    X=  .2300E+00   ADOT= 0.
     SPECIE  OH        C=  .2600E-02    X=  .3033E-02   ADOT= 0.
     SPECIE  H2O       C=  .1900E+00    X=  .2093E+00   ADOT= 0.
     SPECIE  N2        C=  .4200E+00    X=  .2975E+00   ADOT= 0.
     SPECIE  O         C=  .7800E-04    X=  .9668E-04   ADOT= 0.
     SPECIE  O2        C=  .5600E-04    X=  .3471E-04   ADOT= 0.
     SPECIE  N         C=  .1100E-05    X=  .5454E-06   ADOT= 0.
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[illegible]
FFF     = .1E+01,
FFG     = .1E+01,
WNE     = -0.0,
TL      = .330E+00,
CS      = .323E+00,
TPG     = .253E+04,
RHOS    = .4E+01,
DT      = .100E+05,
HTRAN   = .295E+05,
SIG     = -0.0,
EP      = -0.0,
NPG     = 4,
NC      = 1,
NNS     = 10,
RP      = .1E-03, .2E-03, .3E-03, .4E-03, 0.0, 0.0, 0.0, 0.0,
RI      = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
VI      = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
TPI     = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
RHPI    = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
$END
STREAMLINE NO.      1
DOWNSTREAM VELOCITY     1.470E+05   1.390E+05   1.310E+05   1.240E+05
CROSS-STREAM VELOCITY  -2.760E+02  -5.590E+02  -7.600E+02  -1.010E+03
PARTICLE TEMPERATURE    2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-06
STREAMLINE NO.      2
DOWNSTREAM VELOCITY     1.470E+05   1.390E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY  -2.920E+02  -5.920E+02  -8.140E+02  -1.070E+03
PARTICLE TEMPERATURE    2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      3
DOWNSTREAM VELOCITY     1.480E+05   1.390E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY  -3.100E+02  -6.290E+02  -8.640E+02  -1.140E+03
PARTICLE TEMPERATURE    2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      4
DOWNSTREAM VELOCITY     1.480E+05   1.390E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY  -3.310E+02  -6.710E+02  -9.220E+02  -1.210E+03
PARTICLE TEMPERATURE    2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      5
DOWNSTREAM VELOCITY     1.480E+05   1.400E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY  -3.550E+02  -7.190E+02  -9.880E+02  -1.300E+03
PARTICLE TEMPERATURE    2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      6
DOWNSTREAM VELOCITY     1.480E+05   1.400E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY  -3.820E+02  -7.750E+02  -1.060E+03  -1.400E+03
PARTICLE TEMPERATURE    2.813E+03   2.893E+03   2.913E+03   2.973E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      7
DOWNSTREAM VELOCITY     1.490E+05   1.400E+05   1.320E+05   1.250E+05
CROSS-STREAM VELOCITY  -4.140E+02  -8.390E+02  -1.150E+03  -1.510E+03
PARTICLE TEMPERATURE    2.803E+03   2.883E+03   2.913E+03   2.963E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      8
DOWNSTREAM VELOCITY     1.490E+05   1.410E+05   1.330E+05   1.260E+05
CROSS-STREAM VELOCITY  -4.510E+02  -9.150E+02  -1.260E+03  -1.650E+03
PARTICLE TEMPERATURE    2.803E+03   2.883E+03   2.913E+03   2.963E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.      9
DOWNSTREAM VELOCITY     1.500E+05   1.410E+05   1.330E+05   1.260E+05
CROSS-STREAM VELOCITY  -4.970E+02  -1.010E+03  -1.380E+03  -1.820E+03
PARTICLE TEMPERATURE    2.803E+03   2.883E+03   2.913E+03   2.963E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.     10
DOWNSTREAM VELOCITY     1.500E+05   1.420E+05   1.340E+05   1.260E+05
CROSS-STREAM VELOCITY  -5.520E+02  -1.120E+03  -1.540E+03  -2.020E+03
PARTICLE TEMPERATURE    2.793E+03   2.873E+03   2.903E+03   2.953E+03
PARTICLE DENSITY        2.790E-05   1.430E-04   1.020E-04   5.540E-05
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STREAMLINE NO.    11
DOWNSTREAM VELOCITY        1.510E+05   1.430E+05   1.340E+05   1.270E+05
CROSS-STREAM VELOCITY     -6.210E+02  -1.200E+03  -1.730E+03  -2.270E+03
PARTICLE TEMPERATURE       2.703E+03   2.873E+03   2.903E+03   2.933E+03
PARTICLE DENSITY           2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.    12
DOWNSTREAM VELOCITY        1.520E+05   1.430E+05   1.350E+05   1.270E+05
CROSS-STREAM VELOCITY     -7.090E+02  -1.440E+03  -1.960E+03  -2.600E+03
PARTICLE TEMPERATURE       2.703E+03   2.873E+03   2.893E+03   2.943E+03
PARTICLE DENSITY           2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.    13
DOWNSTREAM VELOCITY        1.530E+05   1.440E+05   1.360E+05   1.280E+05
CROSS-STREAM VELOCITY     -8.200E+02  -1.680E+03  -2.310E+03  -3.030E+03
PARTICLE TEMPERATURE       2.703E+03   2.873E+03   2.893E+03   2.943E+03
PARTICLE DENSITY           2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.    14
DOWNSTREAM VELOCITY        1.540E+05   1.450E+05   1.360E+05   1.280E+05
CROSS-STREAM VELOCITY     -9.930E+02  -2.010E+03  -2.770E+03  -3.630E+03
PARTICLE TEMPERATURE       2.763E+03   2.853E+03   2.883E+03   2.933E+03
PARTICLE DENSITY           2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.    15
DOWNSTREAM VELOCITY        1.550E+05   1.460E+05   1.370E+05   1.290E+05
CROSS-STREAM VELOCITY     -1.200E+03  -2.520E+03  -3.400E+03  -4.540E+03
PARTICLE TEMPERATURE       2.763E+03   2.853E+03   2.883E+03   2.953E+03
PARTICLE DENSITY           2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.    16
DOWNSTREAM VELOCITY        1.560E+05   1.470E+05   1.380E+05   1.300E+05
CROSS-STREAM VELOCITY     -1.600E+03  -3.300E+03  -4.610E+03  -6.090E+03
PARTICLE TEMPERATURE       2.743E+03   2.823E+03   2.873E+03   2.923E+03
PARTICLE DENSITY           2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.    17
DOWNSTREAM VELOCITY        1.580E+05   1.490E+05   1.390E+05   1.310E+05
CROSS-STREAM VELOCITY     -2.400E+03  -5.040E+03  -6.920E+03  -9.090E+03
PARTICLE TEMPERATURE       2.743E+03   2.823E+03   2.873E+03   2.923E+03
PARTICLE DENSITY           2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.    18
DOWNSTREAM VELOCITY        1.590E+05   1.500E+05   1.400E+05   1.320E+05
CROSS-STREAM VELOCITY     -4.970E+03  -1.010E+04  -1.380E+04  -1.820E+04
PARTICLE TEMPERATURE       2.713E+03   2.793E+03   2.853E+03   2.903E+03
PARTICLE DENSITY           2.790E-05   1.430E-04   1.020E-04   5.540E-05
STREAMLINE NO.    19
DOWNSTREAM VELOCITY        0.          0.          0.          0.
CROSS-STREAM VELOCITY      0.          0.          0.          0.
PARTICLE TEMPERATURE       0.          0.          0.          0.
PARTICLE DENSITY           0.          0.          0.          0.
STREAMLINE NO.    20
DOWNSTREAM VELOCITY        0.          0.          0.          0.
CROSS-STREAM VELOCITY      0.          0.          0.          0.
PARTICLE TEMPERATURE       0.          0.          0.          0.
PARTICLE DENSITY           0.          0.          0.          0.
STREAMLINE NO.    21
DOWNSTREAM VELOCITY        0.          0.          0.          0.
CROSS-STREAM VELOCITY      0.          0.          0.          0.
PARTICLE TEMPERATURE       0.          0.          0.          0.
PARTICLE DENSITY           0.          0.          0.          0.
STREAMLINE NO.    22
DOWNSTREAM VELOCITY        0.          0.          0.          0.
CROSS-STREAM VELOCITY      0.          0.          0.          0.
PARTICLE TEMPERATURE       0.          0.          0.          0.
PARTICLE DENSITY           0.          0.          0.          0.
STREAMLINE NO.    23
DOWNSTREAM VELOCITY        0.          0.          0.          0.
CROSS-STREAM VELOCITY      0.          0.          0.          0.
PARTICLE TEMPERATURE       0.          0.          0.          0.
PARTICLE DENSITY           0.          0.          0.          0.
STREAMLINE NO.    24
DOWNSTREAM VELOCITY        0.          0.          0.          0.
CROSS-STREAM VELOCITY      0.          0.          0.          0.
PARTICLE TEMPERATURE       0.          0.          0.          0.
PARTICLE DENSITY           0.          0.          0.          0.
STREAMLINE NO.    25
DOWNSTREAM VELOCITY        0.          0.          0.          0.
CROSS-STREAM VELOCITY      0.          0.          0.          0.
PARTICLE TEMPERATURE       0.          0.          0.          0.
PARTICLE DENSITY           0.          0.          0.          0.
  1  O   O         O2    M                     22 .10E-28 1.0      -0.0
  2  O   H         OH    M                     22 .10E-28 1.0      -0.0
  3  H   H         H2    M                     22 .20E-29 1.0      -0.0
  4  H   OH        H2O   M                     22 .20E-27 1.0      -0.0
  5  CO  O         CO2   M                     22 .10E-28 1.0   -2500.0
  6  OH  OH        H2O   O                     15 .10E-10-0.0   -1000.0
  7  OH  H2        H2O   H                     15 .50E-10-0.0   -5200.0
  8  O   H2        OH    H                     15 .50E-10-0.0   -8400.0
  9  H   O2        OH    O                     15 .30E-09-0.0  -16500.0
 10  CO  OH        CO2   H                     15 .50E-12-0.0    -600.0
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1  70      XM= .2200E+02   HM= 0.           PHIM= 0.

2       X= 2.2000E+01    R= 0.2200E-01     PHI= 2.2001E-02  T= 2.0505E+03    P= 3.1135E+00    U= 2.0090E+05
        MA= .1775E+01    DELY= .8225E+00 H= -.7110E+02      HT= .4117E+03    TAN= 0.          V= 0.
        PT= .9247E+01    RHO= .3077E-03  SX= .1021E+02      SUMDOT= .1310E+03

        SPECIE  CO        C= .2961E+00    X= .2106E+00     WDOT= -.0019E-04
        SPECIE  CO2       C= .6617E-01    X= .2995E-01     WDOT= .0019E-04
        SPECIE  H         C= .3123E-03    X= .0221E-02     WDOT= .1055E-02
        SPECIE  H2        C= .2440E-01    X= .2450E+00     WDOT= -.1000E-02
        SPECIE  OH        C= .0500E-03    X= .9905E-03     WDOT= -.1030E-02
        SPECIE  H2O       C= .1895E+00    X= .2096E+00     WDOT= .1300E-02
        SPECIE  N2        C= .4200E+00    X= .2980E+00     WDOT= 0.
        SPECIE  O         C= .1277E-04    X= .1590E-04     WDOT= -.1495E-04
        SPECIE  O2        C= .1144E-04    X= .7123E-05     WDOT= .4630E-06
        SPECIE  N         C= .1100E-05    X= .5477E-06     WDOT= 0.

3       X= 2.2000E+01    R= 1.0019E+00     PHI= 4.4610E-02  T= 2.0520E+03    P= 3.1105E+00    U= 2.0121E+05
        MA= .1777E+01    DELY= .8200E+00 H= -.7332E+02      HT= .4107E+03    TAN= 0.          V= 0.
        PT= .9270E+01    RHO= .3083E-03  SX= .1020E+02      SUMDOT= .5253E+03

        SPECIE  CO        C= .2963E+00    X= .2100E+00     WDOT= -.3990E-04
        SPECIE  CO2       C= .6579E-01    X= .2970E-01     WDOT= .3990E-04
        SPECIE  H         C= .3095E-03    X= .6085E-02     WDOT= .1237E-02
        SPECIE  H2        C= .2447E-01    X= .2437E+00     WDOT= -.1190E-02
        SPECIE  OH        C= .8809E-03    X= .9053E-03     WDOT= -.1210E-02
        SPECIE  H2O       C= .1890E+00    X= .2090E+00     WDOT= .1100E-02
        SPECIE  N2        C= .4200E+00    X= .2900E+00     WDOT= 0.
        SPECIE  O         C= .1259E-04    X= .1567E-04     WDOT= -.1223E-04
        SPECIE  O2        C= .1098E-04    X= .6019E-05     WDOT= .3642E-06
        SPECIE  N         C= .1100E-05    X= .5470E-06     WDOT= 0.

4       X= 2.2745E+01    R= 2.0595E+00     PHI= 6.7190E-02  T= 2.0530E+03    P= 3.1140E+00    U= 2.0109E+05
        MA= .1775E+01    DELY= .8180E+00 H= -.7272E+02      HT= .4107E+03    TAN= 0.          V= 0.
        PT= .9260E+01    RHO= .3082E-03  SX= .1020E+02      SUMDOT= .1179E+04

        SPECIE  CO        C= .2967E+00    X= .2110E+00     WDOT= -.3044E-04
        SPECIE  CO2       C= .6520E-01    X= .2953E-01     WDOT= .3044E-04
        SPECIE  H         C= .3055E-03    X= .6006E-02     WDOT= .9002E-03
        SPECIE  H2        C= .2445E-01    X= .2435E+00     WDOT= -.9512E-03
        SPECIE  OH        C= .8562E-03    X= .1003E-02     WDOT= -.9654E-03
        SPECIE  H2O       C= .1898E+00    X= .2101E+00     WDOT= .9430E-03
        SPECIE  N2        C= .4200E+00    X= .2900E+00     WDOT= 0.
        SPECIE  O         C= .1308E-04    X= .1628E-04     WDOT= -.9337E-05
        SPECIE  O2        C= .1092E-04    X= .6799E-05     WDOT= .2669E-06
        SPECIE  N         C= .1100E-05    X= .5478E-06     WDOT= 0.

5       X= 2.2750E+01    R= 3.2750E+00     PHI= 9.0314E-02  T= 2.0542E+03    P= 3.1002E+00    U= 2.0105E+05
        MA= .1775E+01    DELY= .8180E+00 H= -.7242E+02      HT= .4108E+03    TAN= 0.          V= 0.
        PT= .9243E+01    RHO= .3075E-03  SX= .1019E+02      SUMDOT= .2091E+04

        SPECIE  CO        C= .2967E+00    X= .2111E+00     WDOT= -.2898E-04
        SPECIE  CO2       C= .6517E-01    X= .2950E-01     WDOT= .2898E-04
        SPECIE  H         C= .3088E-03    X= .6100E-02     WDOT= .9517E-03
        SPECIE  H2        C= .2440E-01    X= .2434E+00     WDOT= -.9242E-03
        SPECIE  OH        C= .8625E-03    X= .1011E-02     WDOT= -.9577E-03
        SPECIE  H2O       C= .1898E+00    X= .2101E+00     WDOT= .9172E-03
        SPECIE  N2        C= .4200E+00    X= .2900E+00     WDOT= 0.
        SPECIE  O         C= .1328E-04    X= .1651E-04     WDOT= -.8985E-05
        SPECIE  O2        C= .1102E-04    X= .6859E-05     WDOT= .2510E-06
        SPECIE  N         C= .1100E-05    X= .5478E-06     WDOT= 0.

6       X= 2.2647E+01    R= 4.0897E+00     PHI= 1.1276E-01  T= 2.0536E+03    P= 3.0975E+00    U= 2.0106E+05
        MA= .1775E+01    DELY= .8185E+00 H= -.7240E+02      HT= .4105E+03    TAN= 0.          V= 0.
        PT= .9214E+01    RHO= .3065E-03  SX= .1017E+02      SUMDOT= .3258E+04

        SPECIE  CO        C= .2972E+00    X= .2114E+00     WDOT= -.1450E-04
        SPECIE  CO2       C= .6446E-01    X= .2918E-01     WDOT= .1450E-04
        SPECIE  H         C= .3037E-03    X= .6050E-02     WDOT= .5838E-03
        SPECIE  H2        C= .2441E-01    X= .2431E+00     WDOT= -.5769E-03
        SPECIE  OH        C= .8733E-03    X= .1023E-02     WDOT= -.5778E-03
        SPECIE  H2O       C= .1901E+00    X= .2104E+00     WDOT= .5679E-03
        SPECIE  N2        C= .4200E+00    X= .2988E+00     WDOT= 0.
        SPECIE  O         C= .1367E-04    X= .1702E-04     WDOT= -.4785E-05
        SPECIE  O2        C= .1074E-04    X= .6686E-05     WDOT= .10[illegible]
        SPECIE  N         C= .1100E-05    X= .5478E-06     WDOT= 0.

7       X= 2.2540E+01    R= 4.9004E+00     PHI= 1.3520E-01  T= 2.0527E+03    P= 3.0001E+00    U= 2.0091E+05
        MA= .1774E+01    DELY= .8170E+00 H= -.7332E+02      HT= .4093E+03    TAN= 0.          V= 0.
        PT= .9179E+01    RHO= .3057E-03  SX= .1015E+02      SUMDOT= .4675E+04

        SPECIE  CO        C= .2974E+00    X= .2116E+00     WDOT= -.8347E-05
        SPECIE  CO2       C= .6409E-01    X= .2901E-01     WDOT= .8347E-05
        SPECIE  H         C= .3018E-03    X= .6012E-02     WDOT= .3991E-03
        SPECIE  H2        C= .2440E-01    X= .2430E+00     WDOT= -.3923E-03
        SPECIE  OH        C= .8755E-03    X= .1026E-02     WDOT= -.3969E-03
        SPECIE  H2O       C= .1903E+00    X= .2106E+00     WDOT= .3912E-03
        SPECIE  N2        C= .4200E+00    X= .2988E+00     WDOT= 0.
        SPECIE  O         C= .1378E-04    X= .1716E-04     WDOT= -.2755E-05
        SPECIE  O2        C= .1053E-04    X= .6555E-05     WDOT= .4603E-07
        SPECIE  N         C= .1100E-05    X= .5478E-06     WDOT= 0.
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8    X= 2.2027E+01    M= 5.7091E+00    PHI= 1.5023E-01   T= 2.4517E+03    P= 3.0722E+00    U= 2.0092E+05
     MA= .1779E+01    DELTA= .0175E+00 H= -.7303E+02    HT= .4008E+03    TAW= 0.          Q= 0.
     PI= .9135E+01    RHO= .3003E-03   SX= .1013E+02    SUMDOT= .6341E+04

     SPECIE  CO        C= .2976E+00     X= .2117E+00     WDOT= -.1299E-05
     SPECIE  CO2       C= .6373E-01     X= .2409E-01     WDOT=  .1299E-05
     SPECIE  H         C= .3005E-03     X= .5905E-02     WDOT=  .2150E-03
     SPECIE  H2        C= .2430E-01     X= .2429E+00     WDOT= -.2162E-03
     SPECIE  OH        C= .8009E-03     X= .1032E-02     WDOT= -.2177E-03
     SPECIE  H2O       C= .1908E+00     X= .2107E+00     WDOT=  .2171E-03
     SPECIE  N2        C= .4200E+00     X= .2908E+00     WDOT= 0.
     SPECIE  O         C= .1399E-04     X= .1742E-04     WDOT= -.6438E-06
     SPECIE  O2        C= .1039E-04     X= .6405E-05     WDOT= -.2197E-07
     SPECIE  A         C= .1100E-05     X= .5478E-06     WDOT= 0.

9    X= 2.2206E+01    M= 6.5153E+00    PHI= 1.8167E-01   T= 2.4406E+03    P= 3.0500E+00    U= 2.0111E+05
     MA= .1777E+01    DELTA= .8181E+00 H= -.7557E+02    HT= .4080E+03    TAW= 0.          Q= 0.
     PI= .9091E+01    RHO= .3025E-03   SX= .1011E+02    SUMDOT= .8253E+04

     SPECIE  CO        C= .2976E+00     X= .2117E+00     WDOT= -.1516E-05
     SPECIE  CO2       C= .6370E-01     X= .2807E-01     WDOT=  .1516E-05
     SPECIE  H         C= .2976E-03     X= .5920E-02     WDOT=  .2109E-03
     SPECIE  H2        C= .2439E-01     X= .2429E+00     WDOT= -.2109E-03
     SPECIE  OH        C= .8080E-03     X= .1018E-02     WDOT= -.2205E-03
     SPECIE  H2O       C= .1908E+00     X= .2107E+00     WDOT=  .2197E-03
     SPECIE  N2        C= .4200E+00     X= .2908E+00     WDOT= 0.
     SPECIE  O         C= .1307E-04     X= .1702E-04     WDOT= -.6977E-06
     SPECIE  O2        C= .1016E-04     X= .6323E-05     WDOT= -.1917E-07
     SPECIE  A         C= .1100E-05     X= .5478E-06     WDOT= 0.

10   X= 2.2139E+01    M= 7.3192E+00    PHI= 2.0626E-01   T= 2.4444E+03    P= 3.0177E+00    U= 2.0127E+05
     MA= .1780E+01    DELTA= .0193E+00 H= -.7790E+02    HT= .4065E+03    TAW= 0.          Q= 0.
     PI= .9012E+01    RHO= .2990E-03   SX= .1000E+02    SUMDOT= .1040E+05

     SPECIE  CO        C= .2975E+00     X= .2117E+00     WDOT= -.2208E-05
     SPECIE  CO2       C= .6309E-01     X= .2093E-01     WDOT=  .2208E-05
     SPECIE  H         C= .2943E-03     X= .5862E-02     WDOT=  .2434E-03
     SPECIE  H2        C= .2440E-01     X= .2430E+00     WDOT= -.2427E-03
     SPECIE  OH        C= .8548E-03     X= .1002E-02     WDOT= -.2446E-03
     SPECIE  H2O       C= .1904E+00     X= .2107E+00     WDOT=  .2434E-03
     SPECIE  N2        C= .4200E+00     X= .2908E+00     WDOT= 0.
     SPECIE  O         C= .1330E-04     X= .1657E-04     WDOT= -.9036E-06
     SPECIE  O2        C= .9932E-05     X= .6103E-05     WDOT= -.1390E-07
     SPECIE  A         C= .1100E-05     X= .5478E-06     WDOT= 0.

11   X= 2.1952E+01    M= 8.1207E+00    PHI= 2.3153E-01   T= 2.4593E+03    P= 2.9801E+00    U= 2.0167E+05
     MA= .1786E+01    DELTA= .8211E+00 H= -.8071E+02    HT= .4056E+03    TAW= 0.          Q= 0.
     PI= .8936E+01    RHO= .2967E-03   SX= .1005E+02    SUMDOT= .1270E+05

     SPECIE  CO        C= .2975E+00     X= .2117E+00     WDOT= -.2430E-05
     SPECIE  CO2       C= .6396E-01     X= .2096E-01     WDOT=  .2430E-05
     SPECIE  H         C= .2900E-03     X= .5776E-02     WDOT=  .2467E-03
     SPECIE  H2        C= .2440E-01     X= .2431E+00     WDOT= -.2457E-03
     SPECIE  OH        C= .8370E-03     X= .9809E-03     WDOT= -.2477E-03
     SPECIE  H2O       C= .1904E+00     X= .2107E+00     WDOT=  .2463E-03
     SPECIE  N2        C= .4200E+00     X= .2908E+00     WDOT= 0.
     SPECIE  O         C= .1284E-04     X= .1599E-04     WDOT= -.9468E-06
     SPECIE  O2        C= .9608E-05     X= .5981E-05     WDOT= -.1129E-07
     SPECIE  A         C= .1100E-05     X= .5479E-06     WDOT= 0.

12   X= 2.1753E+01    M= 8.9213E+00    PHI= 2.5695E-01   T= 2.4363E+03    P= 2.9360E+00    U= 2.0207E+05
     MA= .1790E+01    DELTA= .8250E+00 H= -.8237E+02    HT= .4058E+03    TAW= 0.          Q= 0.
     PI= .8836E+01    RHO= .2927E-03   SX= .1001E+02    SUMDOT= .1540E+05

     SPECIE  CO        C= .2975E+00     X= .2117E+00     WDOT= -.2401E-05
     SPECIE  CO2       C= .6398E-01     X= .2897E-01     WDOT=  .2401E-05
     SPECIE  H         C= .2880E-03     X= .5738E-02     WDOT=  .2362E-03
     SPECIE  H2        C= .2440E-01     X= .2431E+00     WDOT= -.2353E-03
     SPECIE  OH        C= .8274E-03     X= .9697E-03     WDOT= -.2372E-03
     SPECIE  H2O       C= .1904E+00     X= .2107E+00     WDOT=  .2350E-03
     SPECIE  N2        C= .4200E+00     X= .2908E+00     WDOT= 0.
     SPECIE  O         C= .1261E-04     X= .1570E-04     WDOT= -.9171E-06
     SPECIE  O2        C= .9429E-05     X= .5870E-05     WDOT= -.9623E-08
     SPECIE  A         C= .1100E-05     X= .5479E-06     WDOT= 0.

13   X= 2.1552E+01    M= 9.7190E+00    PHI= 2.8287E-01   T= 2.4516E+03    P= 2.8869E+00    U= 2.0250E+05
     MA= .1796E+01    DELTA= .8277E+00 H= -.8440E+02    HT= .4054E+03    TAW= 0.          Q= 0.
     PI= .8717E+01    RHO= .2881E-03   SX= .9969E+01    SUMDOT= .1823E+05

     SPECIE  CO        C= .2974E+00     X= .2116E+00     WDOT= -.2292E-05
     SPECIE  CO2       C= .6402E-01     X= .2499E-01     WDOT=  .2292E-05
     SPECIE  H         C= .2846E-03     X= .5671E-02     WDOT=  .2241E-03
     SPECIE  H2        C= .2441E-01     X= .2432E+00     WDOT= -.2232E-03
     SPECIE  OH        C= .8125E-03     X= .9522E-03     WDOT= -.2251E-03
     SPECIE  H2O       C= .1904E+00     X= .2107E+00     WDOT=  .2237E-03
     SPECIE  N2        C= .4200E+00     X= .2909E+00     WDOT= 0.
     SPECIE  O         C= .1224E-04     X= .1524E-04     WDOT= -.8520E-06
     SPECIE  O2        C= .9151E-05     X= .5697E-05     WDOT= -.8923E-08
     SPECIE  A         C= .1100E-05     X= .5479E-06     WDOT= 0.
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14   X= 2.1[illegible]E+01    M= 1.1515E+01    PHI= 3.1[illegible]E-01  T= 2.[illegible]E+03   P= 2.[illegible]E+00   U= 2.0[illegible]E+05
     MAS  .1[illegible]E+01   DELTA  .[illegible]E+00 H= -.[illegible]E+02   MI=  .[illegible]E+03   TAMB 0.                UE 0.
     MI=  .[illegible]E+01    RHOE  .[illegible]E-03  SX=  .[illegible]E+01     SUMDOTS  .2120E+05

     SPECIE  CO      C=  .[illegible]E+00    X=  .2110E+00     WDOTS -.2350E-05
     SPECIE  CO2     C=  .[illegible]E-01    X=  .[illegible]E-01     WDOTS  .2350E-05
     SPECIE  H       C=  .[illegible]E-03    X=  .[illegible]E-02     WDOTS  .2205E-03
     SPECIE  H2      C=  .[illegible]E-01    X=  .[illegible]E+00     WDOTS -.2195E-03
     SPECIE  OH      C=  .[illegible]E-03    X=  .9500E-03     WDOTS -.2215E-03
     SPECIE  H2O     C=  .190[illegible]E+00    X=  .2107E+00     WDOTS  .2200E-03
     SPECIE  N2      C=  .[illegible]E+00    X=  .[illegible]E+00     WDOTS 0.
     SPECIE  O       C=  .[illegible]E-04    X=  .152[illegible]E-04     WDOTS -.[illegible]E-06
     SPECIE  O2      C=  .915[illegible]E-05    X=  .[illegible]E-05     WDOTS -.[illegible]E-08
     SPECIE  N       C=  .1100E-05    X=  .5479E-06     WDOTS 0.

15   X= 2.102[illegible]E+01  M= 1.1311E+01    PHI= 3.4117E-01  T= 2.422[illegible]E+03   P= 2.7[illegible]E+00   U= 2.039[illegible]E+0[illegible]
     MAS  .1[illegible]E+01   DELTA  .6407E+00 H= -.[illegible]E+02   MI=  .40[illegible]E+03   TAMB 0.                UE 0.
     MI=  .[illegible]E+01    RHOE  .[illegible]E-03  SX=  .[illegible]E+01     SUMDOTS  .24[illegible]E+05

     SPECIE  CO      C=  .[illegible]E+00    X=  .2110E+00     WDOTS -.2[illegible]E-05
     SPECIE  CO2     C=  .[illegible]E-01    X=  .2[illegible]E-01     WDOTS  .2503E-05
     SPECIE  H       C=  .2821E-03    X=  .5621E-02     WDOTS  .2245E-03
     SPECIE  H2      C=  .[illegible]E-01    X=  .[illegible]E+00     WDOTS -.2233E-03
     SPECIE  OH      C=  .7[illegible]E-03    X=  .9[illegible]E-03     WDOTS -.225[illegible]E-03
     SPECIE  H2O     C=  .19[illegible]E+00    X=  .21[illegible]E+00     WDOTS  .223[illegible]E-03
     SPECIE  N2      C=  .[illegible]E+00    X=  .2[illegible]E+00     WDOTS 0.
     SPECIE  O       C=  .1193E-04    X=  .1[illegible]E-04     WDOTS -.[illegible]E-06
     SPECIE  O2      C=  .[illegible]E-05    X=  .[illegible]E-05     WDOTS -.[illegible]E-08
     SPECIE  N       C=  .11[illegible]E-05    X=  .5[illegible]E-06     WDOTS 0.

16   X= 2.0[illegible]E+01    M= 1.2[illegible]E+01    PHI= 3.[illegible]E-01  T= 2.[illegible]E+03   P= 2.[illegible]E+00   U= 2.05[illegible]E+05
     MAS  .1[illegible]E+01   DELTA  .[illegible]E+00 H= -.957[illegible]E+02   MI=  .[illegible]E+03   TAMB 0.                UE 0.
     MI=  .[illegible]E+01    RHOE  .[illegible]E-03  SX=  .[illegible]E+01     SUMDOTS  .2792E+05

     SPECIE  CO      C=  .[illegible]E+00    X=  .2115E+00     WDOTS -.2544E-05
     SPECIE  CO2     C=  .[illegible]E-01    X=  .2[illegible]E-01     WDOTS  .2544E-05
     SPECIE  H       C=  .2745E-03    X=  .5[illegible]E-02     WDOTS  .2235E-03
     SPECIE  H2      C=  .[illegible]E-01    X=  .243[illegible]E+00     WDOTS -.2222E-03
     SPECIE  OH      C=  .7[illegible]E-03    X=  .[illegible]E-03     WDOTS -.2243E-03
     SPECIE  H2O     C=  .190[illegible]E+00    X=  .210[illegible]E+00     WDOTS  .22[illegible]E-03
     SPECIE  N2      C=  .[illegible]E+00    X=  .2[illegible]E+00     WDOTS 0.
     SPECIE  O       C=  .1117E-04    X=  .1[illegible]E-04     WDOTS -.[illegible]E-06
     SPECIE  O2      C=  .[illegible]E-05    X=  .5235E-05     WDOTS -.[illegible]E-08
     SPECIE  N       C=  .110[illegible]E-05    X=  .5[illegible]E-06     WDOTS 0.

17   X= 2.0[illegible]E+01    M= 1.2[illegible]E+01    PHI= 4.1[illegible]E-01  T= 2.39[illegible]E+03   P= 2.5110E+00   U= 2.0[illegible]E+05
     MAS  .1[illegible]E+01   DELTA  .[illegible]E+00 H= -.105[illegible]E+03   MI=  .[illegible]E+03   TAMB 0.                UE 0.
     MI=  .[illegible]E+01    RHOE  .[illegible]E-03  SX=  .9710E+01     SUMDOTS  .3152E+05

     SPECIE  CO      C=  .[illegible]E+00    X=  .2115E+00     WDOTS -.2514E-05
     SPECIE  CO2     C=  .[illegible]E-01    X=  .2[illegible]E-01     WDOTS  .2514E-05
     SPECIE  H       C=  .2[illegible]E-03    X=  .520[illegible]E-02     WDOTS  .2[illegible]E-03
     SPECIE  H2      C=  .2445E-01    X=  .243[illegible]E+00     WDOTS -.2035E-03
     SPECIE  OH      C=  .7123E-03    X=  .[illegible]E-03     WDOTS -.2055E-03
     SPECIE  H2O     C=  .190[illegible]E+00    X=  .2107E+00     WDOTS  .2039E-03
     SPECIE  N2      C=  .[illegible]E+00    X=  .2[illegible]E+00     WDOTS 0.
     SPECIE  O       C=  .[illegible]E-05    X=  .1235E-04     WDOTS -.7250E-06
     SPECIE  O2      C=  .7[illegible]E-05    X=  .[illegible]E-05     WDOTS -.5[illegible]E-08
     SPECIE  N       C=  .1100E-05    X=  .5[illegible]E-06     WDOTS 0.

18   X= 2.0[illegible]E+01    M= 1.3724E+01    PHI= 4.5799E-01  T= 2.3[illegible]E+03   P= 2.367[illegible]E+00   U= 2.0[illegible]E+05
     MAS  .1[illegible]E+01   DELTA  .[illegible]E+00 H= -.1115E+03   MI=  .4052E+03   TAMB 0.                UE 0.
     MI=  .[illegible]E+01    RHOE  .[illegible]E-03  SX=  .9[illegible]E+01     SUMDOTS  .3551E+05

     SPECIE  CO      C=  .2971E+00    X=  .2115E+00     WDOTS -.1570E-05
     SPECIE  CO2     C=  .[illegible]E-01    X=  .2[illegible]E-01     WDOTS  .1570E-05
     SPECIE  H       C=  .[illegible]E-03    X=  .50[illegible]E-02     WDOTS  .14[illegible]E-03
     SPECIE  H2      C=  .[illegible]E-01    X=  .243[illegible]E+00     WDOTS -.14[illegible]E-03
     SPECIE  OH      C=  .[illegible]E-03    X=  .7[illegible]E-03     WDOTS -.14[illegible]E-03
     SPECIE  H2O     C=  .190[illegible]E+00    X=  .2107E+00     WDOTS  .147[illegible]E-03
     SPECIE  N2      C=  .[illegible]E+00    X=  .2990E+00     WDOTS 0.
     SPECIE  O       C=  .907[illegible]E-05    X=  .113[illegible]E-04     WDOTS -.4900E-06
     SPECIE  O2      C=  .[illegible]E-05    X=  .[illegible]E-05     WDOTS -.4171E-08
     SPECIE  N       C=  .11[illegible]E-05    X=  .5[illegible]E-06     WDOTS 0.

19   X= 1.9[illegible]E+01    M= 1.4531E+01    PHI= 4.7[illegible]E-01  T= 2.3115E+03   P= 2.2[illegible]E+00   U= 2.13[illegible]E+05
     MAS  .1[illegible]E+01   DELTA  .0[illegible]E+00 H= -.1[illegible]E+03   MI=  .3[illegible]E+03   TAMB 0.                UE 0.
     MI=  .[illegible]E+01    RHOE  .23[illegible]E-03  SX=  .9[illegible]E+01     SUMDOTS  .39[illegible]E+05

     SPECIE  CO      C=  .[illegible]E+00    X=  .2109E+00     WDOTS -.33[illegible]E-05
     SPECIE  CO2     C=  .[illegible]E-01    X=  .2[illegible]E-01     WDOTS  .33[illegible]E-05
     SPECIE  H       C=  .2101E-03    X=  .4191E-02     WDOTS  .22[illegible]E-03
     SPECIE  H2      C=  .2455E-01    X=  .2[illegible]E+00     WDOTS -.225[illegible]E-03
     SPECIE  OH      C=  .5[illegible]E-03    X=  .[illegible]E-03     WDOTS -.22[illegible]E-03
     SPECIE  H2O     C=  .1[illegible]E+00    X=  .21[illegible]E+00     WDOTS  .22[illegible]E-03
     SPECIE  N2      C=  .[illegible]E+00    X=  .2[illegible]E+00     WDOTS 0.
     SPECIE  O       C=  .[illegible]E-05    X=  .[illegible]E-05     WDOTS -.[illegible]E-06
     SPECIE  O2      C=  .[illegible]E-05    X=  .2[illegible]E-05     WDOTS -.1[illegible]E-08
     SPECIE  N       C=  .110[illegible]E-05    X=  .5[illegible]E-06     WDOTS 0.
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20   X= 1.9200E+01     M= 1.5217E+01    PHI= 6.2313E-01   T= 2.1991E+03    P= 2.3500E+00     U= 2.1805E+05
     MA= .2030E+01     DELTA= .7623E+00 H= -.2100E+03     MT= .3500E+03    TAW= 0.           Q= 0.
     PT= .0511E+01     RHO= .2010E-03   S= .9420E+01      SUMDOT= .0332E+05

     SPECIE  CO       C=  .2950E+00    X=  .2103E+00    WDOT= -.2163E-06
     SPECIE  CO2      C=  .6789E-01    X=  .3080E-01    WDOT=  .2163E-06
     SPECIE  H        C=  .1125E-03    X=  .2240E-02    WDOT=  .5448E-04
     SPECIE  H2       C=  .2472E-01    X=  .2408E+00    WDOT= -.5409E-04
     SPECIE  OH       C=  .2268E-03    X=  .2664E-03    WDOT= -.5499E-04
     SPECIE  H2O      C=  .1898E+00    X=  .2101E+00    WDOT=  .5495E-04
     SPECIE  N2       C=  .4200E+00    X=  .2995E+00    WDOT= 0.
     SPECIE  O        C=  .1415E-05    X=  .1760E-05    WDOT= -.1685E-06
     SPECIE  O2       C=  .1088E-05    X=  .6708E-06    WDOT= -.8684E-09
     SPECIE  N        C=  .1100E-05    X=  .5490E-06    WDOT= 0.

21   X= 1.9003E+01     M= 1.5029E+01    PHI= 3.9354E-01   T= 2.2900E+03    P= 2.9415E+00     U= 2.1000E+05
     MA= .1910E+01     DELTA= .6663E+00 H= -.1653E+03     MT= .3625E+03    TAW= 0.           Q= 0.
     PT= .9747E+01     RHO= .3125E-03   S= .9391E+01      SUMDOT= .4759E+05

     SPECIE  CO       C=  .2968E+00    X=  .2116E+00    WDOT=  .2753E-05
     SPECIE  CO2      C=  .6507E-01    X=  .2952E-01    WDOT= -.2754E-05
     SPECIE  H        C=  .1207E-03    X=  .2410E-02    WDOT= -.8812E-04
     SPECIE  H2       C=  .2459E-01    X=  .2454E+00    WDOT=  .8566E-04
     SPECIE  OH       C=  .2650E-03    X=  .3111E-03    WDOT= -.2366E-04
     SPECIE  H2O      C=  .1905E+00    X=  .2113E+00    WDOT= -.0593E-04
     SPECIE  N2       C=  .4200E+00    X=  .2994E+00    WDOT= 0.
     SPECIE  O        C=  .1655E-05    X=  .2066E-05    WDOT=  .1799E-07
     SPECIE  O2       C=  .1153E-05    X=  .7195E-06    WDOT= -.7006E-09
     SPECIE  N        C=  .1100E-05    X=  .5490E-06    WDOT= 0.

22   X= 1.8718E+01     M= 1.6450E+01    PHI= 4.5705E-01   T= 2.2551E+03    P= 2.7000E+00     U= 2.1459E+05
     MA= .1974E+01     DELTA= .6908E+00 H= -.1806E+03     MT= .3700E+03    TAW= 0.           Q= 0.
     PT= .9320E+01     RHO= .2913E-03   S= .9356E+01      SUMDOT= .5197E+05

     SPECIE  CO       C=  .2963E+00    X=  .2112E+00    WDOT= -.6408E-05
     SPECIE  CO2      C=  .6578E-01    X=  .2983E-01    WDOT=  .6408E-05
     SPECIE  H        C=  .1503E-03    X=  .2999E-02    WDOT=  .2003E-03
     SPECIE  H2       C=  .2459E-01    X=  .2454E+00    WDOT= -.1948E-03
     SPECIE  OH       C=  .3554E-03    X=  .4171E-03    WDOT= -.2020E-03
     SPECIE  H2O      C=  .1902E+00    X=  .2108E+00    WDOT=  .1956E-03
     SPECIE  N2       C=  .4201E+00    X=  .2993E+00    WDOT= 0.
     SPECIE  O        C=  .2954E-05    X=  .3684E-05    WDOT= -.5532E-07
     SPECIE  O2       C=  .2282E-05    X=  .1423E-05    WDOT=  .5499E-08
     SPECIE  N        C=  .1100E-05    X=  .5488E-06    WDOT= 0.

23   X= 1.8404E+01     M= 1.7094E+01    PHI= 4.5424E-01   T= 2.2512E+03    P= 2.5088E+00     U= 2.1826E+05
     MA= .2018E+01     DELTA= .7043E+00 H= -.1929E+03     MT= .3766E+03    TAW= 0.           Q= 0.
     PT= .8941E+01     RHO= .2736E-03   S= .9312E+01      SUMDOT= .5643E+05

     SPECIE  CO       C=  .2952E+00    X=  .2102E+00    WDOT= -.2301E-05
     SPECIE  CO2      C=  .6742E-01    X=  .3081E-01    WDOT=  .2301E-05
     SPECIE  H        C=  .1422E-03    X=  .2837E-02    WDOT=  .2066E-03
     SPECIE  H2       C=  .2470E-01    X=  .2465E+00    WDOT= -.2053E-03
     SPECIE  OH       C=  .3143E-03    X=  .3690E-03    WDOT= -.2876E-03
     SPECIE  H2O      C=  .1893E+00    X=  .2099E+00    WDOT=  .2058E-03
     SPECIE  N2       C=  .4200E+00    X=  .2994E+00    WDOT= 0.
     SPECIE  O        C=  .2494E-05    X=  .3117E-05    WDOT= -.4811E-06
     SPECIE  O2       C=  .2018E-05    X=  .1259E-05    WDOT= -.3108E-08
     SPECIE  N        C=  .1100E-05    X=  .5488E-06    WDOT= 0.

24   X= 1.8094E+01     M= 1.7707E+01    PHI= 4.6525E-01   T= 2.2481E+03    P= 2.5033E+00     U= 2.1010E+05
     MA= .2109E+01     DELTA= .6847E+00 H= -.1849E+03     MT= .3838E+03    TAW= 0.           Q= 0.
     PT= .9147E+01     RHO= .2794E-03   S= .9277E+01      SUMDOT= .6100E+05

     SPECIE  CO       C=  .2956E+00    X=  .2107E+00    WDOT= -.1199E-05
     SPECIE  CO2      C=  .6608E-01    X=  .3033E-01    WDOT=  .1199E-05
     SPECIE  H        C=  .1375E-03    X=  .2744E-02    WDOT=  .1205E-03
     SPECIE  H2       C=  .2465E-01    X=  .2460E+00    WDOT= -.1194E-03
     SPECIE  OH       C=  .3074E-03    X=  .3610E-03    WDOT= -.1212E-03
     SPECIE  H2O      C=  .1898E+00    X=  .2104E+00    WDOT=  .1203E-03
     SPECIE  N2       C=  .4200E+00    X=  .2994E+00    WDOT= 0.
     SPECIE  O        C=  .2321E-05    X=  .2496E-05    WDOT= -.2717E-06
     SPECIE  O2       C=  .1794E-05    X=  .1119E-05    WDOT= -.1007E-08
     SPECIE  N        C=  .1100E-05    X=  .5489E-06    WDOT= 0.

25   X= 1.7801E+01     M= 1.8303E+01    PHI= 4.6426E-01   T= 2.1585E+03    P= 2.6014E+00     U= 2.0957E+05
     MA= .1989E+01     DELTA= .6865E+00 H= -.2313E+03     MT= .2938E+03    TAW= -.2977E+05   Q= -.1610E+03
     PT= .8961E+01     RHO= .2934E-03   S= .9252E+01      SUMDOT= .6563E+05

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                                        WALL TEMPERATURE= 1000. KELVIN

                                        BOUNDARY LAYER PARAMETERS

RED=  .7888E+08   DELTAI=  .2188E+00   THETAI=  .2123E-01   CFI=  .3703E-02   UFI=  .6138E+04
RETH= .1725E+  1  DELTAC=  .2588E+00   THETAC=  .2438E-01   CFC=  .4626E-02   CFC/CFI=  .1248E+01
HI2=  .1135E+  1  DELTA= -.1110E+05    TAUWALL= -.2977E+05
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BOUNDARY LAYER PROFILES

U/UE	T/TE	U/UF INC	Y/DEL
.1000E-01	.4694E+00	.3045E+00	.2100E-03
.2000E-01	.4771E+00	.6067E+00	.4197E-03
.3000E-01	.4855E+00	.9064E+00	.6270E-03
.4000E-01	.4943E+00	.1203E+01	.8320E-03
.5000E-01	.5034E+00	.1498E+01	.1036E-02
.6000E-01	.5127E+00	.1789E+01	.1238E-02
.7000E-01	.5221E+00	.2070E+01	.1438E-02
.8000E-01	.5317E+00	.2365E+01	.1636E-02
.9000E-01	.5413E+00	.2649E+01	.1832E-02
.1000E+00	.5510E+00	.2930E+01	.2027E-02
.1500E+00	.5996E+00	.4296E+01	.2972E-02
.2000E+00	.6474E+00	.5639E+01	.3900E-02
.2500E+00	.6936E+00	.6875E+01	.5035E-02
.3000E+00	.7375E+00	.8101E+01	.6434E-02
.3500E+00	.7780E+00	.9292E+01	.8165E-02
.4000E+00	.8172E+00	.1045E+02	.1030E-01
.4500E+00	.8525E+00	.1159E+02	.1295E-01
.5000E+00	.8845E+00	.1270E+02	.1615E-01
.5500E+00	.9130E+00	.1380E+02	.2011E-01
.6000E+00	.9380E+00	.1488E+02	.3527E-01
.6500E+00	.9594E+00	.1595E+02	.5405E-01
.7000E+00	.9769E+00	.1700E+02	.8244E-01
.7500E+00	.9907E+00	.1805E+02	.1254E+00
.8000E+00	.1001E+01	.1909E+02	.1902E+00
.8500E+00	.1006E+01	.2013E+02	.2891E+00
.9000E+00	.1008E+01	.2117E+02	.4360E+00
.9500E+00	.1006E+01	.2220E+02	.6600E+00
.1000E+01	.1000E+01	.2324E+02	.1000E+01

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SPECIE  CO     C= .2908E+00   X= .2101E+00   ADOT= -.1007E-05
SPECIE  CO2    C= .6844E-01   X= .3106E-01   ADOT=  .1007E-05
SPECIE  H      C= .9230E-04   X= .1844E-02   ADOT=  .7067E-08
SPECIE  H2     C= .2476E-01   X= .2472E+00   ADOT= -.7807E-08
SPECIE  OH     C= .1791E-03   X= .2104E-03   ADOT= -.7025E-08
SPECIE  H2O    C= .1893E+00   X= .2100E+00   ADOT=  .7036E-08
SPECIE  N2     C= .4200E+00   X= .2495E+00   ADOT= 0.
SPECIE  O      C= .9244E-06   X= .1154E-05   ADOT= -.1173E-06
SPECIE  O2     C= .7230E-06   X= .4512E-06   ADOT= -.4391E-09
SPECIE  A      C= .1110E-05   X= .5492E-06   ADOT= 0.
---STREAMLINE=    1  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.0102E+05  T= 2.458E+03  DENSITY= 3.077E-04  REYNOLDS NO.= 6.911E+21  Y2= 8.225E-01  H2= 8.220E-01
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY      1.890E+05    1.681E+05    1.530E+05    1.421E+05
CROSS-STREAM VELOCITY   -3.756E+01   -2.959E+02   -5.585E+02   -8.415E+02
PARTICLE REYNOLDS NO.    1.228E+00    6.675E+00    1.453E+01    2.373E+01
PARTICLE TEMPERATURE     2.527E+03    2.634E+03    2.715E+03    2.792E+03
PARTICLE DENSITY         1.208E-05    7.015E-05    9.811E-05    3.204E-05
 PARTICLE MOMENTUM FLUX        2.650E+00
--- STREAMLINE=    2  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.0102E+05  T= 2.455E+03  DENSITY= 3.083E-04  REYNOLDS NO.= 6.902E+21  Y2= 1.642E+00  H2= 1.642E+00
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY      1.892E+05    1.681E+05    1.535E+05    1.427E+05
CROSS-STREAM VELOCITY   -1.103E+02   -5.540E+02   -8.011E+02   -1.096E+03
PARTICLE REYNOLDS NO.    1.244E+00    6.740E+00    1.449E+01    2.366E+01
PARTICLE TEMPERATURE     2.523E+03    2.628E+03    2.710E+03    2.788E+03
PARTICLE DENSITY         1.207E-05    6.794E-05    9.200E-05    2.912E-05
 PARTICLE MOMENTUM FLUX        2.524E+00
---STREAMLINE=    3  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.0111E+05  T= 2.454E+03  DENSITY= 3.082E-04  REYNOLDS NO.= 6.877E+21  Y2= 2.461E+00  H2= 2.458E+00
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY      1.891E+05    1.681E+05    1.534E+05    1.426E+05
CROSS-STREAM VELOCITY   -2.599E+02   -8.670E+02   -1.252E+03   -1.525E+03
PARTICLE REYNOLDS NO.    1.233E+00    6.718E+00    1.447E+01    2.364E+01
PARTICLE TEMPERATURE     2.523E+03    2.628E+03    2.710E+03    2.788E+03
PARTICLE DENSITY         1.222E-05    6.815E-05    9.195E-05    2.902E-05
 PARTICLE MOMENTUM FLUX        2.524E+00
---STREAMLINE=    4  S=    10.20905
 -- LOCAL GAS PROPERTIES
 U= 2.010E+05  T= 2.454E+03  DENSITY= 3.075E-04  REYNOLDS NO.= 6.851E+21  Y2= 3.280E+00  H2= 3.275E+00
----- PARTICLE PHASE PROPERTIES -----
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY      1.891E+05    1.681E+05    1.534E+05    1.426E+05
CROSS-STREAM VELOCITY   -[illegible]  -1.2[illegible]  -1.720E+03   -2.014E+03
PARTICLE REYNOLDS NO.    1.230E+00    6.698E+00    1.443E+01    2.358E+01
PARTICLE TEMPERATURE     2.523E+03    2.629E+03    2.711E+03    2.788E+03
PARTICLE DENSITY         1.224E-05    6.820E-05    9.184E-05    2.888E-05
 PARTICLE MOMENTUM FLUX        2.524E+00
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***STREAMLINES     5  S=     10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.011E+05  T= 2.450E+03  DENSITY= 3.065E-04  REYNOLDS NO.= 6.825E+21  V2= 6.000E+00  W2= 6.000E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY     1.891E+05    1.688E+05    1.534E+05    1.428E+05
CROSS-STREAM VELOCITY  -6.755E+02   -1.671E+03   -2.145E+03   -2.511E+03
PARTICLE REYNOLDS NO.   1.257E+00    6.628E+00    1.441E+01    2.354E+01
PARTICLE TEMPERATURE    2.523E+03    2.628E+03    2.710E+03    2.768E+03
PARTICLE DENSITY        1.227E-05    6.873E-05    9.180E-05    2.888E-05
 PARTICLE MOMENTUM FLUX       2.535E+00
***STREAMLINES     6  S=     10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.009E+05  T= 2.451E+03  DENSITY= 3.157E-04  REYNOLDS NO.= 6.788E+21  V2= 6.915E+00  W2= 6.900E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1                         3            4
DOWNSTREAM VELOCITY     1.890E+05    1.688E+05    1.533E+05    1.425E+05
CROSS-STREAM VELOCITY  -8.215E+02   -2.014E+03   -2.605E+03   -2.967E+03
PARTICLE REYNOLDS NO.   1.228E+00    6.608E+00    1.438E+01    2.348E+01
PARTICLE TEMPERATURE    2.521E+03    2.626E+03    2.708E+03    2.767E+03
PARTICLE DENSITY        1.231E-05    6.888E-05    9.201E-05    2.892E-05
 PARTICLE MOMENTUM FLUX       2.538E+00
***STREAMLINES     7  S=     10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.009E+05  T= 2.452E+03  DENSITY= 3.063E-04  REYNOLDS NO.= 6.752E+21  V2= 5.733E+00  W2= 5.704E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY     1.890E+05    1.682E+05    1.533E+05    1.425E+05
CROSS-STREAM VELOCITY  -1.021E+03   -2.409E+03   -3.078E+03   -3.469E+03
PARTICLE REYNOLDS NO.   1.215E+00    6.565E+00    1.431E+01    2.337E+01
PARTICLE TEMPERATURE    2.519E+03    2.622E+03    2.707E+03    2.774E+03
PARTICLE DENSITY        1.241E-05    6.893E-05    9.218E-05    2.893E-05
 PARTICLE MOMENTUM FLUX       2.541E+00
***STREAMLINES     8  S=     10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.011E+05  T= 2.449E+03  DENSITY= 3.125E-04  REYNOLDS NO.= 6.720E+21  V2= 6.551E+00  W2= 6.515E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY     1.891E+05    1.687E+05    1.546E+05    1.435E+05
CROSS-STREAM VELOCITY  -1.247E+03   -2.905E+03   -3.666E+03   -4.101E+03
PARTICLE REYNOLDS NO.   1.218E+00    6.568E+00    1.411E+01    2.303E+01
PARTICLE TEMPERATURE    2.518E+03    2.621E+03    2.706E+03    2.761E+03
PARTICLE DENSITY        1.241E-05    6.951E-05    9.242E-05    2.918E-05
 PARTICLE MOMENTUM FLUX       2.578E+00
***STREAMLINES     9  S=     10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.013E+05  T= 2.448E+03  DENSITY= 2.998E-04  REYNOLDS NO.= 6.670E+21  V2= 7.370E+00  W2= 7.310E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY     1.892E+05    1.688E+05    1.538E+05    1.450E+05
CROSS-STREAM VELOCITY  -1.672E+03   -3.490E+03   -4.525E+03   -4.801E+03
PARTICLE REYNOLDS NO.   1.221E+00    6.515E+00    1.412E+01    2.306E+01
PARTICLE TEMPERATURE    2.513E+03    2.619E+03    2.700E+03    2.779E+03
PARTICLE DENSITY        1.252E-05    6.950E-05    9.248E-05    2.925E-05
 PARTICLE MOMENTUM FLUX       2.577E+00
***STREAMLINES    10  S=     10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.017E+05  T= 2.459E+03  DENSITY= 2.967E-04  REYNOLDS NO.= 6.626E+21  V2= 8.191E+00  W2= 8.121E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY     1.894E+05    1.691E+05    1.540E+05    1.431E+05
CROSS-STREAM VELOCITY  -2.145E+03   -4.280E+03   -5.188E+03   -5.849E+03
PARTICLE REYNOLDS NO.   1.252E+00    6.485E+00    1.391E+01    2.300E+01
PARTICLE TEMPERATURE    2.509E+03    2.614E+03    2.698E+03    2.750E+03
PARTICLE DENSITY        1.250E-05    7.013E-05    9.302E-05    2.958E-05
 PARTICLE MOMENTUM FLUX       2.615E+00
***STREAMLINES    11  S=     10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.021E+05  T= 2.458E+03  DENSITY= 2.927E-04  REYNOLDS NO.= 6.579E+21  V2= 9.018E+00  W2= 8.921E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY     1.898E+05    1.698E+05    1.544E+05    1.440E+05
CROSS-STREAM VELOCITY  -2.618E+03   -5.150E+03   -6.029E+03   -6.638E+03
PARTICLE REYNOLDS NO.   1.233E+00    6.381E+00    1.394E+01    2.255E+01
PARTICLE TEMPERATURE    2.507E+03    2.614E+03    2.699E+03    2.768E+03
PARTICLE DENSITY        1.258E-05    7.063E-05    9.395E-05    2.968E-05
 PARTICLE MOMENTUM FLUX       2.635E+00
***STREAMLINES    12  S=     10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.025E+05  T= 2.452E+03  DENSITY= 2.881E-04  REYNOLDS NO.= 6.511E+21  V2= 9.888E+00  W2= 9.719E+00
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1            2            3            4
DOWNSTREAM VELOCITY     1.901E+05    1.698E+05    1.552E+05    1.458E+05
CROSS-STREAM VELOCITY  -3.051E+03   -5.795E+03   -7.013E+03   -7.598E+03
PARTICLE REYNOLDS NO.   1.236E+00    6.397E+00    1.368E+01    2.261E+01
PARTICLE TEMPERATURE    2.503E+03    2.611E+03    2.692E+03    2.771E+03
PARTICLE DENSITY        1.268E-05    7.126E-05    9.519E-05    2.998E-05
 PARTICLE MOMENTUM FLUX       2.688E+00
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***STREAMLINE=   13  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.032E+05  T= 2.429E+03  DENSITY= 2.823E-04  REYNOLDS NO.= 6.636E+21  Y2= 1.060E+01  R2= 1.051E+01
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.906E+05   1.703E+05   1.550E+05   1.449E+05
CROSS-STREAM VELOCITY  -3.580E+03  -6.750E+03  -8.142E+03  -8.699E+03
PARTICLE REYNOLDS NO.   1.237E+00   6.293E+00   1.347E+01   2.201E+01
PARTICLE TEMPERATURE    2.502E+03   2.612E+03   2.698E+03   2.769E+03
PARTICLE DENSITY        1.269E-05   7.143E-05   9.624E-05   3.041E-05
 PARTICLE MOMENTUM FLUX       2.718E+00
***STREAMLINE=   14  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.040E+05  T= 2.425E+03  DENSITY= 2.751E-04  REYNOLDS NO.= 6.361E+21  Y2= 1.152E+01  R2= 1.131E+01
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.911E+05   1.708E+05   1.555E+05   1.441E+05
CROSS-STREAM VELOCITY  -4.378E+03  -8.054E+03  -9.583E+03  -1.046E+04
PARTICLE REYNOLDS NO.   1.251E+00   6.243E+00   1.351E+01   2.214E+01
PARTICLE TEMPERATURE    2.494E+03   2.604E+03   2.687E+03   2.758E+03
PARTICLE DENSITY        1.274E-05   7.210E-05   9.722E-05   3.101E-05
 PARTICLE MOMENTUM FLUX       2.747E+00
***STREAMLINE=   15  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.052E+05  T= 2.411E+03  DENSITY= 2.660E-04  REYNOLDS NO.= 6.270E+21  Y2= 1.237E+01  R2= 1.211E+01
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.917E+05   1.714E+05   1.567E+05   1.459E+05
CROSS-STREAM VELOCITY  -5.500E+03  -9.908E+03  -1.105E+04  -1.307E+04
PARTICLE REYNOLDS NO.   1.295E+00   6.242E+00   1.324E+01   2.151E+01
PARTICLE TEMPERATURE    2.492E+03   2.603E+03   2.690E+03   2.760E+03
PARTICLE DENSITY        1.277E-05   7.336E-05   1.003E-04   3.245E-05
 PARTICLE MOMENTUM FLUX       2.853E+00
***STREAMLINE=   16  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.067E+05  T= 2.394E+03  DENSITY= 2.548E-04  REYNOLDS NO.= 6.192E+21  Y2= 1.324E+01  R2= 1.291E+01
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.926E+05   1.721E+05   1.572E+05   1.461E+05
CROSS-STREAM VELOCITY  -7.049E+03  -1.261E+04  -1.494E+04  -1.682E+04
PARTICLE REYNOLDS NO.   1.353E+00   6.282E+00   1.323E+01   2.145E+01
PARTICLE TEMPERATURE    2.479E+03   2.582E+03   2.672E+03   2.742E+03
PARTICLE DENSITY        1.279E-05   7.535E-05   1.059E-04   3.563E-05
 PARTICLE MOMENTUM FLUX       3.002E+00
***STREAMLINE=   17  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.079E+05  T= 2.362E+03  DENSITY= 2.414E-04  REYNOLDS NO.= 6.123E+21  Y2= 1.414E+01  R2= 1.373E+01
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.936E+05   1.736E+05   1.580E+05   1.473E+05
CROSS-STREAM VELOCITY  -8.654E+03  -1.593E+04  -2.007E+04  -2.462E+04
PARTICLE REYNOLDS NO.   1.375E+00   6.171E+00   1.313E+01   2.129E+01
PARTICLE TEMPERATURE    2.467E+03   2.584E+03   2.676E+03   2.763E+03
PARTICLE DENSITY        1.294E-05   8.180E-05   1.245E-04   4.786E-05
 PARTICLE MOMENTUM FLUX       3.503E+00
***STREAMLINE=   18  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.133E+05  T= 2.311E+03  DENSITY= 2.321E-04  REYNOLDS NO.= 6.033E+21  Y2= 1.504E+01  R2= 1.453E+01
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     1.959E+05   0.          0.          0.
CROSS-STREAM VELOCITY  -8.134E+03   0.          0.          0.
PARTICLE REYNOLDS NO.   1.573E+00   0.          0.          0.
PARTICLE TEMPERATURE    2.435E+03   0.          0.          0.
PARTICLE DENSITY        1.344E-05   0.          0.          0.
 PARTICLE MOMENTUM FLUX       2.548E-01
***STREAMLINE=   19  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.180E+05  T= 2.199E+03  DENSITY= 2.618E-04  REYNOLDS NO.= 5.887E+21  Y2= 1.590E+01  R2= 1.522E+01
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     0.          0.          0.          0.
CROSS-STREAM VELOCITY   0.          0.          0.          0.
PARTICLE REYNOLDS NO.   0.          0.          0.          0.
PARTICLE TEMPERATURE    0.          0.          0.          0.
PARTICLE DENSITY        0.          0.          0.          0.
 PARTICLE MOMENTUM FLUX       0.
***STREAMLINE=   20  S=    10.20905
 ** LOCAL GAS PROPERTIES
 U= 2.101E+05  T= 2.291E+03  DENSITY= 3.125E-04  REYNOLDS NO.= 5.871E+21  Y2= 1.667E+01  R2= 1.583E+01
***** PARTICLE PHASE PROPERTIES *****
PARTICLE GROUP              1           2           3           4
DOWNSTREAM VELOCITY     0.          0.          0.          0.
CROSS-STREAM VELOCITY   0.          0.          0.          0.
PARTICLE REYNOLDS NO.   0.          0.          0.          0.
PARTICLE TEMPERATURE    0.          0.          0.          0.
PARTICLE DENSITY        0.          0.          0.          0.
 PARTICLE MOMENTUM FLUX       0.
 BOUNDARY OF PARTICLE PHASE AT S=   10.61209  1.479E+01  1.417E+01  1.376E+01  1.362E+01
 BOUNDARY OF PARTICLE PHASE AT S=   11.01090  1.496E+01  1.431E+01  1.389E+01  1.353E+01
 BOUNDARY OF PARTICLE PHASE AT S=   11.41940  1.513E+01  1.447E+01  1.403E+01  1.366E+01
 BOUNDARY OF PARTICLE PHASE AT S=   11.82986  1.530E+01  1.462E+01  1.417E+01  1.378E+01
 BOUNDARY OF PARTICLE PHASE AT S=   12.25150  1.547E+01  1.476E+01  1.431E+01  1.391E+01
 BOUNDARY OF PARTICLE PHASE AT S=   12.67440  1.564E+01  1.493E+01  1.445E+01  1.405E+01
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APPENDIX C

SAMPLE OUTPUT - EXPLANATIONS

APPENDIX C

SAMPLE OUTPUT - EXPLANATIONS

The first page of output contains all the input data on Cards 1-5 and 7, followed by the species identification data (Card 9) and the distributions of properties along the initial orthogonal surface. The units of each variable are identical with those used for the input data. These are followed by the axis location and the nozzle wall contour.

The standard printed output at each value of KP (Card 5, Cols. 11-15) or DXLSS (Card 3, Cols. 11-22) gives properties for each streamtube, from K (streamtube index) = 2 to K = KMAX. In addition to the usual output* i.e. X, R, PHI, T, P, U, the following properties are printed:

	MA	Mach number
	DELY	streamtube width (cm)
	H	enthalpy (cal/g)
	HT	stagnation enthalpy (cal/g)
	TAW	shear stress at tube interface (dynes/cm^2)
	Q	heat flux at tube interface (cal/cm^2-sec)
	PT	dynamic pressure (atm)
	RHO	density (g/cm^3)
	SX	distance along streamtube (cm)
	SUMDOT	total mass flow bounded by streamtube (g/sec)
	C	species mass fraction
	X	species mole fraction
	WDOT	species production rate (g/cm^3 sec)
only for viscous flows	F1	total mass flow of species up to present streamtube (g/sec)
	ZJ	species flux at tube interface

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* X and R refer to the coordinates of the outer boundary of streamtube while the flow properties are average values across the streamtube.

Boundary layer parameters, if computed, are printed between the tube properties and the composition data in the last streamtube (at downstream print stations). The following parameters are printed:

RES	Reynolds number based on distance along wall
DELTAI	boundary layer thickness (incompressible)
THETAI	momentum thickness (incompressible)
CFI	skin friction coefficient (incompressible)
UFI	friction velocity (incompressible)
DISP	displacement thickness
DELTAC	boundary layer thickness
THETAC	momentum thickness
CFC	skin friction coefficient
H12	shape factor (= DISP/THETAC)
QWALL	heat flux at wall (cal/cm^2-sec)
TAUWALL	shear stress at wall (dynes/cm^2)
U/UE	B.L. velocity profile (UE = velocity in last tube)
T/TE	B.L. temperature profile (TE = temperature in last tube)
Y/DEL	location in B.L. (DEL ≡ DELTAC)

If IPART = 1, particle properties are printed; first, a NAMELIST of the input data on Cards 15 through 19 (and 20 through 23 for NC = 0), followed by the initial particle properties in each streamtube. The standard particle print gives the downstream and cross-stream velocity, temperature, Reynolds number and particle cloud density for each particle group and total particle momentum flux, for each streamtube. Since, typically, the limiting particle streamlines are within streamtube KMAX the outer tubes will contain no particles Limiting particle streamlines are noted as, 'BOUNDARY OF PARTICLE PHASE AT S = X.XXXXX', followed by the radial position of the limiting particle streamline for each particle group. If the particles are initially in the liquid phase the program will print where they start to solidify.

APPENDIX D

FORTRAN LISTING

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      PROGRAM FNOZ(INPUT,OUTPUT,TAPE5,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,     MAIN        2
     1 TAPE8,TAPE9,TAPE10)                                                MAIN        3
C     *********************************************************************MAIN        4
C     **              FULLY COUPLED NOZZLE PROGRAM                     ** MAIN        5
C     **          AEROCHEM RESEARCH LABORATORIES, INC.                 ** MAIN        6
C     **                 PRINCETON, NEW JERSEY   08540                 ** MAIN        7
C     *********************************************************************MAIN        8
      COMMON A(25,7)     ,AA(40)      ,ALFA(25,25),ALPHAN    ,ALPHAP      A           2
     1       ,ATOL       ,BETAP       ,BMIX       ,C11(25)    ,C(25,40)   A           3
     2       ,C12(25)    ,C2(25,40)   ,CABAR(25)  ,CBBAR(25)  ,CP         A           4
     3       ,CPS(25)    ,CPSH        ,CSH(25)    ,CSH1(25)   ,CSTREM(25) A           5
     4       ,MXSTRM     ,D2IN(25,25),DEFF(25)    ,D2EFF(25)  ,DELTA      A           6
     5       ,D11        ,DELSS(40)   ,DELS       ,DELSU      ,DLS(40)    A           7
     6       ,DIM(25,25) ,D12         ,DELY(40)   ,D13        ,DPDY(40)   A           8
     7       ,D14        ,DPHIUS(40)  ,EPCON                              A           9
     8       ,EPSLON     ,EXTRA(50)   ,FSTEP      ,FMAX       ,GRAD       A          10
     9       ,H11        ,H(40)       ,HH         ,HJ         ,HPM(25)    A          11
     *       ,H2PM(25)   ,HSPM(25)    ,ICONST     ,ICOUNT     ,IDENT(25)  A          12
     1       ,IERROR     ,IEXTRA(50)  ,IFLAG      ,IKIND                  A          13
     2       ,IPTOL      ,ISHOCK      ,ITYPE      ,IPO                    A          14
     3       ,IDIFF      ,K           ,KAY        ,KAYS       ,KAY2       A          15
     4       ,KLO        ,KMAX                                            A          16
     5       ,KUP        ,KW          ,LL         ,LPLANE     ,MA         A          17
     6       ,MASH       ,MCOI        ,MMAX       ,MOU        ,MU         A          18
     7       ,MU2        ,MUS         ,MW         ,MW2        ,MWSH       A          19
     8       ,NBOUND     ,NDS         ,NITER      ,NMAX       ,NN         A          20
      COMMON NUCASE      ,OMEGA(25)   ,P11        ,P(40)      ,P12        A          21
     1       ,P2(40)                  ,PB(50)     ,PABAR      ,PBBAR      A          22
     2       ,PHS        ,P15         ,PHI(40)                ,PHIN(50)   A          23
     3       ,PHISH1     ,PHSTRM                  ,PHIW(50)   ,P16        A          24
     4       ,PHI2(40)   ,PHIUS       ,PI         ,PH(25)     ,PSH        A          25
     5       ,PSH1       ,PSI         ,PSTREM                 ,PW(50)     A          26
     6       ,Q11        ,Q(40)       ,QXTR1      ,QXTR2                  A          27
     7       ,QW(50)     ,R11         ,R(40)                  ,RB(50)     A          28
     8       ,RHS        ,R13         ,RBAR(40)   ,R14        ,R2(40)     A          29
     9       ,RCON       ,R15         ,RE(40)     ,RESH       ,R16        A          30
     *       ,RHO(40)    ,R17         ,RHO2(40)   ,RHS(25)    ,RHSEN      A          31
     1       ,RHSMOM     ,RHABAR      ,RHOBAR     ,RU         ,RSH        A          32
     2       ,RSTREM     ,RV          ,R19        ,RW(100)    ,S          A          33
     3                   ,SH(50)      ,SC(25)                 ,SW(50)     A          34
     4       ,S13        ,SX(40)      ,T11        ,T(40)      ,T12        A          35
     5       ,T2(40)     ,TABAR       ,TBBAR      ,T0(25)     ,T14        A          36
     6       ,TAX(40)    ,TXTR1       ,TXTR2      ,TOL        ,TSH        A          37
     7       ,TSH1       ,TSTREM                  ,TW(50)     ,TWS        A          38
     8       ,TS         ,U11         ,U(40)      ,U12        ,U2(40)     A          39
      COMMON UXTR1       ,UXTR2       ,U14        ,UBAR(40)   ,USH        A          40
     1       ,USH1       ,USTREM                  ,UW(50)     ,UWS        A          41
     2       ,X11        ,X(40)       ,X12        ,X2(40)                 A          42
     3       ,XW(50)     ,XWS         ,XABAR(25)  ,XBBAR(25)  ,X15        A          43
     4       ,XS(25,40)  ,XSH         ,XSTREM                 ,XW(50)     A          44
     5       ,ZXXX(40)                ,Y11        ,Y(40)      ,Y12        A          45
     6       ,Y2(40)     ,YABAR       ,YBBAR      ,ZA(25)     ,Z11(25)    A          46
     7       ,ZJ(25,40)  ,ZHW         ,S2X        ,W2SH       ,X2SH       A          47
     8       ,FX(2,40)   ,FW(2,40)    ,FPHI(2,40) ,FP(2,40)   ,FT(2,40)   A          48
     9       ,FU(2,40)   ,INDL(2,40)  ,INDW(2,40) ,FC(2,40,25),CANDI      A          49
     *       ,W          ,K                                               A          50
      DIMENSION IP(20)                                                    MAIN       10


      DIMENSION G(2),GG(2,2),A1(2)                                        MAIN       11
      REAL    KAY          ,KAYS(25)    ,KAY2       ,KK         ,MDOT(40) MAIN       12
     *       ,MW(40)       ,MU          ,MUS(25)    ,MOU(25)    ,MU2      MAIN       13
     *       ,MW(25)       ,MW2         ,MASH       ,MASH1      ,MASH     MAIN       14
     * ,      KAP                                                         MAIN       15
      COMMON/P11/SHOPV(8), SHOMP(8),ENEP1(8),HEP(40,8),V(40,8),W(40,8),   MAIN       16
     1V2(40,8), W2(40,8), THOOV(8), TP(40,8), TP2(40,8), WP(8),           MAIN       17
     2HMP(40,8), HMP2(40,8) ,ENEP2(8),RML(8),UM(40)                       MAIN       18
     3,VOLP(8),XIF(8),PC(8),DENG(40,8),ICOND(40,8)                        MAIN       19
      COMMON/P12/PPI,PPL,GAMA,CPI,PU,RPL,KPL,UMDSP(8)                     MAIN       20
       COMMON/P15/LL,CS,TPS,WMSS,XI,XINAR,SIG,EP,IPART,IKINE,IK(40)       MAIN       21
     1 ,SUMP,SUMPV,SUMPE                                                  MAIN       22
      COMMON/MAINSH/ KOUNT,KINT                                           MAIN       23
      COMMON/IROUSI/ IPUUSH                                               MAIN       24
      COMMON/CHEMI/ ZID(5), IWW(40),IWT(40),WC(40,3),IWWW(40,5),          MAIN       25
     1 AV,CM(20,20),FI(20),AM(20),                                        MAIN       26
     2 PM(20),CUT(20,40),CST(20),CX(20)                                   MAIN       27
      COMMON/INIT/KLX,IXI,KEX                                             MAIN       28
      COMMON/WMEII/WMET(40)                                               MAIN       29
      COMMON/INPUT/ITP,XU,YO,FRAC  ,XPL                                   MAIN       30
      COMMON/SHOPUT/ PSHP,RSHP,PSIP,PSHA,TSHA,USHA,CSHA(25)               MAIN       31
      COMMON/INSHOK/ KEL,IHO,UHU,PHIPJ,CIN(25)                            MAIN       32
      COMMON/ALP/ALPHC                                                    MAIN       33
      COMMON/XYZ/IXYZ,JXYZ                                                MAIN       34
      DOUBLE PRECISION ERROR (3)                                          MAIN       35
      EQUIVALENCE (MUVP,IEXTRA(15))                                       MAIN       36
      EQUIVALENCE (KALAMW, IEXTRA(20))                                    MAIN       37
      DATA ERROR / 8HFAILS,8HEQDRY,8HSTEP /                               MAIN       38
C     SETTING UP THE PROBLEM                                              MAIN       39
C     REVISED SUBSCRIPTS (ZEROS DELETED)                                  MAIN       40
      WRITE(6,150)                                                        MAIN       41
  150 FORMAT(1H1,////////////61X,40FULLY COUPLED NOZZLE FLOW PROGRAM,///  25SEPT      1
     1 46X,44HAEROCHEM RESEARCH LABORATORIES, INC.,//45X,                 25SEPT      2
     2 44HPRINCETON, NEW JERSEY 08540)                                    25SEPT      3
      IXY=81                                                              MAIN       46
      JXY=80                                                              MAIN       47
      IDATA=0                                                             MAIN       48
      READ(5,50) NDATA                                                    MAIN       49
  201 CONTINUE                                                            MAIN       50
      READ (5,9006) (IC(I), I=1,20)                                       MAIN       51
      WRITE (6,9007) (IC(I),I=1,20)                                       MAIN       52
 9006 FORMAT (20A4)                                                       MAIN       53
 9007 FORMAT (1H1,20A4)                                                   MAIN       54
      WRITE(6,51) NDATA                                                   MAIN       55
```

```
   51 FORMAT (1H0,/10X,17HNO. OF DATA SETS   ,I5)                        MAIN    56
      DO 5 I=1,7971                                                    MAIN    57
    5 A(I,1)=0.0                                                       MAIN    58
      NALARM=0                                                         MAIN    59
      NOUNT=0                                                          MAIN    60
      KINT=0                                                           MAIN    61
      LL=-1                                                            MAIN    62
      READ (5,50) FSEC,DXLSS,XLMAX,XLMOD,IMO,NNT                       MAIN    63
      WRITE (6,52) FSEC,DXLSS,XLMAX,XLMOD,IMO,NNT                      MAIN    64
   50 FORMAT(I10,3E12.5,2I2)                                           MAIN    65
   52 FORMAT (1H ,4X,5HNSEC=,I5,4X,6HDXLSS=,1PE10.3,4X,6HXLMAX=,E10.3, MAIN    66
     *  4X,6HXLMOD=,E10.3,4X,4HIMO=,I5,4X,4HNNT=,I5///)                MAIN    67
      XLMX=DXLSS                                                       MAIN    68


      FSEC=NSEC                                                        MAIN    69
      IOLD=0.                                                          MAIN    70
      ANG=1.                                                           MAIN    71
      XLM=1.E10                                                        MAIN    72
  100 CALL RDTIN                                                       MAIN    73
      DO105 I=1,NMAX                                                   MAIN    74
  105 RME(I)=0.0                                                       MAIN    75
      IF (IPART.NE.0) CALL RROTIN                                      MAIN    76
      IF (INIKF.NE.0) CALL CROTIN(IDENT,INIKF,NOS)                     MAIN    77
      IF(ININD.LT.3.OR.INI.NE.0) GO TO 21                              MAIN    78
      CPM=0.0                                                          MAIN    79
      ZMM=0.0                                                          MAIN    80
      DO109 I=1,NOS                                                    MAIN    81
      ZMM=ZMM+CSINEM(I)/MP(I)                                          MAIN    82
  109 CPM=CPM+CSTREM(I)*A(I,3)                                         MAIN    83
      ZMM=1.0/ZMM                                                      MAIN    84
      EMF=U/STREM*SQRT((CPM/MM-RCON)/(CPM*ISTREM*RU))                  MAIN    85
      PE=0.0                                                           MAIN    86
      EM=0.0                                                           MAIN    87
      DO25 I=2,NMAX                                                    MAIN    88
      EM=EM+MA(I)                                                      MAIN    89
   25 PE=PE+P(I)                                                       MAIN    90
      EM=EM/(NMAX-1)                                                   MAIN    91
      PE=PE/(NMAX-1)                                                   MAIN    92
      IF(IPART.EQ.0) GO TO 25                                          MAIN    93
      NMG=0.0                                                          MAIN    94
      PGM=0.0                                                          MAIN    95
      DO24 I=2,NMAX                                                    MAIN    96
      NMG=NMG+MU(I)                                                    MAIN    97
      DO24 J=1,NPG                                                     MAIN    98
      K=I-1                                                            MAIN    99
   24 PGM=PGM+NMP2(K,J)                                                MAIN   100
      PGM=PGM/NMG                                                      MAIN   101
      GO TO 26                                                         MAIN   102
   25 PGM=0.0                                                          MAIN   103
      WRITE(6,282) PE,PSTREM,GAMA,EMF                                  MAIN   104
   26 XLM=XMEX0.6*EMF*SQRT(GAMA*PE/PSTREM)/(EMF**.25*(1.+.197*EM**1.45*P MAIN   105
     *GM**.65))**2.                                                    MAIN   106
      WRITE(9,5) XLM                                                   MAIN   107
    5 FORMAT(E12.5)                                                    MAIN   108
      IF(ININD.LT.3) XLM=1.E10                                         MAIN   109
      IF(IMO.NE.0) XLM=XLMOD                                           MAIN   110
      WRITE(6,28) XLM                                                  MAIN   111
   28 FORMAT(2X,5HXLM =,E12.5)                                         MAIN   112
      GO TO 104                                                        MAIN   113
   21 IF(ISHOCK.EQ.1) GO TO 101                                        MAIN   114
      PE=PE+PSTREM                                                     MAIN   115
      GAMM=CPM/(CPM-RCON/ZMM)                                          MAIN   116
      EME=MA(NMAX)                                                     MAIN   117
      SEM2=SQRT(EME**2-1.0)                                            MAIN   118
      EM2=EME**2                                                       MAIN   119
      THE=PH(NMAX)                                                     MAIN   120
      PE=P(NMAX)                                                       MAIN   121
      EM=EME*(PE/PEE**.5)**((GAMA-1.)/GAMA)                            MAIN   122
      IL=1,EM=EMO                                                      MAIN   123
      C1=SQRT((GAMA+1.)/(GAMA-1.))                                     MAIN   124
      C3=GAMA/(GAMA-1.)                                                MAIN   125


      THE=C1*ATAN(SEM2/C1)-ATAN(SEM2)-THN                              MAIN   126
      DO 104 II=1,100                                                  MAIN   127
      EM2=EM**2                                                        MAIN   128
      SQEM=SQRT(EM2-1.0)                                               MAIN   129
      ZTA=C1*ATAN(SQEM/C1)-ATAN(SQEM)-THE                              MAIN   130
      PP=PE*((1.+(GAMA-1.)/2.*EME**2)**C3/(1.+(GAMA-1.)/2.*EM**2)**C3) MAIN   131
      ETA=ASIN (SQRT(1.+(GAMM+1.)/(2.*GAMM)*(PP/PENF-1.))/EMF)         MAIN   132
      SINETA=SIN(ETA)                                                  MAIN   133
      SETA2=SINETA**2                                                  MAIN   134
      COSETA=COS(ETA)                                                  MAIN   135
      F=((EMF*SINETA)**2-1.)/TAN(ETA)/((GAMM+1.)/2.*EMF2-(EMF*SINETA)  MAIN   136
     1   **2+1.) -TAN(ZTA)                                             MAIN   137
      [illegible]                                                      MAIN   138
      [illegible]                                                      MAIN   139
      [illegible]                                                      MAIN   140
      [illegible]                                                      MAIN   141
      [illegible]                                                      MAIN   142
     1[illegible]                                                      MAIN   143
     2[illegible]                                                      MAIN   144
      IF (ABS(DEL) .LT. 1E-3) GO TO 107                                MAIN   145
      [illegible]                                                      MAIN   146
  104 CONTINUE                                                         MAIN   147
      WRITE (6,108)  [illegible]                                       MAIN   148
  108 FORMAT(1H0,27HITERATION DOES NOT CONVERGE ,10X,E12.5)            MAIN   149
  107 CONTINUE                                                         MAIN   150
```

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```
      PSI=BETA
      PS=PP
      ASHOM(NMAX)
      ASHOP(NMAX)
      GPI=(GAMMA+1.)/(GAMMA-1.)
      TSH=TSTHE*(PP/PENF+GM1)
     1 (    GP1+PENF/PP)
      UN=(PP/PENF+GP1)/(GM1+PP/PENF+1.)+USTHE*SINBETA
      USH=SQRT((USTHE*COSBTA  )**2+UN**2)
  100 CONTINUE
  101 AMA2= AMA*2
      ICONT=0
      INTGE=ALPHAP
      NUCASE=0
      JTHRU=0
      LL=0
      S=0.0
      FLAG=1.0E5
      SPDT=0.0
      IAA=P
      LIAT=0
      SLEL=(1.0E-8)*NE
C     ESTABLISHING STABLE STEP SIZE
  200 TIME=0.0
      TLEFT=FSEC-TIME
      TSTEP=TIME-TOLD
      IF (LL.LE.0) GO TO 205
      IF (TSTEP.GT.(0.5*TLEFT)) GO TO 210
  205 TOLD=TIME
      CALL STABLE
      NCOUNT = 0
      ICOUNT=0


      MOVE=0
      IF((LL.GT.LPLANE).OR.(X(2).GT.XLMAX)) GO TO 210
      IF(X2(2).GE.XLPD.AND.ISHOCK.NE.4) GO TO 206
      IF((IMO.NE.0).OR.(X2(2).LT.XLMD)) GO TO 250
C     TAKE OUT
      GO TO 303
C     TAKE OUT
  303 GAMMA=GAMA
      GAMMA=GAMA
      PSH1=P2(2)
      TSH1=T2(2)
      USH1=U2(2)
      MASH1=MA(2)
      MASH=ZMAH(2)
      H1=H(2)
      ITER=0
      DELPHI=PHI2(2)
      IF(ICONST) 3500,3400,3500
 3400 B1=-(MASH1**2+2.0)/(MASH1**2)-GAMMA*SIN(DELPHI)**2
      B2=(2.0*MASH1**2+1.0)/(MASH1**4)
      B3=B2+((GAMMA+1.0)**2/4.0+(GAMMA-1.0)/(MASH1**2))*SIN(DELPHI)**2
      FS=C(S  E(PHI))**2/(MASH1**4)*.-1.0)
      ZETA=(1.0/MASH1*SIN(DELPHI))**2
 2700 ITER=ITER+1
      GG=ZETA**3+B1*ZETA**2+B2*ZETA+B3
      DGDZ=3.0*ZETA**2+2.0*B1*ZETA+B2
      DLZETA=-GG/DGDZ
      IF(ABS(DLZETA/ZETA)-TOL) 2100,2005,2005
 2005 IF (ITER-NITER) 2900,2900,2000
 2900 ZETA=ZETA+DLZETA
      GO TO 2700
 2000 WRITE (6,2050)
 2050 FORMAT(27H ITERATIONS FOR ZETA FAILED)
      CALL POUPP (A(1,1),N,S)
C     DETERMINATION OF SHOCKED GAS PROPERTIES
 2100 CONS=CP  *TSH1+USH1**2/(2.0*HJ)
      PS =(2.0*GAMMA*MASH1**2*ZETA-GAMMA+1.0)/(GAMMA+1.0)*PSH1
      TS =(PS /PSH1)*((GAMMA-1.0)*MASH1**2*ZETA+2.0)
      TS =TS /((GAMMA+1.0)*MASH1**2*ZETA)*TSH1
      US =SQRT(2.0*HJ*(CONS-CP  *TS ))
      THS=ASIN (SQRT(ZETA))
      IF (IHUGSH.NE.0) WRITE (6,2220) PS  ,TS  ,US  ,ZETA
 2220 FORMAT (1X,2HPS,1P1E11.4,3X,5HTSH =,1P1E11.4,3X,5HUSH =,1P1E11.4,
     *3X,5HZETA=,1P1E11.4)
       GO TO 4000
 3500 THS=PHI2(2)*(GAMMA+1.)/2.000
      TS=2.*TSH1
 3200 E=MASH1**2
      F=GAMMA+1.
      TERM1=GAMMA*F*DELPHI/SQRT(E-1.)
      TERM2=TERM1*(F*E**2-4.*(E-1.))*DELPHI/(4.*(E-1.)**(3./2.))
      IF (ITER.GT.0.001*TERM1) GO TO 2250
      TERM3=TERM1*(F*E**2*E**4/32.-(7.+12.*GAMMA-3.*GAMMA**2)*E**3+.75*F*E
     ***2*E*2./3.)*DELPHI**2/(E-1.)**3
      X=1.+TERM1+TERM2+TERM3
      ZETA=(F*X*E-2.)/(2.*GAMMA*E)
      GO TO 2100


 2250 ITER=ITER+1
      H2=0.0
      C2=C.0
      DO 2500 I=1,NCS
      DO 2500 J=1,NN
      H2=H2+A(I,J)*C2(I,2)*TS**(J-2)
 2500 C2=C2+CONT(J-2)*A(I,J)*TS**(J-3)*C2(I,2)
```

```
      S1=SIN(THB)
      S10=SIN(THB-DELPHI)
      C1=COS(THB)
      C10=COS(THB-DELPHI)
      TA1=S1/CLOT
      TA0=S10/C10
      CO1=COT*CLOT
      C0=C0*C1
      G(1)=C(H2-H1-US-1)**2-(1.+ C1/(2/C0)  1/(2.*M)))
      G(2)=...
     *1*(1.-TAU/TA1))
      G(1,1)=C2
      G(1,2)=USH1**2*CLOT*(CUT*TAN-S1))/(H-C0)
      G(2,1)=PSH1/TA1
      [illegible]
     *...(1.-TAU/TA1)*CLOT  /CLOT  *TAU/TA1)
      IF (IPROBSH.ET.0) WRITE (6,2950) G(1),G(2),IS,THB,G(1,1),G(1,2)
     *,G(2,1),G(2,2)
 2950 FORMAT (12E.12.5)
      TTYP.0
      CALL ...(2,2,...,TTY,AA,J)
      GO TO (2600,2601,2500),J
 2600 WRITE (6,2605)
 2605 FORMAT (62H1SIGNIFICANT OVERFLOW IN SUBROUTINE SHOCK)
      GO TO 2510
 2500 WRITE (6,2505)
 2505 FORMAT (42H1SINGULAR DETERMINANT IN SUBROUTINE SHOCK)
 2510 CALL ...(A(1,1),4,1)
      CALL EXIT
 2600 DO 2650 I=1,2
 2650 AA(I)=G(I,1)
      IF (ABS(AA(1)/IS)-TLL ) 2600,2705,2705
 2705 IS=IS+AA(1)
      THB=THB+AA(2)
      IF (ITER-ITMAX) 3200,3200,2750
 2750 WRITE (6,2050)
      GO TO 2510
 2800 IF (ABS(AA(2)/THB)-SCRIT(TOL)) 2905,2700,2700
 2905 CS  ...
      PS  ...(1.-TAU/TA1))
      ZETA=SIN(THB)**2
 4000 WRITE(7,220)  X2(1),H2(1),THB,PS,TS,US
      WRITE (6,5000) X2(1),H2(1),THB,PS,TS,US
      WRITE(7,230)  (C2(I,2),I=1,NOS)
      WRITE (6,5001) (C2(I,2),I=1,NOS)
 5000 FORMAT(1H ,/5X,60HDOWNSTREAM OF REFLECTED SHOCK CONDITIONS,/5X,
     * 2HXS,1PE10.3,5X,2HHS,E10.3,5X,4HPS10,E10.3,5X,5HPS...,E10.3,
     1 5X,5HTS...,E10.3,5X,5HUS...,E10.3)
 5001 FORMAT (1H ,/5X,30HSPECIES MASS FRACTIONS  ...,/5X,A(1PE10.3,
     * 5X))
C     TAKE OUT
  305 CONTINUE
      ITYP=1
      ISH=NS1
      [illegible]
      ...ASIN(1./MA(2)))
      IF ... 02,10
      [illegible]
 1120 [illegible]
      [illegible]
      [illegible]
      [illegible]
      MA(2)=0.0
      WRITE (6,021)
      S(1)=S(2)
      [illegible]
      [illegible]
      [illegible]
 3500 [illegible]
      IF ... 4100,4200,4200
 4100 [illegible]
      GO TO 4800
 4200 [illegible]
      [illegible]
 4400 [illegible]
      IF ... 4600,4800,4500
 4500 [illegible]
      GO TO 4700
 4600 [illegible]
      [illegible]
      [illegible]
      [illegible]
      IF ... 3500,4400,4900
  820 FORMAT (1H ,10,12,14, ...)
  821 FORMAT (1H ,/20,...
     1  2HS)
 4900 ...
      J=1
      [illegible]
      GO TO 250
 2100 ...
      WRITE(7,220) ...
  220 FORMAT (6E12.5)
      IF ... 
      WRITE ... 
      WRITE(7,230) ...
  230 FORMAT(1P10.3)
  240 CONTINUE
      ...
      ...
```

```
      WRITE(7,221)X(1),H(1),X11,H(1),X(KMAX),H(KMAX),X22,H(KMAX)
  221 FORMAT(2E12.5/2E12.5/2E12.5/2E12.5)
      IF(IPING.LT.4) GO TO 207
      WRITE(7,220)X(KMAX),H(KMAX),PSI,PSN,TSN,USN
      WRITE(7,230)(CSTHEN(I),I=1,NOS)
      WRITE(7,220) XSTHEN,RSTHEN,PHSTAN,PSTHEN,TSTHEN,USTHEN
      WRITE(7,230) ((CSTHEN(I),I=1,NOS)


      IF(ITYPE.NE.3) GO TO 207
      WRITE(7,220) XSMN,RSMN,PSIN,PSMN,TSMN,USMN
      WRITE(7,230)  ((CSMN(I),I=1,NOS)
      WRITE(7,220) XOU,R(O),PHOU,POU,TOU,UOU
      WRITE(7,230)  ((COU(I),I=1,NOS)
      GO TO 207
  206 IF(I=1.EQ.0) GO TO 211
      WRITE(7,220)   X2(1),R2(1),PHI2(1)
      K=K
      DO 207 K=2,KMAX
      ILST2(K)=1.E-6
      RHOXY=.15
C     TAKE OUT
      RHOXY=(GAMA-1.)/(GAMA+1.)
C     TAKE OUT
      RHOY1=RHOU2(K)/RHOXY
      RHOY=RHO2(K)/RHOXY
      DO 40 II=1,100
      PY=P2(K)+RHOU2(K)*U2(K)**2*(1.-RHOXY)/BETAP
      HY=H(K)+U2(K)**2/(2.*HJ)*(1.-RHOXY**2)
      TY=T2(K)*PY/P2(K)*RHOXY
C     TAKE OUT
      GO TO 44
      DO 41 III=1,100
      DHYT=0.0
      HYT=0.0
      DO 42 I=1,NOS
      DO 42 JJ=1,NN
      HYT=HYT+A(I,JJ)*TY    **(JJ-2)*C2(I,K)
   42 DHYT=DHYT+A(I,JJ)*FLOAT(JJ-2)*TY   **(JJ-3)*C2(I,K)
      D=HYT-HY
      IF(ABS(D).LT.TL) GO TO 43
      TY=TY-D/DHYT
   41 CONTINUE
      WRITE(6,44) II,K,HY,HYT ,DHYT
      STOP
   43 RHOY1=PY*AZ/RRR(K)/HY/TY
      IF((ABS(RHOY1/RHOY)-1.) .LT. .001) GO TO 46
      RHOY=(RHOY1+RHOY)*.5
      RHOXY=RHOU2(K)/RHOY
   40 CONTINUE
      WRITE (6,44) II,K,RHOY,RHOY1,RHOXY
   44   FORMAT(2X,26HITERATIONS DO NOT CONVERGE,/2X,3HIT=,I3,2X,2HK=,I3,
     *2X,3HHY=,E12.5,2X,5HH(K)=,F12.5,2X,5HDHYT=,E12.5)
   46 UY=U2(K)*RHO2(K)/RHOY1
      WRITE(7,45) X2(1),R2(K),PY,TY,UY
      WRITE(6,45) X2(1),R2(K),PY,TY,UY
      WRITE(7,230)    (C2(I,K),I=1,NOS)
   45 FORMAT(2E12.5,12X,3E12.5)
  207 CONTINUE
      K=K
  207 IF (IPART.EQ.0) GO TO 266
      L=1
      KP=NHL(1)
      IF (NPG.LE.1) GO TO 265
      DO 261 J=2,NPG
      IF (KK.LT.NPG(J)) KP=NHL(J)


  261 CONTINUE
  265 CONTINUE
      WRITE(7,262) FFF,FFG,CL,CS,TRAN,AT,PC
      WRITE(7,262) RHSS,SIG,EP     ,TPS    ,UPI
      WRITE(7,263) NPG,NC
      WRITE(7,263) (NPL(J),J=1,NPG)
      WRITE(7,262) (HP(J),J=1,NPG)
      DO 264 K=1,KP
      WRITE(7,262) (F(K,J),J=1,NPG)
      WRITE(7,262) (V(K,J),J=1,NPG)
      WRITE(7,262) (TP(K,J),J=1,NPG)
      WRITE(7,262) (RHP(K,J),J=1,NPG)
      WRITE(7,263)(ILLND(K,J),J=1,NPG)
      WRITE(7,262)(DENG(K,J),J=1,NPG)
  264 CONTINUE
      WRITE(7,262) (IPLV(J),J=1,NPG)
      WRITE(7,262) (CONSP(J),J=1,NPG)
  262 FORMAT(6E12.5)
  263 FORMAT(8I5)
  266 CONTINUE
      IF(X2(2).GE.XLPT.AND.ISHOCK.NE.0) GO TO 212
      TDATA=TLATA+1
      IF (TDATA.LT.CDATA) GO TO 261
      CALL EXIT
  212 EPLAP=ELL+1
  211 XLP=1.E20
  250 IFLAG=0
      IF(DELS.LT.SEP) GO TO 4961
      K=1
      IF (ICOUNT    ) 261,270,260
  260 SS=DELS0
      DELS0=.S0DELS0
```

```
  875 AA(K)=PI*(R2(K)+R2(K-1))**DELTA*DELY(K)
      Y2(K)=Y2(K-1)+DELY(K)
      CALL STEP
      IF((IFLAG.NE.0) .AND.((K-1).LE.KMX2).AND.(IPART.NE.0)) CALL PART
      IF (KALARM) 885,885,877
  877 KALARM=0
      IF (ICOUNT-25)250,9910,9910
  885 IF (NUCASE) 9960,886,9960
  886 IF (MOVE) 1500,890,1500
  890 IF (INUGSH) 968,970,968
  968 CALL PUTOUT(3)
      JXYZ=10
      IF (IPART.NE.0) CALL PPTOUT(3)
  970 K=K+1
      IF (K-KMAX)  500,1000,1000
C     OUTER BOUNDARY CONDITIONS
 1000 KBOUND=1
      IK=0
      SPUT=0.0
      CALL RBDRY
      IF(MOVE) 801,1025,801
 1025 MOVE=0
      IF (KALARM) 1030,1030,877
 1030 IF (NUCASE) 9960,1050,9960
 1050 Y2(K)=Y2(K-1)+DELY(K)
      IF (INUGSH) 1060,1070,1060
 1060 CALL PUTOUT(3)
      JXYZ=11
      IF (IPART.NE.0) CALL PPTOUT(3)
 1070 IF (IFLAG) 1080,1150,1080
 1080 MAX=KMAX+1
      DO 1100 L=2,MAX
      J=L-1
      R(J)=R2(J)
      X(J)=X2(J)
      PHI(J)=PHI2(J)
      IF (J-1) 1100,1100,1062
 1062 U(J)=U2(J)
      P(J)=P2(J)
      T(J)=T2(J)
      RHO(J)=RHO2(J)
      ZM=0.0
      DO 1088 I=1,NDS
 1088 ZM=ZM+A(2,I,J)/W(I)
      ZM=1.0/ZM
      ZMW(J)=ZM
      DO 1086 I=1,NDS
      C(I,J)=C2(I,J)
 1086 XS(I,J)=C(I,J)*ZM/W(I)
      H(J)=0.0
      DO 1088 I=1,NDS
      DO 1088 JJ=1,NN
 1088 H(J)=H(J)+A(I,JJ)*T(J)**(JJ-2)*C(I,J)
      Y(J)= Y(J-1)+DELY(J)
      SX(J)=SX(J)+DLS(J)
 1100 CONTINUE
      IF (IKIND.GT.3) CALL SHOCKE
      ICONT=ICONT+1
      IF ((IFLAG.NE.0).AND.(IPART.NE.0))CALL PBNDY
      XXX2= XXX2
      LC=LC+1
      ICOUNT=0
      IF(MOD(ICONT,INTGER)) 201,1130,201
  201 IF(X (2).LT.XLMAX) GO TO 200
      [illegible]
 1130 K=K+1
      CALL PUTOUT(1)
      IF ((IFLAG.NE.0).AND.(IPART.NE.0))CALL PPTOUT(1)
      GO TO 200
 1150 IF (IKIND.GE.4) CALL SHOCKE
      IFLAG=1
      GO TO 5 [illegible]
C     ERROR MESSAGES
 9910 NUCASE=NTB
 9955 IERROR=1
 9960 IF (IERROR.EQ.0) GO TO 9966
      WRITE (6,9985) ERROR(IERROR),NUCASE
      WRITE (6,9960) IFLAG,ICONT,ICOUNT,MOVE,KALARM,IXYZ,JXYZ
C     CALL PCURVE (A(1,1),K,S)
      DO 9969 I=1,NDS
      IF(C2(I,K).LT.0.0) GO TO 9961
 9969 CONTINUE
      GO TO 9988
 9966 WRITE(6,9983) IERROR
      WRITE (6,9960) IFLAG,ICONT,ICOUNT,MOVE,KALARM,IXYZ,JXYZ
 9960 FORMAT (1H0,10X,23HPROGRAM EXIT CONDITIONS,/15X,8HIFLAG=,I3,4X,
     1 8HICONT=,I3,4X,7HICOUNT=,I3,4X,5HMOVE=,I3,4X,7HKALARM=,I3,
     2  /15X,14HSUBROUTINE NO.,I3,5X,8HAREA NO.,I3/)
 9983 FORMAT (1H0,/10X,7HIERROR=,I3/)
      GO TO 9988
 9961 WRITE(6,9962)
 9962 FORMAT(2X,11HNEGATIVE C2)
 9985 FORMAT(27H1ERROR ORIGIN IN SUBROUTINE,1X,A6,19H,  STATEMENT NUMBER
     *,I4,1H.)
 9988 CONTINUE
      CALL EXIT
      END
```

```
      SUBROUTINE BNDRY                                                  BNDRY   2
C     THIS SUBROUTINE HANDLES MOST BOUNDARY CONDITIONS                  BNDRY   3
      COMMON A(25,7)     ,AA(40)     ,ALFA(25,25),ALPHAH    ,ALPHAP     A       2
     1       ,ATOL       ,BETAP      ,BMIX       ,C11(25)   ,C(25,40)   A       3
     2       ,C12(25)    ,C2(25,40)  ,CABAR(25)  ,CBBAR(25) ,CP         A       4
     3       ,CPS(25)    ,CPSH       ,CSH(25)    ,CSH1(25)  ,CSTREM(25) A       5
     4       ,MXSTRX     ,D2IN(25,25),DEFF(25)   ,D2EFF(25) ,DELTA      A       6
     5       ,D11        ,DELSS(40)  ,DELS       ,DELSO     ,DLS(40)    A       7
     6       ,DIM(25,25) ,D12        ,DELY(40)   ,D13       ,DPDY(40)   A       8
     7       ,D14        ,DPHIDS(40) ,EPCON                             A       9
     8       ,EPSLON     ,EXTRA(50)  ,FSTEP      ,FMAX      ,GHAD       A      10
     9       ,H11        ,H(40)      ,HH         ,HJ        ,HPM(25)    A      11
     *       ,H2PM(25)   ,H3PM(25)   ,ICONST     ,ICOUNT    ,IDENT(25)  A      12
     1       ,IERROR     ,IEXTRA(50) ,IFLAG      ,IKIND                 A      13
     2       ,IPTOC      ,ISHOCK     ,ITYPE      ,IPO                   A      14
     3       ,IOTYP      ,K          ,KAY        ,KAYS      ,KAY2       A      15
     4       ,KCO        ,KMAX                                          A      16
     5       ,KUP        ,KR         ,LL         ,LPLANE    ,MA         A      17
     6       ,MASH       ,MDOT       ,MMAX       ,MUO       ,MU         A      18
     7       ,MU2        ,MUS        ,MR         ,MR2       ,MRSH       A      19
     8       ,NBOUND     ,NDS        ,NITER      ,NMAX      ,NN         A      20
      COMMON NUCASE      ,OMEGA(25)  ,P11        ,P(40)     ,P12        A      21
     1       ,P2(40)                 ,PB(50)     ,PABAR     ,PBBAR      A      22
     2       ,PBS        ,P15        ,PHI(40)               ,PHIN(50)   A      23
     3       ,PHISH1     ,PHSTRM                 ,PHIW(50)  ,P18        A      24
     4       ,PHI2(40)   ,PHIBS      ,PI         ,PR(25)    ,PSH        A      25
     5       ,PSH1       ,PSI        ,PSTREM                ,PW(50)     A      26
     6       ,Q11        ,Q(40)      ,QXTR1      ,QXTR2                 A      27
     7       ,QW(50)     ,R11        ,R(40)                 ,RB(50)     A      28
     8       ,RBS        ,R13        ,RBAR(40)   ,R14       ,R2(40)     A      29
     9       ,RCON       ,R15        ,RE(40)     ,RESH      ,R16        A      30
     *       ,RHO(40)    ,R17        ,RHO2(40)   ,RHS(25)   ,RHSEN      A      31
     1       ,RHSHOP     ,RHABAR     ,RHBBAR     ,RU        ,RSH        A      32
     2       ,RSTREM     ,RV         ,R19        ,RW(100)   ,S          A      33
     3                   ,SB(50)     ,SC(25)                ,SW(50)     A      34
     4       ,S13        ,SX(40)     ,T11        ,T(40)     ,T12        A      35
     5       ,T2(40)     ,TABAR      ,TBBAR      ,TO(25)    ,T14        A      36
     6       ,TAW(40)    ,TXTR1      ,TXTR2      ,TOL       ,TSH        A      37
     7       ,TSH1       ,TSTREM                 ,TW(50)    ,TWS        A      38
     8       ,TS         ,U11        ,U(40)      ,U12       ,U2(40)     A      39
      COMMON UXTR1       ,UXTR2      ,U14        ,UBAR(40)  ,USH        A      40
     1       ,USH1       ,USTREM                 ,UW(50)    ,UWS        A      41
     2       ,X11        ,X(40)      ,X12        ,X2(40)                A      42
     3       ,XB(50)     ,XBS        ,XABAR(25)  ,XBBAR(25) ,X15        A      43
     4       ,XS(25,40)  ,XSH        ,XSTREM                ,XW(50)     A      44
     5       ,ZMKK(40)               ,Y11        ,Y(40)     ,Y12        A      45
     6       ,Y2(40)     ,YABAR      ,YBBAR      ,ZA(25)    ,Z11(25)    A      46
     7       ,ZJ(25,40)  ,ZWW        ,S2X        ,R2SH      ,X2SH       A      47
     8       ,FX(2,40)   ,FR(2,40)   ,FPHI(2,40) ,FP(2,40)  ,FT(2,40)   A      48
     9       ,FU(2,40)   ,INDL(2,40) ,INDH(2,40) ,FL(2,40,25),CARD1     A      49
     *       ,N          ,M                                             A      50
      REAL    KAY        ,KAYS(25)   ,KAY2       ,KR        ,MDOT(40)   BNDRY   5
     *       ,MA(40)     ,MU         ,MUS(25)    ,MUO(25)   ,MU2        BNDRY   6
     *       ,MR(25)     ,MR2        ,MASH       ,MASH1     ,MASH       BNDRY   7
     * ,      MAP                                                       BNDRY   8
      COMMON/IOUGS1/ IPUGSH                                             BNDRY   9
      COMMON/XYZ/IXYZ,JXYZ                                              BNDRY  10


      EQUIVALENCE (MOVE,IEXTRA(15))                                     BNDRY  11
      EQUIVALENCE (PASH,EXTRA(11))                                      BNDRY  12
      IXYZ=2                                                            BNDRY  13
      JXYZ=0                                                            BNDRY  14
      IF (MOVE) 4950,50,4950                                            BNDRY  15
   50 IF (NBOUND) 3100,100,3100                                         BNDRY  16
C     WALL CONDITIONS                                                   BNDRY  17
  100 K=1                                                               BNDRY  18
      IF (ITYPE-2) 200,110,101                                          BNDRY  19
  110 PASH=PX(1)+(PX(2)-PX(1))*S/SX(2)                                  BNDRY  20
      GO TO 101                                                         BNDRY  21
C     SHOCK BOUNDARY                                                    BNDRY  22
  101 IF (IFLAG) 103,102,103                                            BNDRY  23
  102 DPDY(K)=2.0*(P(K+1)-PASH)/(Y(K+1)-Y(K))                           BNDRY  24
      DPHIDS(K)=-DPDY(K)*BETAP/(RHO(K+1)*U(K+1)**2)                     BNDRY  25
      GO TO 104                                                         BNDRY  26
  103 DPDY(K)=2.0*(P2(K+1)-PASH)/(Y2(K+1)-Y(K))                         BNDRY  27
      DPHIDS    =-DPDY(K)*BETAP/(RHO2(K+1)*U2(K+1)**2)                  BNDRY  28
      DPHIDS(K)=.45*DPHIDS(K)+.55*DPHIDS                                BNDRY  29
  104 PHI2(K)=PHI(K)+DPHIDS(K)*DLS(K)                                   BNDRY  30
      IF (ABS(PHI2(K)-PHI(K))-10.0**(-4)) 105,105,106                   BNDRY  31
  105 X2(K)=X(K)+DLS(K)*COS(PHI(K))                                     BNDRY  32
      R2(K)=R(K)+DLS(K)*SIN(PHI(K))                                     BNDRY  33
      GO TO 107                                                         BNDRY  34
  106 RADR=DLS(K)/(PHI(K)-PHI2(K))                                      BNDRY  35
      XO=X(K)+RADR*SIN(PHI(K))                                          BNDRY  36
      RO=R(K)-RADR*COS(PHI(K))                                          BNDRY  37
      X2(K)=XO-RADR*SIN(PHI2(K))                                        BNDRY  38
      R2(K)=RO+RADR*COS(PHI2(K))                                        BNDRY  39
  107 Y2(K)=0.0                                                         BNDRY  40
      Y(K)=0.0                                                          BNDRY  41
      MAX=KMAX                                                          BNDRY  42
      IF (ITYPE-3) 575,1075,1075                                        BNDRY  43
 1075 CALL SHOCK                                                        BNDRY  44
      IF (K-MAX-1) 108,108,109                                          BNDRY  45
  108 K=1                                                               BNDRY  46
      GO TO 575                                                         BNDRY  47
  109 K=2                                                               BNDRY  48
      GO TO 575                                                         BNDRY  49
  200 K=1                                                               BNDRY  50
      MAX=KMAX                                                          BNDRY  51
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```
C     FIXED WALL                                                          BNDRY
  300 IF (S-SA(M+1)) 500,500,400                                          BNDRY
  400 M=M+1                                                               BNDRY
      IF (M-MMAX) 300,300,9030                                            BNDRY
  500 K=1                                                                 BNDRY
      Y(K)=0.0                                                            BNDRY
      Y2(K)=0.0                                                           BNDRY
      PHI2(K)=PHIA(M)+(PHIA(M+1)-PHIA(M))*(S-SA(M))/(SA(M+1)-SA(M))       BNDRY
      IF (ABS(PHIA(M+1)-PHIA(M))-10.**(-4)) 525,525,550                   BNDRY
  525 X2(K)=XA(M)+(XA(M+1)-XA(M))*(S-SA(M))/(SA(M+1)-SA(M))               BNDRY
      R2(K)=RA(M)+(RA(M+1)-RA(M))*(S-SA(M))/(SA(M+1)-SA(M))               BNDRY
      GO TO 575                                                           BNDRY
  550 RAD=DELSO/(PHI(K)-PHI2(K))                                          BNDRY
      XO=X(K)+RAD*SIN(PHI(K))                                             BNDRY
      RO=R(K)-RAD*COS(PHI(K))                                             BNDRY
      X2(K)=XO-RAD*SIN(PHI2(K))                                           BNDRY

      R2(K)=RAD*COS(PHI2(K))+RO                                           BNDRY
  575 IF (IFLAG) 600,900,600                                              BNDRY
  600 RBAR(K)=.5*(R(K)+R2(K))                                             BNDRY
      RBAR(K+1)=.5*(R(K+1)+R2(K+1))                                       BNDRY
      YABAR=.5*(Y(K+1)+Y2(K+1))                                           BNDRY
      YBBAR=0.0                                                           BNDRY
      UBAR(K+1)=SQRT(.5*(U(K+1)**2+U2(K+1)**2))                           BNDRY
      RHABAR=.5*(RHO(K+1)+RHO2(K+1))                                      BNDRY
      TABAR=.5*(T(K+1)+T2(K+1))                                           BNDRY
      PABAR=.5*(P(K+1)+P2(K+1))                                           BNDRY
      MA2=0.0                                                             BNDRY
      DO 700 I=1,NOS                                                      BNDRY
      CABAR(I)=.5*(C(I,K+1)+C2(I,K+1))                                    BNDRY
  700 MA2=MA2+CABAR(I)/MA(I)                                              BNDRY
      MA2=1.0/MA2                                                         BNDRY
      DO 800 I=1,NOS                                                      BNDRY
      XABAR(I)=CABAR(I)*MA2/MA(I)                                         BNDRY
      H2PP(I)=0.0                                                         BNDRY
      HPM(I)=0.0                                                          BNDRY
      DO 800 J=1,NN                                                       BNDRY
  800 HPM(I)=HPM(I)+A(I,J)*TABAR**(J-2)                                   BNDRY
      GO TO 1050                                                          BNDRY
  900 RBAR(K)=R(K)                                                        BNDRY
      RBAR(K+1)=R(K+1)                                                    BNDRY
      YABAR=Y(K+1)                                                        BNDRY
      YBBAR=0.0                                                           BNDRY
      UBAR(K+1)=U(K+1)                                                    BNDRY
      RHABAR=RHO(K+1)                                                     BNDRY
      TABAR=T(K+1)                                                        BNDRY
      PABAR=P(K+1)                                                        BNDRY
      DO 1000 I=1,NOS                                                     BNDRY
      CABAR(I)=C(I,K+1)                                                   BNDRY
      XABAR(I)=XS(I,K+1)                                                  BNDRY
      H2PP(I)=0.0                                                         BNDRY
      HPM(I)=0.0                                                          BNDRY
      DO 1000 J=1,NN                                                      BNDRY
 1000 HPM(I)=HPM(I)+A(I,J)*T(K+1)**(J-2)                                  BNDRY
 1050 IF (IEXTRA(1)) 1100,1200,1100                                       BNDRY
 1100 MULT=0                                                              BNDRY
      IBIG=1                                                              BNDRY
      KK=K+1                                                              BNDRY
      CALL TRANSP (TABAR,PABAR,KK,MULT,IBIG)                              BNDRY
 1200 TAN(K)=0.0                                                          BNDRY
      G(K)=0.0                                                            BNDRY
      DO 1300 I=1,NOS                                                     BNDRY
 1300 ZJ(I,K)=0.0                                                         BNDRY
 1500 IF (KMAX-KAX) 1510,1510,1520                                        BNDRY
 1510 K=2                                                                 BNDRY
      GO TO 10000                                                         BNDRY
 1520 K=3                                                                 BNDRY
      GO TO 10000                                                         BNDRY
C     OUTER BOUNDARY CONDITIONS                                           BNDRY
 3100 K=1                                                                 BNDRY
      IF (LL) 3110,3110,3190                                              BNDRY
 3110 D=SQRT((X(K)-XB(N))**2+(R(K)-RB(N))**2)                             BNDRY
      IF (ABS(PHI(K)-PHIB(N))-1.E-04) 3120,3120,3130                      BNDRY
 3120 SX(K)=D                                                             BNDRY

      GO TO 3190                                                          BNDRY
 3130 SX(K)=D*(PHI(K)-PHIB(N))/(2.*SIN(0.5*(PHI(K)-PHIB(N))))             BNDRY
 3190 GO TO (3200,5000,5100,5700), IKIND                                  BNDRY
C     FIXED BOUNDARY                                                      BNDRY
 3200 N=1                                                                 BNDRY
      SSX=SX(K)+DLS(K-1)                                                  BNDRY
 3300 IF (SSX-SB(N+1)) 3500,3500,3400                                     BNDRY
 3400 N=N+1                                                               BNDRY
      IF (N-NMAX) 3300,9050,9050                                          BNDRY
 3500 IF (ABS(PHIB(N+1)-PHIB(N))-1.E-04) 3600,3600,3700                   BNDRY
 3600 PHIBAR=0.5*(PHI2(K-1)+PHIB(N))                                      BNDRY
      TPHBR=TAN(PHIBAR)                                                   BNDRY
      IF (ABS(PHIBAR)-1.E-04) 3620,3620,3640                              BNDRY
 3620 X2(K)=X2(K-1)                                                       BNDRY
      GO TO 3660                                                          BNDRY
 3640 X2(K)=(R2(K-1)-R(K)+TAN(PHIB(N))*X(K)+X2(K-1)/TPHBR      )/(TAN(PH BNDRY
     *IB(N))+1./TPHBR)                                                    BNDRY
 3660 R2(K)=R(K)+TAN(PHIB(N))*(X2(K)-X(K))                                BNDRY
      PHI2(K)=PHIB(N)                                                     BNDRY
      GO TO 4200                                                          BNDRY
 3700 RADB=(SB(N+1)-SB(N))/(PHIB(N)-PHIB(N+1))                            BNDRY
      ELL1=SQRT((XB(N+1)-XB(N))**2+(RB(N+1)-RB(N))**2)                    BNDRY
      ELL2=SQRT(RADB**2-ELL1**2/4.)                                       BNDRY
```

```
      FIOTA=ATAN((RB(N+1)-RB(N))/(XB(N+1)-XB(N)))
      IF (RADB) 3740,3740,3720
 3720 XX=XB(N)+.5*(XB(N+1)-XB(N))+ELL2*SIN(FIOTA)
      RR=RB(N)+.5*(RB(N+1)-RB(N))-ELL2*COS(FIOTA)
      GO TO 3800
 3740 XX=XB(N)+.5*(XB(N+1)-XB(N))-ELL2*SIN(FIOTA)
      RR=RB(N)+.5*(RB(N+1)-RB(N))+ELL2*COS(FIOTA)
 3800 L=1
      EXS=X(K)+DLS(K-1)*COS(PHI(K))
      IF (RADB) 3820,3840,3840
 3820 AMR=RR-SQRT(RADB**2-(EXS-XX)**2)
      GO TO 3900
 3840 AMR=RR+SQRT(RADB**2-(EXS-XX)**2)
 3900 PHIBAR=.5*(PHI2(K-1)+ATAN((EXS-XX)/(RR-AMR)))
      TPHBR=TAN(PHIBAR)
      GEE=(R2(K-1)-RR-(EXS-X2(K-1))/TPHBR      )**2-RADB**2+(EXS-XX)**2
      DRDX=(EXS-XX)/SQRT(RADB**2-(EXS-XX)**2)
      IF (RADB) 3910,3910,3905
 3905 DRDX=-DRDX
 3910 DPHDX=-.5*((AMR-RR)+(EXS-XX)*DRDX)/RADB**2
      DTPH=DPHDX/(COS(PHIBAR))**2
      DGEEDX=2.*((EXS-XX)-(R2(K-1)-RR-(EXS-X2(K-1))/TPHBR      )*(1./
     *TPHBR    -(EXS-X2(K-1))*DTPH/(TAN(PHIBAR))**2))
      DX=-GEE/DGEEDX
      L=L+1
      EXS=EXS+DX
      IF (RADB) 3920,3940,3940
 3920 AMR=RR-SQRT(RADB**2-(EXS-XX)**2)
      GO TO 4000
 3940 AMR=RR+SQRT(RADB**2-(EXS-XX)**2)
 4000 IF (L-4) 3900,4100,4100
 4100 X2(K)=EXS
      R2(K)=AMR
      PHI2(K)=-ATAN((EXS-XX)/(AMR-RR))


 4200 D=SQRT((X2(K)-X(K))**2+(R2(K)-R(K))**2)
      IF (ABS(PHI2(K)-PHI(K))-1.E-04) 4300,4300,4400
 4300 DLS(K)=D
      GO TO 4500
 4400 DLS(K)=D*(PHI2(K)-PHI(K))/(2.*SIN(0.5*(PHI2(K)-PHI(K))))
 4500 W=SQRT((X2(K)-X2(K-1))**2+(R2(K)-R2(K-1))**2)
      IF (ABS(PHI2(K)-PHI2(K-1))-1.E-04) 4600,4600,4700
 4600 DELY(K)=W
      GO TO 4800
 4700 DELY(K)=W*(PHI2(K)-PHI2(K-1))/(2.0*SIN(.5*(PHI2(K)-PHI2(K-1))))
 4800 AA(K)=PI*(R2(K)+R2(K-1))*DELTA*DELY(K)
      Y2(K)=Y2(K-1)+DELY(K)
 4900 CALL STEP
      JAY=1
 4950 KOVER=0
      GO TO 10000
C       FREE BOUNDARY
 5000  =1
      PHS=PB(N)+(PB(N+1)-PB(N))*(S2X-SB(N))/(SB(N+1)-SB(N))
      GO TO 5700
C       NEWTONIAN BOUNDARY
 5100 FMSTRM=0.0
      DO 5300 I=1,NCS
 5300 FMSTRM=FMSTRM+CSTREM(I)/WM(I)
      FMSTRM=1.0/FMSTRM
      GSTRM=PSTREM*FMSTRM*(USTREM**2)/(RV*TSTREM*BETAP)
 5400 IF (IFLAG) 5525,5500,5525
 5500 SIGMA=PHI(K)-PHSTRM
      GO TO 5550
 5525 SIGMA=.5*(PHI(K)+PHI2(K))-PHSTRM
 5550 IF (SIGMA) 5575,5575,5600
 5575 PBS=PSTREM
      GO TO 5700
 5600 IF (SIGMA-0.5*PI) 5650,5650,5625
 5625 PHS=PSTREM+GSTRM
      GO TO 5700
 5650 PBS=PSTREM+GSTRM *(SIN(SIGMA))**2
      IF (IHUGSH.NE.0) WRITE(6,9901) K,IFLAG,Y(K),Y(K-1),RHO(K),U(K),
     1 Y2(K),Y2(K-1),RHO2(K),U2(K)   ,SIGMA,PHS
 9901 FORMAT(1X,2I5,10F11.3)
 5700 IF (IFLAG) 5900,5800,5900
 5800 DPDY(K)=2.0*(PHS-P(K))/(Y(K)-Y(K-1))
      DPHIDS(K)=-DPDY(K)*BETAP/(RHO(K)*U(K)**2)
      GO TO 6000
 5900 DPDY(K)=2.0*(PHS-P2(K))/(Y2(K)-Y2(K-1))
      DPHDS=-DPDY(K)*BETAP/(RHO2(K)*U2(K)**2)
      DPHIDS(K)=.45*DPHIDS(K)+.55*DPHDS
 6000 MOVE=1
      RETURN
C       ERROR MESSAGES
 9000 NOCASE=100
      GO TO 9900
 9050 NOCASE=400
      GO TO 9900
 9050 NOCASE=3200
 9900 IERROR=2
10000 RETURN


      END
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      SUBROUTINE CHEM(IKINE)                                                  CHEM       3
      COMMON A(25,7)      ,AA(40)       ,ALFA(25,25),ALPHAH    ,ALPHAP       A          2
     1       ,ATOL        ,BETAP        ,BMIX        ,C11(20)     ,C(25,40)    A          3
     2       ,C12(25)     ,C2(25,40)    ,CABAR(25)   ,CBBAR(25)   ,CP          A          4
     3       ,CPS(25)     ,CPSH         ,CSH(25)     ,CSH1(25)    ,CSTREM(25)  A          5
     4       ,HXSTHA      ,D2IM(25,25),DEFF(25)     ,D2EFF(25)   ,DELTA        A          6
     5       ,D11         ,DELBB(40)    ,DELB        ,DELBO       ,DLB(40)     A          7
     6       ,DIM(25,25) ,D12          ,DELY(40)    ,D13         ,DPBY(40)    A          8
     7       ,D14         ,DPHIDS(40)   ,EPCON                                 A          9
     8       ,EPSLON      ,EXTRA(50)    ,FSTEP       ,FMAX        ,GRAD        A         10
     9       ,H11         ,H(40)        ,HH          ,HJ          ,HPR(25)     A         11
     0       ,H2PM(25)    ,H3PM(25)     ,ICONST      ,ICOUNT      ,IDENT(25)   A         12
     1       ,IERROR      ,IEXTRA(50)   ,IFLAG       ,IKIND                    A         13
     2       ,IPTUC       ,ISHOCK       ,ITYPE       ,IPD                      A         14
     3       ,IDIFF       ,K            ,KAY         ,KAYS        ,KAY2        A         15
     4       ,KLO         ,KMAX                                                A         16
     5       ,KUP         ,KK           ,L[illegible] ,LPLANE     ,MA          A         17
     6       ,MASH        ,MLUT         ,MMAX        ,MUO         ,MU          A         18
     7       ,MU2         ,MUS          ,MN          ,MN2         ,MNSH        A         19
     8       ,NBOUND      ,NDS          ,NITER       ,NMAX        ,NN          A         20
      COMMON NUCASE       ,OMEGA(25)    ,P11         ,P(40)       ,P12         A         21
     1       ,P2(40)                    ,PB(50)      ,PABAR       ,PBBAR       A         22
     2       ,PHS         ,P15          ,PHI(40)                  ,PHIB(50)    A         23
     3       ,PHISH1      ,PHSTRM                    ,PHIA(50)    ,P18         A         24
     4       ,PHI2(40)    ,PHIBS        ,P1          ,PH(25)      ,PSH         A         25
     5       ,PSH1        ,PSI          ,PSTREM                   ,PN(50)      A         26
     6       ,Q11         ,[illegible]40) ,QXTR1     ,QXTR2                    A         27
     7       ,QN(50)      ,R11          ,R(40)                    ,RB(50)      A         28
     8       ,RHS         ,R15          ,RBAR(40)    ,R14         ,R2(40)      A         29
     9       ,RCON        ,[illegible]15 ,RE(40)     ,RESH        ,R16         A         30
     0       ,RHO(40)     ,R17          ,RHO2(40)    ,RHB(25)     ,RHREM       A         31
     1       ,RHSHM       ,RHABAR       ,RHBBAR      ,RU          ,R[illegible] A        32
     2       ,RSTREM      ,RV           ,R19         ,RN(100)     ,S           A         33
     3                    ,SB(50)       ,SC(25)                   ,SN(50)      A         34
     4       ,S13         ,SX(40)       ,T11         ,T(40)       ,T12         A         35
     5       ,T2(40)      ,TABAR        ,TBBAR       ,TO(25)      ,T14         A         36
     6       ,TAN(40)     ,TXTR1        ,TXTR2       ,TOL         ,TSH         A         37
     7       ,TSH1        ,TSTREM                    ,TN(50)      ,TNS         A         38
     8       ,TS          ,U11          ,U(40)       ,U12         ,U2(40)      A         39
      COMMON UXTR1        ,UXTR2        ,U14         ,UBAR(40)    ,USH         A         40
     1       ,USH1        ,USTREM                    ,UN(50)      ,UNS         A         41
     2       ,X11         ,X(40)        ,X12         ,X2(40)                   A         42
     3       ,XB(50)      ,XNB          ,XABAR(25)   ,XBBAR(25)   ,X15         A         43
     4       ,XS(25,40)   ,XSH          ,XSTREM                   ,XN(50)      A         44
     5       ,ZMAK(40)                  ,Y11         ,Y(40)       ,Y12         A         45
     6       ,Y2(40)      ,YABAR        ,YBBAR       ,ZA(25)      ,Z11(25)     A         46
     7       ,ZJ(25,40)   ,ZPA          ,S2X         ,H2SH        ,X2SH        A         47
     8       ,FX(2,40)    ,FH(2,40)     ,FPH1(2,40) ,FP(2,40)    ,F1(2,40)    A         48
     9       ,FU(2,40)    ,INDL(2,40) ,INDR(2,40) ,FC(2,40,25),CARD1          A         49
     0       ,M           ,N                                                   A         50
      REAL    KAY         ,KAYS(25)     ,KAY2        ,KN          ,MDOT(40)    CHEM       4
     *       ,MA(40)      ,MU           ,MUS(25)     ,MUO(25)     ,MU2         CHEM       5
     *       ,MN(25)      ,MN2          ,MASH        ,MASH1       ,MNSH        CHEM       6
     * ,      MAP                                                              CHEM       7
      DIMENSION G(25),HP(25),HM(25)                                           CHEM       8
      COMMON/CHEM1/ ZIO(5), INR(40),IKI(40),HC(40,3),IRHR(40,5),              CHEM       9
     1 AV,CM(26,26),FI(26),WP(26),                                            CHEM      10


     2 AF(26),FOUT(26,40),CSI(26),GA(26)                                      CHEM      11
      COMMON/IHUGS1/ IHUGSH                                                   CHEM      12
      COMMON/XYZ/IXYZ,JXYZ                                                    CHEM      13
C     GAS CONSTANT IN 1.987 CAL/G-MOLE-K                                      CHEM      14
      IXYZ=3                                                                  CHEM      15
      JXYZ=0                                                                  CHEM      16
      RR=1.987*T(K)                                                           CHEM      17
C     GAS CONSTANT IN 82.06 CM3-ATM/G-MOLE-K                                  CHEM      18
      RRT=82.06*T(K)                                                          CHEM      19
      XLOGT=ALOG(T(K))                                                        CHEM      20
      XLLGT=ALOG(T(K)/1000.0)                                                 CHEM      21
      DO 3 IR=1,NDS                                                           CHEM      22
      FI(IR)=C(IR,K)/MN(IR)                                                   CHEM      23
      GA(IR)=0.0                                                              CHEM      24
      WP(IR)=0.0                                                              CHEM      25
      WM(IR)=0.0                                                              CHEM      26
      FOUT(IR,K)=0.0                                                          CHEM      27
      DO 4 JR=1,NDS                                                           CHEM      28
    4 CM(IR,JR)=0.0                                                           CHEM      29
    3 CONTINUE                                                                CHEM      30
C     CALCULATING GIBBS ENERGY                                                CHEM      31
      DO 6 IR=1,NDS                                                           CHEM      32
      G(IR)=A(IR,1)*.5/T(K)+(A(IR,3)*(1.-XLLGT) -CSI(IR))*T(K)+A(IR,2)        CHEM      33
      IF (NN.LT.4) GO TO 7                                                    CHEM      34
      G(IR)=G(IR)-A(IR,4)*T(K)**2-.5*A(IR,5)*T(K)**3-A(IR,6)/3.*T(K)**4       CHEM      35
    7 G(IR)= G(IR)*MN(IR)                                                     CHEM      36
C   CALCULATE GIBBS ENERGY IN CAL/MOLE                                        CHEM      37
    6 CONTINUE                                                                CHEM      38
      DO 1 IN=1,IKINE                                                         CHEM      39
      KIKI=IKI(IN)                                                            CHEM      40
      GO TO (841,842,843,844,845,846,847,848),KIKI                            CHEM      41
  848 RKF=HC(IN,1)*(T(K)**HC(IR,2))*EXP(HC(IR,3)/RRT)                         CHEM      42
      GO TO 849                                                               CHEM      43
  841 RKF=HC(IN,1)                                                            CHEM      44
      GO TO 849                                                               CHEM      45
  842 RKF=HC(IN,1)/T(K)                                                       CHEM      46
      GO TO 849                                                               CHEM      47
  843 RKF=HC(IN,1)/T(K)/T(K)                                                  CHEM      48
      GO TO 849                                                               CHEM      49
  844 RKF=HC(IN,1)/SQRT(T(K))                                                 CHEM      50
      GO TO 849                                                               CHEM      51
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845 RRF=RC(IR,1)*EXP(RC(IR,3)/RRT)                                  CHEM    52
    GO TO 849                                                       CHEM    53
846 RRF=RC(IR,1)*EXP(RC(IR,3)/RRT)/T(K)                             CHEM    54
    GO TO 849                                                       CHEM    55
847 RR/=RC(IR,1)/T(K)/SQRT(T(K))                                    CHEM    56
849 CONTINUE                                                        CHEM    57
    NIRR=IRR(IR)                                                    CHEM    58
    GO TO (851,852,853,854,855,856,857,858,859,860),NIRR            CHEM    59
851 J1=IRRR(IR,1)                                                   CHEM    60
    J2=IRRR(IR,2)                                                   CHEM    61
    J3=IRRR(IR,3)                                                   CHEM    62
    J4=IRRR(IR,4)                                                   CHEM    63
    E=(G(J1)+G(J2)-G(J3)-G(J4))/RRT                                 CHEM    64
    IF (E.LT.-40.0) E=-40.0                                         CHEM    65
    IF (E .GT. +40.0) E=+40.0                                       CHEM    66
    E=EXP(E)                                                        CHEM    67


    CRR=RRF*RHO(K)                                                  CHEM    68
    RP(IR)=CRR*FI(J1)*FI(J2)                                        CHEM    69
    RM(IR)=CRR*FI(J3)*FI(J4)/E                                      CHEM    70
    DO 773 J=1,4                                                    CHEM    71
    SIGN=1.0                                                        CHEM    72
    IF (J .GT. 2) SIGN=-1.0                                         CHEM    73
    IRON=IRRR(IR,J)                                                 CHEM    74
    CR(IRON,J1)=CR(IRON,J1)+SIGN*CRR*FI(J2)                         CHEM    75
    CR(IRON,J2)=CR(IRC    2)+SIGN*CRR*FI(J1)                        CHEM    76
    CR(IRON,J3)=CR(IRON,J3)-SIGN*CRR*FI(J4)/E                       CHEM    77
    CR(IRON,J4)=CR(IRON,J4)-SIGN*CRR*FI(J3)/E                       CHEM    78
    UX(IRON)=UX(IRON)+SIGN*(RP(IR)-RM(IR))                          CHEM    79
773 CONTINUE                                                        CHEM    80
    GO TO 867                                                       CHEM    81
852 J1=IRRR(IR,1)                                                   CHEM    82
    J2=IRRR(IR,2)                                                   CHEM    83
    J3=IRRR(IR,3)                                                   CHEM    84
    E=(G(J1)+G(J2)-G(J3))/RRT                                       CHEM    85
    IF (E .LT. -40.0) E=-40.0                                       CHEM    86
    IF (E .GT. +40.0) E=+40.0                                       CHEM    87
    E=EXP(E)                                                        CHEM    88
    CRR=RRF*RHO(K)/ZWN*AV                                           CHEM    89
    RP(IR)=CRR*RHO(K)*FI(J1)*FI(J2)                                 CHEM    90
    RM(IR)=CRR*FI(J3)/(E*RRT1)                                      CHEM    91
    DO  774 J=1,3                                                   CHEM    92
    SIGN=1.0                                                        CHEM    93
    IF (J .GT. 2) SIGN =-1.0                                        CHEM    94
    IRON=IRRR(IR,J)                                                 CHEM    95
    CR(IRON,J1)=CR(IRON,J1)+SIGN*CRR*RHO(K)*FI(J2)                  CHEM    96
    CR(IRON,J2)=CR(IRON,J2)+SIGN*CRR*RHO(K)*FI(J1)                  CHEM    97
    CR(IRON,J3)=CR(IRON,J3)-SIGN*CRR/(E*RRT1)                       CHEM    98
    UX(IRON)= UX(IRON)+SIGN*RP(IR)                                  CHEM    99
774 CONTINUE                                                        CHEM   100
    GO TO 866                                                       CHEM   101
853 J1=IRRR(IR,1)                                                   CHEM   102
    J2=IRRR(IR,2)                                                   CHEM   103
    J3=IRRR(IR,3)                                                   CHEM   104
    J4=IRRR(IR,4)                                                   CHEM   105
    J5=IRRR(IR,5)                                                   CHEM   106
    E=(G(J1)+G(J2)-G(J3)-G(J4)-G(J5))/RRT                           CHEM   107
    IF (E .LT. - 40.0) E=-40.0                                      CHEM   108
    IF (E .GT. +40.0) E=+40.0                                       CHEM   109
    E=EXP (E)                                                       CHEM   110
    CRR=RRF*RHO(K)                                                  CHEM   111
    RP(IR)=CRR*FI(J1)*FI(J2)                                        CHEM   112
    RM(IR)=CRR*FI(J3)*FI(J4)*FI(J5)*RHO(K)*RRT1/E                   CHEM   113
    DO 775 J=1,5                                                    CHEM   114
    SIGN = 1.0                                                      CHEM   115
    IF (J .GT. 2) SIGN =-1.0                                        CHEM   116
    IRON=IRRR(IR,J)                                                 CHEM   117
    CR(IRON,J1)=CR(IRON,J1)+SIGN*CRR*FI(J2)                         CHEM   118
    CR(IRON,J2)=CR(IRON,J2)+SIGN*CRR*FI(J1)                         CHEM   119
    CR(IRON,J3)=CR(IRON,J3)-SIGN*CRR*FI(J4)*FI(J5)*RHO(K)*RRT1/E    CHEM   120
    CR(IRON,J4)=CR(IRON,J4)-SIGN*CRR*FI(J3)*FI(J5)*RHO(K)*RRT1/E    CHEM   121
    CR(IRON,J5)=CR(IRON,J5)-SIGN*CRR*FI(J3)*FI(J4)*RHO(K)*RRT1/E    CHEM   122
    UX(IRON)=UX(IRON)+SIGN*(RP(IR)-2.0*RM(IR))                      CHEM   123
775 CONTINUE                                                        CHEM   124


    GO TO 861                                                       CHEM   125
854 J1=IRRR(IR,1)                                                   CHEM   126
    J2=IRRR(IR,2)                                                   CHEM   127
    J3=IRRR(IR,3)                                                   CHEM   128
    E=(G(J1)+G(J2)-G(J3))/RRT                                       CHEM   129
    IF (E .LT. -40.0) E=-40.0                                       CHEM   130
    IF (E .GT. +40.0) E=+40.0                                       CHEM   131
    E=EXP(E)                                                        CHEM   132
    CRR=RRF*RHO(K)                                                  CHEM   133
    RP(IR)=CRR*FI(J1)*FI(J2)                                        CHEM   134
    RM(IR)=CRR*FI(J3)/E/RRT1*RHO(K)                                 CHEM   135
    DO 771 J=1,3                                                    CHEM   136
    SIGN=1.0                                                        CHEM   137
    IF (J .GT. 2) SIGN = -1.0                                       CHEM   138
    IRON = IRRR(IR,J)                                               CHEM   139
    CR(IRON,J1)=CR(IRON,J1)+SIGN*CRR*RHO(K)*FI(J2)                  CHEM   140
    CR(IRON,J2)=CR(IRON,J2)+SIGN*CRR*RHO(K)*FI(J1)                  CHEM   141
    CR(IRON,J3)=CR(IRON,J3)-SIGN*CRR/(E*RRT1) )*RHO(K)              CHEM   142
    UX(IRON)=UX(IRON)+SIGN*RP(IR)                                   CHEM   143
771 CONTINUE                                                        CHEM   144
    GO TO 868                                                       CHEM   145
855 J1=IRRR(IR,1)                                                   CHEM   146
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```
      J2=NCS+1
      J3=INNR(IR,3)
      J4=INNR(IR,4)
      E=(G(J1)-G(J3)-G(J4))/RRT
      IF (E .LT. -40.0) E= -40.0
      IF (E .GT. +40.0) E=+40.0
      E=EXP (E)
      CHR=RNF*RHO(K)/ZPR
      RP(IR)=CHR*FI(J1)
      RM(IR)=CHR*RRT1*RHO(K)*FI(J3)*FI(J4)/E
      DO 772 J=1,4
      IF (J .EQ. 2) GO TO 772
      SIGN =1.0
      IF (J .GT. 2) SIGN=-1.0
      IRUN=INNR(IR,J)
      CM(IRUN,J1)=CM(IRUN,J1)+SIGN*CHR
      CM(IRUN,J3)=CM(IRUN,J3)-SIGN*CHR*RRT1*RHO(K)*FI(J4)/E
      CM(IRUN,J4)=CM(IRUN,J4)-SIGN*CHR*RRT1*RHO(K)*FI(J3)/E
      QX(IRUN)=QX(IRUN)-SIGN*RM(IR)
  772 CONTINUE
      GO TO 867
  856 J1=INNR(IR,1)
      J2=INNR(IR,2)
      J3=INNR(IR,3)
      J4=INNR(IR,4)
      CHR=RNF*RHO(K)
      RP(IR)=CHR*FI(J1)*FI(J2)
      RM(IR)=0.0
      DO 778 J=1,4
      SIGN=1.0
      IF (J .GT. 2) SIGN=-1.0
      IRUN=INNR(IR,J)
      CM(IRUN,J1)=CM(IRUN,J1)+SIGN*CHR*FI(J2)
      CM(IRUN,J2)=CM(IRUN,J2)+SIGN*CHR*FI(J1)
      QX(IRUN)=QX(IRUN)+SIGN*RP(IR)


  778 CONTINUE
      GO TO 867
  857 J1=INNR(IR,1)
      J2=INNR(IR,2)
      J3=INNR(IR,3)
      CHR=RNF*RHO(K)*AV/ZPR
      RP(IR)=CHR*RHO(K)*FI(J1)*FI(J2)
      RM(IR)=0.0
      DO 779 J=1,3
      SIGN=1.0
      IF (J .GT.2) SIGN=-1.0
      IRUN=INNR(IR,J)
      CM(IRUN,J1)= CM(IRUN,J1)+SIGN*CHR*RHO(K)*FI(J2)
      CM(IRUN,J2)= CM(IRUN,J2)+SIGN*CHR*RHO(K)*FI(J1)
      QX(IRUN)=QX(IRUN)+SIGN*RP(IR)
  779 CONTINUE
      GO TO 868
  858 J1=INNR(IR,1)
      J2=INNR(IR,2)
      J3=INNR(IR,3)
      J4=INNR(IR,4)
      J5=INNR(IR,5)
      CHR =RNF*RHO(K)
      RP(IR)=CHR *FI(J1)*FI(J2)
      RM(IR)=0.0
      DO 780 J=1,5
      SIGN=1.0
      IF (J .GT. 2) SIGN=-1.0
      IRUN=INNR(IR,J)
      CM(IRUN,J1)=CM(IRUN,J1)+SIGN*CHR*FI(J2)
      CM(IRUN,J2)=CM(IRUN,J2)+SIGN*CHR*FI(J1)
      QX(IRUN)=QX(IRUN)+SIGN*RP(IR)
  780 CONTINUE
      GO TO 861
  859 J1=INNR(IR,1)
      J2=INNR(IR,2)
      J3=INNR(IR,3)
      CHR=RNF
      RP(IR)=CHR*RHO(K)*FI(J1)*FI(J2)
      RM(IR)=0.0
      DO 776 J=1,3
      SIGN=1.0
      IF (J .GT. 2) SIGN =-1.0
      IRUN = INNR(IR,J)
      CM(IRUN,J1)=CM(IRUN,J1)+SIGN*CHR*RHO(K)*FI(J2)
      CM(IRUN,J2)=CM(IRUN,J2)+SIGN*CHR*RHO(K)*FI(J1)
      QX(IRUN)=QX(IRUN)+SIGN*RP(IR)
  776 CONTINUE
      GO TO 866
  860 J1=INNR(IR,1)
      J2=NCS+1
      J3=INNR(IR,3)
      J4=INNR(IR,4)
      CHR=RNF*RHO(K)/ZPR
      RP(IR)=CHR*FI(J1)
      RM(IR)=0.0
      DO 777 J=1,4


      IF (J .EQ. 2) GO TO 777
      SIGN=1.0
      IF (J .GT. 2) SIGN=-1.0
```

```
      IROW = IRRR(IR,J)
      CM(IROW,J1)=CM(IROW,J1)+SIGN*CRR
  777 CONTINUE
      GO TO 867
  861 WP(J5)=WP(J5)+RP(IR)
      WM(J5)=WM(J5)+RM(IR)
  867 WP(J4)=WP(J4)+RP(IR)
      WM(J4)=WM(J4)+RM(IR)
  866 WP(J3)=WP(J3)+RP(IR)
      WM(J3)=WM(J3)+RM(IR)
      WP(J2)=WP(J2)-RP(IR)
      WM(J2)=WM(J2)-RM(IR)
      WP(J1)=WP(J1)-RP(IR)
      WM(J1)=WM(J1)-RM(IR)
    1 CONTINUE
      DO 897 J=1,NOS
C       PRODUCTION RATE IN MOLE/GM-CM
      WDOT(J,K)=(WP(J)-WM(J))/U(K)
  897 CONTINUE
      DSUM=DLS(K)/U(K)
      DO 10 IR=1,NOS
      DSMUR=DSUM*PM(IR)
      QX(IR)= C(IR,K)+WMS(IR)/WDOT(K)+DSMUR*AUX(IR)
      DO 11 JR=1,NOS
      CM(IR,JR)= CM(IR,JR)*DSMUR
      IF (IR.EQ.JR) CM(IR,JR)= 1.0+CM(IR,JR)
   11 CONTINUE
      IF (IDUGBM .NE. 0)
     *WRITE(6,100) K,IR,(CM(IR,JR),JR=1,NOS),QX(IR)
  100 FORMAT(1X,2I5,1P8E12.3)
   10 CONTINUE
      CALL SLDP(QX,CM,NOS)
      DO 12 IR=1,NOS
      IF (IDUGBM .NE. 0)
     *WRITE(6,100) K,IR,(CM(IR,JR),JR=1,NOS),QX(IR)
      C2(IR,K)= QX(IR)
C     CALCULATE NEW MASS FRACTION OF SPECIES
   12 CONTINUE
      RETURN
      END


      SUBROUTINE CPUTIN(IDENT,IKINE,NOS)
C       ------------------------------------------------------------
      DIMENSION IDENT (25),IZO(5)
      COMMON/CHEM1/ ZI(5), IRR(40),IRT(40),RC(40,3),IRRR(40,5),
     1 AV,CM(26,26),FI(26),WP(26),
     2 WM(26),WDOT(26,40),CSI(26),QX(26)
      COMMON/XYZ/IXYZ,JXYZ
      IXYZ=4
      JXYZ=0
      AV=6.03E23
      DO 2 I=1,IKINE
      READ (5,100) (IZO(J),J=1,5),IRR(I),IRT(I),(RC(I,KK),KK=1,3)
      WRITE(6,101) I, (IZO(J),J=1,5),IRR(I),IRT(I),(RC(I,KK),KK=1,3)
      DO 5 J=1,5
      IRRR (I,J)=0
      DO 3 L=1,NOS
      IF (IZO(J)-IDENT(L)) 3,4,3
    4 IRRR(I,J)=L
    3 CONTINUE
    5 CONTINUE
      RC(I,1)=RC(I,1)*AV
    2 CONTINUE
  100 FORMAT (A4,3X,A4,10X,A4,3X,A4,3X,A4,9  I2,I1,E8.2,F4.1,F9.1)
  101 FORMAT (2X,I2,2X,A4,3X,A4,10X,A4,3X,A4,3X,A4,9X,I2,I1,E8.2,
     1 F4.1,F9.1)
      RETURN
      END


      SUBROUTINE DRAG
      COMMON A(25,7)      ,AA(40)      ,ALFA(25,2 ),ALPHAM     ,ALPHAP
     1        ,ATOL       ,BETAP       ,BMIX        ,C11(25)    ,C(25,40)
     2        ,C12(25)    ,C2(25,40)   ,CABAR(25)   ,CBBAR(25)  ,CP
     3        ,CPS(25)    ,CPSH        ,CSH(25)     ,CSH1(25)   ,CSTREM(25)
     4        ,MXSTRM     ,D21M(25,25),DEFF(25)     ,D2EFF(25)  ,DELTA
     5        ,D11        ,DELSS(40)   ,DELS        ,DELSO      ,DLS(40)
     6        ,DIM(25,25) ,D12         ,DFLY(40)    ,DIS        ,DPDY(40)
     7        ,D14        ,DPHIDS(10)  ,EPCON
     8        ,EPSLON     ,EXTRA(50)   ,FSTEP       ,FMAX       ,GRAD
     9        ,H11        ,H(40)       ,HH          ,HJ         ,HPM(25)
     *        ,H2PM(25)   ,H3PM(25)    ,ICONST      ,ICOUNT     ,IDENT(25)
     1        ,IERROR     ,IEXTRA(50)  ,IFLAG       ,IKIND
     2        ,IPTCC      ,ISHOCK      ,ITYPE       ,IPO
     3        ,IPIFF      ,K           ,KAY         ,KAYS       ,KAY2
     4        ,KLO        ,KMAX
     5        ,KOP        ,KK          ,LL          ,LPLANE     ,MA
     6        ,MASH       ,MLOT        ,MMAX        ,MUO        ,MU
     7        ,MU2        ,NOS         ,NN          ,MM2        ,MASH
     8        ,NBOUNL     ,NDS         ,NITER       ,NMAX       ,NN
      COMMON NUCASE       ,OMEGA(25)   ,P11         ,P(40)      ,P12
     1        ,P2(40)                  ,PB(50)      ,PABAR      ,PBBAR
     2        ,PHS        ,P15         ,PHI(40)                 ,PHIB(50)
     3        ,PHISH1     ,PFSTOM                   ,PHIW(50)   ,P18
     4        ,PHI2(40)   ,PHIBS       ,PI          ,PR(25)     ,PSH
     5        ,PSH1       ,PSI         ,PSTREM                  ,PW(50)
     6        ,Q11        ,Q(40)       ,QXTR1       ,QXTR2
     7        ,QW(50)     ,R11         ,R(40)                   ,RB(50)
```

```
      IRON = IRRR(IR,J)
      CM(IROW,J1)=CM(IROW,J1)+SIGN*CRR
  777 CONTINUE
      GO TO 867
  861 WP(J5)=WP(J5)+WP(IR)
      WM(J5)=WM(J5)+WM(IR)
  867 WP(J4)=WP(J4)+WP(IR)
      WM(J4)=WM(J4)+WM(IR)
  866 WP(J3)=WP(J3)+WP(IR)
      WM(J3)=WM(J3)+WM(IR)
      WP(J2)=WP(J2)-WP(IR)
      WM(J2)=WM(J2)-WM(IR)
      WP(J1)=WP(J1)-WP(IR)
      WM(J1)=WM(J1)-WM(IR)
    1 CONTINUE
      DO 897 J=1,NOS
C       PRODUCTION RATE IN MOLE/GM-CM
      WDOT(J,K)=(WP(J)-WM(J))/U(K)
  897 CONTINUE
      DSUM=DLS(K)/U(K)
      DO 10 IR=1,NOS
      DSWUM=DSUM*PN(IR)
      QX(IR)= C(IR,K)+WWS(IR)/WDOT(K)+DSWUM*QX(IR)
      DO 11 JR=1,NOS
      CM(IR,JR)= CM(IR,JR)*DSWUM
      IF (IR.EQ.JR) CM(IR,JR)= 1.0+CM(IR,JR)
   11 CONTINUE
      IF (IDUGSH .NE. 0)
     *WRITE(6,100) K,IR,(CM(IR,JR),JR=1,NOS),QX(IR)
  100 FORMAT(1X,2I5,1P8E12.3)
   10 CONTINUE
      CALL SLDP(QX,CM,NOS)
      DO 12 IR=1,NOS
      IF (IDUGSH .NE. 0)
     *WRITE(6,100) K,IR,(CM(IR,JR),JR=1,NOS),QX(IR)
      C2(IR,K)= QX(IR)
C     CALCULATE NEW MASS FRACTION OF SPECIES
   12 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CPUTIN(IDENT,IKINE,NOS)
C       -------------------------------------------------------------
      DIMENSION IDENT (25),IZD(5)
      COMMON/CHEM1/ ZI((5), IRR(40),IRT(40),RC(40,3),IRRR(40,5),
     1 AV,CM(26,26),F1(26),WP(26),
     2 WM(26),WDOT(26,40),CS1(26),QX(26)
      COMMON/XYZ/IXYZ,JXYZ
      IXYZ=4
      JXYZ=0
      AV=6.03E23
      DO 2 I=1,IKINE
      READ (5,100) (IZD(J),J=1,5),IRR(I),IRT(I),(RC(I,KK),KK=1,3)
      WRITE(6,101) I, (IZD(J),J=1,5),IRR(I),IRT(I),(RC(I,KK),KK=1,3)
      DO 5 J=1,5
      IRRR (I,J)=0
      DO 3 L=1,NOS
      IF (IZD(J)-IDENT(L)) 3,4,3
    4 IRRR(I,J)=L
    3 CONTINUE
    5 CONTINUE
      RC(I,1)=RC(I,1)*AV
    2 CONTINUE
  100 FORMAT (A4,3X,A4,10X,A4,3X,A4,3X,A4,9  I2,I1,E8.2,F4.1,F9.1)
  101 FORMAT (2X,I2,2X,A4,3X,A4,10X,A4,3X,A4,3X,A4,9X,I2,I1,E8.2,
     1 F4.1,F9.1)
      RETURN
      END
```

```
      SUBROUTINE DRAG
      COMMON A(25,7)      ,AA(40)        ,ALFA(25,2 ),ALPHAM      ,ALPHAP
     1        ,ATOL       ,BETAP         ,BMIX        ,C11(25)      ,C(25,40)
     2        ,C12(25)    ,C2(25,40)     ,CABAR(25)   ,CBBAR(25)    ,CP
     3        ,CPS(25)    ,CPSH          ,CSH(25)     ,CSH1(25)     ,CSTREM(25)
     4        ,MSSTRM     ,D2IN(25,25),DEFF(25)      ,D2EFF(25)    ,DELTA
     5        ,D11        ,DELSS(40)     ,DELS        ,DELSO        ,DLS(40)
     6        ,DIN(25,25) ,D12           ,DFLY(40)    ,D1S          ,DPDY(40)
     7        ,D14        ,DPHIDS(10)    ,EPCON
     8        ,EPSLON     ,EXTRA(50)     ,FSTEP       ,FMAX         ,GRAD
     9        ,H11        ,H(40)         ,HH          ,HJ           ,HPM(25)
     *        ,H2PM(25)   ,H3PM(25)      ,ICONST      ,ICOUNT       ,IDENT(25)
     1        ,IERROR     ,IEXTRA(50)    ,IFLAG       ,IKIND
     2        ,IPTOL      ,ISHOCK        ,ITYPE       ,IPO
     3        ,IDIFF      ,K             ,KAY         ,KAYS         ,KAY2
     4        ,KLU        ,KMAX
     5        ,KOP        ,KK            ,LL          ,LPLANE       ,MA
     6        ,MASH       ,MEUT          ,MMAX        ,MUO          ,MU
     7        ,MU2        ,MUS           ,MW          ,MW2          ,MASH
     8        ,NBOUNL     ,NDS           ,NITER       ,NMAX         ,NN
      COMMON NUCASE       ,OMEGA(25)     ,P11         ,P(40)        ,P12
     1        ,P2(40)                    ,PB(50)      ,PABAR        ,PBBAR
     2        ,PHS        ,P1S           ,PHI(40)                   ,PHIB(50)
     3        ,PHISH1     ,PHSTOP                     ,PHIN(50)     ,P1R
     4        ,PHI2(40)   ,PHIBS         ,PI          ,PR(25)       ,PSH
     5        ,PSH1       ,PS1           ,PSTREM                    ,PW(50)
     6        ,Q11        ,Q(40)         ,QXTR1       ,QXTR2
     7        ,QW(50)     ,R11           ,R(40)                     ,RB(50)
```

```
     8      ,RUS      ,R13       ,RBAR(40)   ,R18       ,R2(40)
     9      ,RCUM     ,R15       ,RE(40)     ,RESM      ,R16
     A      ,RHO(40)  ,R17       ,RHO2(40)   ,RHS(25)   ,RHOEN
     1      ,RHSMUM   ,RHABAR    ,RHOBAR     ,RU        ,RSM
     2      ,RSTHEM   ,RV        ,R19        ,RR(100)   ,S
     3                ,SB(50)    ,SC(25)                ,SH(50)
     4      ,S15      ,SX(40)    ,T11        ,T(40)     ,T12
     5      ,T2(40)   ,TABAR     ,TBBAR      ,TO(25)    ,T14
     6      ,TAP(40)  ,TXTH1     ,TXTH2      ,TOL       ,TSM
     7      ,TSM1     ,TSTHEM                ,TA(50)    ,TAS
     8      ,TS       ,U11       ,U(40)      ,U12       ,U2(40)
      COMMON UXTH1    ,UXTH2     ,U14        ,UBAR(40)  ,USM
     1      ,USM1     ,USTHEM                ,UM(50)    ,UMS
     2      ,X11      ,X(40)     ,X12        ,X2(40)
     3      ,XM(50)   ,XUS       ,XABAR(25)  ,XBBAR(25) ,X15
     4      ,XS(25,40) ,XSM      ,XSTHEM                ,XM(50)
     5      ,ZMAP(40)            ,Y11        ,Y(40)     ,Y12
     6      ,Y2(40)   ,YABAR     ,YBBAR      ,ZA(25)    ,Z11(25)
     7      ,ZJ(25,40) ,ZMP      ,S2X        ,R2BM      ,X2BM
     8      ,FX(2,40) ,FR(2,40)  ,FPH1(2,40) ,FP(2,40)  ,FT(2,40)
     9      ,FU(2,40) ,IXOL(2,40) ,INDR(2,40) ,FL(2,40,25),CARD1
     *      ,B        ,K
      REAL   RAY      ,RAYS(25)  ,RAY2       ,RR        ,MOUT(40)
     *      ,MA(40)   ,MU        ,MUS(25)    ,MUO(25)   ,MU2
     *      ,MA(25)   ,MA2       ,MASM       ,MASM1     ,MMSM
     * ,      MAP
      COMMON/P11/XMOMV(8), XMOMP(8),ENEP1(8),REP(40,8),V(40,8),W(40,8),
     1V2(40,8), W2(40,8), IWBDY(8), TP(40,8), TP2(40,8), HP(8),
     2HMP(40,8), HMP2(40,8) ,ENEP2(8),NBL(8),UM(40)


     3,VOLP(8),AIP(8),MC(8),DENG(40,8),ICOND(40,8)
      COMMON/P12/FFF,FFG,GAMA,UM1,PU,NPG,RMX,DNDSP(8)
       COMMON/P13/CL,CS,TPS,RHSS,W1,HTRAN,SIG,EP,IPANT,IRINE,TR(40)
     1 ,SUMP,SUMPV,SUMPE
      COMMON/CFF/IPTU
      COMMON/XYZ/IXYZ,JXYZ
      IXYZ=5
      JXYZ=0
      KZZ=K
      N=K-1
       GAMP1=GAMA+1.
      SQGAM=SQRT(GAMA)
      SQTPI=1.7724
      DO 1 J=1, NPG
      IF (N.GT. NBL(J) ) GO TO 6
    2 CONTINUE
      AXX1=    ((U(K)-W(N,J))**2 +V(N,J)**2)
      AXX= SQRT(AXX1)
      UM(K)=0.0
      DO7 I=1,NUS
    7 UM(K)=UM(K)+XS(I,K)*MUO(I)*(T(K)/TO(I))**OMEGA(I)
C        CALCULATE DRAG COEFFICIENT
      REP(N,J)=RHO(K)*AXX*RP(J)*2.0/UM(K)
      MAP= MA(K)*AXX/U (K)
      RMK=MAP/REP(N,J)
      CDO=24./REP(N,J)
      IF (REP(N,J).GE.60.) CDO=0.40
      TARG=2.*ALOG(MAP)
      TANY=(EXP( 2.*TARG)-1.)/(EXP(2.*TARG)+1.)
      CD1=.66+.20*TANY+.17*EXP(-2.5*(ALOG(MAP)/1.4)**2)
      IF(MAP.LT..3) CD1=.40
      CDO=1.0
      CD=CD1
      XKN=1.26 * SQGAM*RMK
      IF (XKN.GT.4.) GO TO 4
      IF (XKN .LT. 1.E-8) GO TO 5
      XX1=XKN**0.6
      XX2=EXP(1.2* XKP**0.5)
      GKN=XX1*XX2/(1.0+XX1*XX2)
      XX3=XKN**0.6
      XX4=EXP(XKN)
      DRE=1.0-EXP(-XX3*XX4*(CDO-.4)*REP(N,J)/8.)
      CD=GKN*DRE
    4 CONTINUE
      S1=SQRT(.5*GAMA)*MAP
      S2=S1*S1
      S3=S2*S1
      S4=S3*S1
      S32=S2**.5
      SU=S1*SQRT(T (K)  /TP(N,J))
      COFF= EXP(-S32)*(1.0+2.0*S2)/SQTPI/S3
     1      +(4.0*(S4+S2)-1.0)/2.0/S4*ERF(S1)
     2   +0.667*SQTPI/SU
      CD=CDO*(COFF-CD1)+CD1
    5 FU=CD/24.*REP(N,J)*FFF
C        CALCULATE NUSSELT NUMBER
      XUO= 2.0+ 0.459*(REP(N,J)  **0.55)*(PU**0.33)


      XXS= 5.0*(GAMA**1.5)*RMK/GAMP1/PU*XUO
      XURF= XUO/(1.0+XXS)
      XUR= XURF*(GAMP1/GAMA*REP(N,J)*PU*EXP(-0.5/RMK))
      GP= 0.5*XUR*FFG
      XX7 = 4.5 * UM(K) * FU / (RHSS*RP(J)*RP(J))
      XMOMV(J) = XX7*V(K-1,J)
      XMOMP(J) = XX7 * (U (K)-W(K-1,J))
      ENEP1(J)= XX7   *AXX1
      RF=GAMA/GAMP1*(2.+.67*EXP(-MAP**2./3.)   )
      RCE=0.0
```

```
      DO 20 I=1,NOS                                                     FLUX  24
   20 ZJ(I,K)=0.0                                                       FLUX  25
      GO TO 10000                                                       FLUX  26
C     ----- SETUP OF AVERAGED FLUX QUANTITIES NEEDED -----              FLUX  27
   30 TCMAX=TUBAR                                                       FLUX  28
      TUBAR=TABAR                                                       FLUX  29
      TUBAR=TABAR                                                       FLUX  30
      RHOBAR=RHOBAR                                                     FLUX  31
      DO 50 I=1,NOS                                                     FLUX  32
      CUBAR(I)=CABAR(I)                                                 FLUX  33
   50 XUBAR(I)=XABAR(I)                                                 FLUX  34
      PUBAR=PABAR                                                       FLUX  35
      NU=K-1                                                            FLUX  36
      IF (IFLAG) 100,400,100                                            FLUX  37
  100 TABSF=.5*(Y(K+1)+Y2(K+1))                                         FLUX  38
      TABAR=.5*(T(K+1)+T2(K+1))                                         FLUX  39
      NU=K+1                                                            FLUX  40
      UBAR(NU)=SQRT(.5*(U(K+1)**2+U2(K+1)**2))                          FLUX  41
      RHOBAR=.5*(RHO(K+1)+RHO2(K+1))                                    FLUX  42
  110 HAVG=0.25*(H(K)+H(K-1)+H2(K)+H2(K+1))                             FLUX  43
      HAVG=0.25*(H(K+1)+H(K)+H2(K+1)+H2(K))                             FLUX  44
  130 ZM=ZM+0.0                                                         FLUX  45
      DO 200 I=1,NOS                                                    FLUX  46
      CABAR(I)=.5*(C(I,K+1)+C2(I,K+1))                                  FLUX  47
  200 ZM=ZM+ZM+CABAR(I)/MW(I)                                           FLUX  48
      ZM=1.0/ZM                                                         FLUX  49
      DO 300 I=1,NOS                                                    FLUX  50
  300 XABAR(I)=CABAR(I)*ZM/MW(I)                                        FLUX  51
      PABAR=.5*(P(K+1)+P2(K+1))                                         FLUX  52
      GO TO 605                                                         FLUX  53
  400 TABAR=T(K+1)                                                      FLUX  54
      NU=K+1                                                            FLUX  55
      UBAR(NU)=U(K+1)                                                   FLUX  56
      RHOBAR=RHO(K+1)                                                   FLUX  57
  120 HAVG=.5*(H(K)+H(K-1))                                             FLUX  58
      HAVG=.5*(H(K+1)+H(K))                                             FLUX  59
      DO 500 I=1,NOS                                                    FLUX  60
      CABAR(I)=C(I,K+1)                                                 FLUX  61
  500 XABAR(I)=XS(I,K+1)                                                FLUX  62
      PABAR=P(K+1)                                                      FLUX  63
  605 CALL TRANSP(TABAR,PABAR,K+1,MULT,IB16)                            FLUX  64


C     ----- CALCULATION OF HEAT FLUX AND SHEAR -----                    FLUX  65
      QE=(FUB(HDOT(K+1)+HDOT(K))/(RHOBAR*UBAR(K+1)*HAVG**DELTA*MU*RHOBAR FLUX  66
     1 *UBAR(K)*HAVG**DELTA*K2)/(2.0*DELTA*PI)                          FLUX  67
      FF(K)=(HDOT(K+1)+HDOT(K))/(RHOBAR*UBAR(K+1)*HAVG**DELTA*RAVG      FLUX  68
     1  +RHOBAR*UBAR(K)*HAVG**DELTA*RAV2)/(2.0*DELTA*PI)                FLUX  69
      TAU(K)=(UBAR(K+1)-UBAR(K))/(FNUMU                                 FLUX  70
      Q(K)=(TABAR-TABAR)/(FNUM)                                         FLUX  71
C     ----- CALCULATION OF MASS FLUX -----                              FLUX  72
      DO 1900 I=1,NOS                                                   FLUX  73
      CDENOM(I)=(HDOT(K)+HDOT(K+1))/(RHOBAR**2*D2IM(I,2)*UBAR(K)*PI*(2.0 FLUX  74
     1 *HAVG)**DELTA+RHOBAR**2*DIM(I,2)*UBAR(K+1)*PI*(2.0*HAVG)**DELTA)  FLUX  75
 1900 ZJ(I,K)=(CABAR(I)-CUBAR(I))/CDENOM(I)                             FLUX  76
      IF(ISMECH.NE.1) GO TO 1925                                        FLUX  77
      IF(RFAS.GT.RFL) GO TO 1925                                        FLUX  78
      XO=A(I)                                                           FLUX  79
 1925 L=I                                                               FLUX  80
      DIST=A(L)-XC                                                      FLUX  81
      IF (ABS(DIST)-FRAC*YO) 1930,10000,10000                           FLUX  82
 1930 FL=1.-(ABS(DIST)/(FRAC*YO))                                       FLUX  83
      Q(K)=Q(K)*FL+TT                                                   FLUX  84
      TAU(K)=TAU(K)*FL(I-1)                                             FLUX  85
      DO 1935 I=1,NOS                                                   FLUX  86
 1935 ZJ(I,K)=ZJ(I,K)*FL(K)                                             FLUX  87
10000 RETURN                                                            FLUX  88
      END                                                               FLUX  89


      SUBROUTINE LOCATE(XM,YO,X1,Y1,X2,Y2,X3,Y3,IFGOOD)                 LOCATE   2
      RETURN                                                            LOCATE   3
      END                                                               LOCATE   4


      SUBROUTINE MATE7(IDIM,NN,MM,A,B,DET,IND,NOGO)                     MATE7    2
CSIMEQ          SOLVES THE EQUATION AX=B WHERE A,X, AND B ARE MATRICES  MATE7    3
C                          WHERE                                        MATE7    4
C        IDIM   IS A FIXED POINT CONSTANT OR VARIABLE WHOSE VALUE       MATE7    5
C               MUST BE EQUAL TO THE MAXIMUM VALUE THAT MAY EVER BE     MATE7    6
C               ASSUMED BY THE SUBSCRIPT I OF THE MATRIX A(I,J). THIS   MATE7    7
C               VALUE IS IDENTICAL WITH THAT USED IN THE DIMENSION      MATE7    8
C               STATEMENTS WHEN SETTING THE UPPER LIMIT OF THE          MATE7    9
C               SUBSCRIPT.                                              MATE7   10
C        N      IS A FIXED POINT VARIABLE OR CONSTANT WHOSE VALUE       MATE7   11
C               MUST EQUAL THE NUMBER OF ROWS IN THE MATRIX A.          MATE7   12
C        MM     IS A FIXED POINT VARIABLE OR CONSTANT WHOSE VALUE       MATE7   13
C               MUST EQUAL THE NUMBER OF COLUMNS IN THE MATRIX B.       MATE7   14
C        A      IS THE SOURCE PROGRAM FLOATING POINT VARIABLE USED TO   MATE7   15
C               DESIGNATE THE ELEMENTS OF MATRIX A.                     MATE7   16
C        B      IS THE SOURCE PROGRAM FLOATING POINT VARIABLE USED TO   MATE7   17
C               DESIGNATE THE ELEMENTS OF MATRIX B.                     MATE7   18
         DET    MUST BE A FLOATING POINT VARIABLE WHOSE VALUE SERVES    MATE7   19
C               AS A SCALE FACTOR BY WHICH SIMEQ MULTIPLIES THE VALUE   MATE7   20
C               OF THE DETERMINANT OF A. AFTER THE EXECUTION OF THIS    MATE7   21
      DIMENSION A(IDIM,1),B(IDIM,1),IND(1)                              MATE7   22
C               SUBROUTINE, DET CONTAINS THE SCALED VERSION OF THE      MATE7   23
C                DETERMINANT.                                           MATE7   24
```

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C        IND     MUST BE A FIXED OR FLOATING POINT VARIABLE DESIGNATING
C                A ONE-DIMENSIONAL ERASABLE ARRAY OF LENGTH AT LEAST
C                EQUAL TO THE NUMBER OF ROWS IN MATRIX A. IT IS IN THIS
C                AREA SIMEQ KEEPS A RECORD OF THE COLUMN PERMUTATIONS.
C        KEGO    IS A FIXED POINT VARIABLE WHICH WILL BE ASSIGNED THE
C                FIXED POINT CONSTANTS.
C                    1 IF THE SOLUTION WAS SUCCESSFUL.
C                    3 IF THE MATRIX A WAS SINGULAR.
C                              DIMENSIONS
C        A       IDIM X ICIM     IF MM IS LESS THAN OR EQUAL TO IDIM
C                IDIM X MM       IF MM IS GREATER THAN IDIM
C        B       IDIM X MM
C        IND     IDIM
C                              NOTE
C                FOR MATRICES THE ROW DIMENSION MUST BE THE SAME AS
C                THAT GIVEN ABOVE. THE COLUMN DIMENSION MUST AT LEAST
C                BE THAT GIVEN ABOVE.
      ****
C                FOR THE VECTOR THE DIMENSION MUST AT LEAST BE THAT
C                GIVEN ABOVE
C                EXECUTION OF THIS ROUTINE DESTROYS THE ORIGINAL A AND
C                B MATRICES
C                AFTER A SUCCESSFUL EXIT FROM THIS SUBROUTINE, THE
C                ANSWERS OR THE X MATRIX REPLACE THE A MATRIX.
C                THIS REPLACEMENT IS DONE ACCORDING TO THE SCHEME.
C                           A(I,J) IS REPLACED BY X(I,J) .
      ****
C        SET INITIAL CONSTANTS
      KEGO=1
C        SPECIAL CONSIDERATION WHEN THE ORDER OF MATRIX A IS 1.
      IF(N.NE.1) GO TO 5
      IF (A(1,1).EQ.0.) GO TO 110
      HOLD=A(1,1)
      DO 1 I=1,M

    1 A(1,I)=B(1,I)/HOLD
      DET=DET*HOLD
      RETURN
    5 NM1=N-1
      NP1=N+1
C        INITIALIZE DETERMINANT
      DET=1.
C        INITIALIZE COLUMN INDICATORS
      DO 5 I=1,N
    5 IND(I)=I
C        BEGIN TRIANGULARIZATION TO GET UPPER TRIANGLE
      DO 70 K=1,NM1
      KP1=K+1
      KR=K
      KC=K
C        SEARCH FOR PIVOTAL ELEMENT
      BIGA=ABS(A(K,K))
      DO 10 I=K,N
      DO 10 J=K,N
      IF(BIGA.GE.ABS(A(I,J))) GO TO 10
      BIGA=ABS(A(I,J))
      KR=I
      KC=J
   10 CONTINUE
C        TEST FOR SINGULAR MATRIX
      IF(BIGA.EQ.0.) GO TO 110
C        UPDATE DETERMINANT
      DET=DET*A(KR,KC)
C        INTERCHANGE ROWS
      IF(KR.EQ.K) GO TO 30
      DO 20 I=K,N
      HOLD=A(K,I)
      A(K,I)=A(KR,I)
   20 A(KR,I)=HOLD
C        INTERCHANGE ELEMENTS OF RIGHT HAND SIDES
      DO 25 L=1,M
      HOLD=B(K,L)
      B(K,L)=B(KR,L)
   25 B(KR,L)=HOLD
C        CHANGE SIGN OF DETERMINANT DUE TO ROW INTERCHANGE
      DET=-DET
C        INTERCHANGE COLUMNS
   30 IF(KC.EQ.K) GO TO 55
      DO 40 J=1,N
      HOLD=A(J,K)
      A(J,K)=A(J,KC)
   40 A(J,KC)=HOLD
C        INTERCHANGE COLUMN INDICATORS
      I=IND(K)
      IND(K)=IND(KC)
      IND(KC)=I
C        CHANGE SIGN OF DETERMINANT DUE TO COLUMN INTERCHANGE
      DET=-DET
C        DIVIDE REDUCED EQUATION-ONE BY LEADING ELEMENT
   55 DO 60 I=KP1,N
   60 A(K,I)=A(K,I)/A(K,K)
      DO 65 L=1,M

   65 B(K,L)=B(K,L)/A(K,K)
C        REDUCE MATRIX AND RIGHT HAND SIDES
         DO 70 I=KP1,N
         DO 68 J=KP1,N
```

```
C        IND      MUST BE A FIXED OR FLOATING POINT VARIABLE DESIGNATING
C                 A ONE-DIMENSIONAL ERASABLE ARRAY OF LENGTH AT LEAST
C                 EQUAL TO THE NUMBER OF ROWS IN MATRIX A. IT IS IN THIS
C                 AREA SIMEQ KEEPS A RECORD OF THE COLUMN PERMUTATIONS.
C        KOGO     IS A FIXED POINT VARIABLE WHICH WILL BE ASSIGNED THE
C                 FIXED POINT CONSTANTS.
C                    1 IF THE SOLUTION WAS SUCCESSFUL.
C                    3 IF THE MATRIX A WAS SINGULAR.
C                             DIMENSIONS
C        A        IDIM X IDIM     IF NN IS LESS THAN OR EQUAL TO IDIM
C                 IDIM X NN       IF NN IS GREATER THAN IDIM
C        B        IDIM X NN
C        IND      IDIM
C                             NOTE
C                 FOR MATRICES THE ROW DIMENSION MUST BE THE SAME AS
C                 THAT GIVEN ABOVE. THE COLUMN DIMENSION MUST AT LEAST
C                 BE THAT GIVEN ABOVE.
      NNNN
C                 FOR THE VECTOR THE DIMENSION MUST AT LEAST BE THAT
C                 GIVEN ABOVE
C                 EXECUTION OF THIS ROUTINE DESTROYS THE ORIGINAL A AND
C                 B MATRICES.
C                 AFTER A SUCCESSFUL EXIT FROM THIS SUBROUTINE, THE
C                 ANSWERS OR THE X MATRIX REPLACE THE A MATRIX.
C                 THIS REPLACEMENT IS DONE ACCORDING TO THE SCHEME,
C                             A(I,J) IS REPLACED BY X(I,J) .
      NNNN
C        SET INITIAL CONSTANTS
      KOGO=1
C        SPECIAL CONSIDERATION WHEN THE ORDER OF MATRIX A IS 1.
      IF(N.NE.1) GO TO 3
      IF (A(1,1).EQ.0.) GO TO 110
      HOLD=A(1,1)
      DO 1 I=1,M

    1 A(1,I)=B(1,I)/HOLD
      DET=DET*HOLD
      RETURN
    3 NM1=N-1
      NP1=N+1
C        INITIALIZE DETERMINANT
      DETM=DET
C        INITIALIZE COLUMN INDICATORS
      DO 5 I=1,N
    5 IND(I)=I
C        BEGIN TRIANGULARIZATION TO GET UPPER TRIANGLE
      DO 70 K=1,NM1
      KP1=K+1
      KR=K
      KC=K
C        SEARCH FOR PIVOTAL ELEMENT
      BIGA=ABS(A(K,K))
      DO 10 I=K,N
      DO 10 J=K,N
      IF(BIGA.GE.ABS(A(I,J))) GO TO 10
      BIGA=ABS(A(I,J))
      KR=I
      KC=J
   10 CONTINUE
C        TEST FOR SINGULAR MATRIX
      IF(BIGA.EQ.0.) GO TO 110
C        UPDATE DETERMINANT
      DETM=DETM*A(KR,KC)
C        INTERCHANGE ROWS
      IF(KR.EQ.K) GO TO 30
      DO 20 I=K,N
      HOLD=A(K,I)
      A(K,I)=A(KR,I)
   20 A(KR,I)=HOLD
C        INTERCHANGE ELEMENTS OF RIGHT HAND SIDES
      DO 25 L=1,M
      HOLD=B(K,L)
      B(K,L)=B(KR,L)
   25 B(KR,L)=HOLD
C        CHANGE SIGN OF DETERMINANT DUE TO ROW INTERCHANGE
      DETM=-DETM
C        INTERCHANGE COLUMNS
   30 IF(KC.EQ.K) GO TO 55
      DO 40 J=1,N
      HOLD=A(J,K)
      A(J,K)=A(J,KC)
   40 A(J,KC)=HOLD
C        INTERCHANGE COLUMN INDICATORS
      I=IND(K)
      IND(K)=IND(KC)
      IND(KC)=I
C        CHANGE SIGN OF DETERMINANT DUE TO COLUMN INTERCHANGE
      DETM=-DETM
C        DIVIDE REDUCED EQUATION-ON, BY LEADING ELEMENT
   55 DO 60 I=KP1,N
   60 A(K,I)=A(K,I)/A(K,K)
      DO 65 L=1,M

   65 B(K,L)=B(K,L)/A(K,K)
C        REDUCE MATRIX AND RIGHT HAND SIDES
      DO 70 I=KP1,N
      DO 65 J=KP1,M
```

```
   65 A(I,J)=A(I,J)-A(I,K)*A(K,J)                                    MATE7   120
      DO 70 L=1,M                                                    MATE7   121
   70 B(I,L)=B(I,L)-A(I,K)*B(K,L)                                    MATE7   122
C        FINAL TEST FOR SINGULAR MATRIX                              MATE7   123
      IF(A(N,N).EQ.0.) GO TO 110                                     MATE7   124
C        COMPUTE FINAL DETERMINANT                                   MATE7   125
      DET=DET*A(N,N)                                                 MATE7   126
C        BACK SUBSTITUE TO OBTAIN SOLUTION VECTORS                   MATE7   127
      DO 80 L=1,M                                                    MATE7   128
      B(N,L)=B(N,L)/A(N,N)                                           MATE7   129
      DO 80 I=1,NN1                                                  MATE7   130
      HOLD=0.                                                        MATE7   131
      J=N-I                                                          MATE7   132
      DO 75 KC=1,I                                                   MATE7   133
      K=NP1-KC                                                       MATE7   134
   75 HOLD=HOLD+A(J,K)*B(K,L)                                        MATE7   135
   80 B(J,L)=B(J,L)-HOLD                                             MATE7   136
C        REARRANGE SOLUTION VECTORS TO ORIGINAL ORDER                MATE7   137
      DO 90 I=1,N                                                    MATE7   138
      J=IND(I)                                                       MATE7   139
      DO 90 L=1,M                                                    MATE7   140
   90 A(J,L)=B(I,L)                                                  MATE7   141
      RETURN                                                         MATE7   142
C        SINGULAR MATRIX - REDUNDANT SET OF EQUATIONS                MATE7   143
  110 KODE=3                                                         MATE7   144
      DET=0.                                                         MATE7   145
      RETURN                                                         MATE7   146
      END                                                            MATE7   147

      SUBROUTINE ORTHOG(SIDE,LIM1,LIM2)                              ORTHOG    2
      RETURN                                                         ORTHOG    3
      END                                                            ORTHOG    4

      SUBROUTINE PBNDY                                               PBNDY     2
      COMMON A(25,7)    ,AA(40)     ,ALFA(25,25),ALPHAM    ,ALPHAP     A         2
     1      ,ATOL       ,BETAP      ,BMIX       ,C11(25)    ,C(25,40)   A         3
     2      ,C12(25)    ,C2(25,40)  ,CABAR(25)  ,CHBAR(25)  ,CP         A         4
     3      ,CPS(25)    ,CPSH       ,CSH(25)    ,CSH1(25)   ,CSTREM(25) A         5
     4      ,CXSTRM     ,D21M(25,25),DEFF(25)   ,D2EFF(25)  ,DELTA      A         6
     5      ,D11        ,DELSS(40)  ,DELS       ,DELSO      ,DLS(40)    A         7
     6      ,D1M(25,25) ,D12        ,DELY(40)   ,D13        ,DPDY(40)   A         8
     7      ,D14        ,DPHIDS(40) ,EPCON                              A         9
     8      ,EPSLON     ,EXTRA(50)  ,FSTEP      ,FMAX       ,GRAD       A        10
     9      ,H11        ,H(40)      ,HH         ,HJ         ,HPM(25)    A        11
     *      ,H2PM(25)   ,H3PM(25)   ,ICONST     ,ICOUNT     ,IDENT(25)  A        12
     1      ,IERROR     ,IEXTRA(50) ,IFLAG      ,IKIND                  A        13
     2      ,IFTOC      ,ISHOCK     ,ITYPE      ,IPD                    A        14
     3      ,IDIFF      ,K          ,KAY        ,KAYS       ,KAY2       A        15
     4      ,KLO        ,KMAX                                           A        16
     5      ,KUP        ,KF         ,LL         ,LPLANE     ,MA         A        17
     6      ,MASH       ,MDOT       ,MMAX       ,MUO        ,MU         A        18
     7      ,MU2        ,MUS        ,MW         ,MW2        ,MWSH       A        19
     8      ,NBOUND     ,NOS        ,NITER      ,NMAX       ,NN         A        20
      COMMON NUCASE     ,OMEGA(25)  ,P11        ,P(40)      ,P12        A        21
     1      ,P2(40)                 ,PB(50)     ,PABAR      ,PBBAR      A        22
     2      ,PHS        ,P15        ,PHI(40)                ,PHIB(50)   A        23
     3      ,PHISH1     ,PHSTRM                 ,PHIF(50)   ,P18        A        24
     4      ,PHI2(40)   ,PHIBS      ,PI         ,PR(25)     ,PSH        A        25
     5      ,PSH1       ,PS1        ,PSTREM                 ,PW(50)     A        26
     6      ,Q11        ,Q(40)      ,QXTW1      ,QXTW2                  A        27
     7      ,RB(50)     ,R11        ,R(40)                  ,RO(50)     A        28
     8      ,ROS        ,R13        ,RBAR(40)   ,R14        ,R2(40)     A        29
     9      ,RECN       ,R15        ,RE(40)     ,RESH       ,R16        A        30
     *      ,RHO(40)    ,R17        ,RHO2(40)   ,RHS(25)    ,RHSFN      A        31
     1      ,RHSHOC     ,RHABAR     ,RHBBAR     ,RO         ,RSH        A        32
     2      ,RSTREM     ,RV         ,R19        ,RW(100)    ,S          A        33
     3                  ,SP(50)     ,SL(25)                 ,SW(50)     A        34
     4      ,S13        ,SX(40)     ,T11        ,T(40)      ,T12        A        35
     5      ,T2(40)     ,TAHAR      ,TBHAR      ,TO(25)     ,T14        A        36
     6      ,TAW(40)    ,TXTW1      ,TXTW2      ,TOL        ,TSH        A        37
     7      ,TSH1       ,TSTREM                 ,TW(50)     ,TWS        A        38
     8      ,TS         ,U11        ,U(40)      ,U12        ,U2(40)     A        39
      COMMON UXTW1      ,UXTW2      ,U14        ,UBAR(40)   ,USH        A        40
     1      ,USH1       ,USTREM                 ,UW(50)     ,UWS        A        41
     2      ,X11        ,X(40)      ,X12        ,X2(40)                 A        42
     3      ,XB(50)     ,XBS        ,XABAR(25)  ,XBBAR(25)  ,X15        A        43
     4      ,XS(25,40)  ,XSH        ,XSTREM                 ,XW(50)     A        44
     5      ,YBAR(40)               ,Y11        ,Y(40)      ,Y12        A        45
     6      ,Y2(40)     ,YAHAR      ,YBHAR      ,Z4(25)     ,Z11(25)    A        46
     7      ,Z3(25,40)  ,ZMF        ,S2X        ,K2SH       ,X2SH       A        47
     8      ,F3(2,40)   ,FK(2,40)   ,FPHI(2,40) ,FP(2,40)   ,FT(2,40)   A        48
     9      ,FU(2,40)   ,INDL(2,40) ,INDR(2,40) ,FC(2,40,25),CARD1      A        49
     *      ,W          ,N                                              A        50
      REAL     KAY       ,KAYS(25)   ,KAY2       ,KR         ,MDOT(40)   PBNDY     4
     *      ,MA(40)     ,MU         ,MUS(25)    ,MUO(25)    ,MU2        PBNDY     5
     *      ,MW(25)     ,MW2        ,MASH       ,MASH1      ,MWSH       PBNDY     6
     *  ,    KAP                                                       PBNDY     7
      COMMON/P11/XBONL(8), XBUPP(8),ENERI(8),REP(40,8),V(40,8),R(40,8),  PBNDY     8
     1V2(40,8), R2(40,8), IHBDY(8), IP(40,8), IP2(40,8), RP(8),        PBNDY     9
     2RMP(40,8), RMP2(40,8) ,ENEP2(8),RNL(8),UM(40)                    PBNDY    10

     3,VOLF(8),XIP(8),RC(8),LENG(40,8),ICOND(40,8)                     PBNDY    11
      COMMON/P12/FFF,FFG,GAMA,GMI,PO,NPG,RMX,DNDSP(8)                  PBNDY    12
      COMMON/P13/CL,CS,IPS,RHSS,WT,MIRAN,SIG,EP,IPART,IKINE,IR(40)     PBNDY    13
     1 ,SUFP,SUFFV,SUFFE                                               PBNDY    14
      COMMON/XYZ/IXYZ,JXYZ                                             PBNDY    15
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```
      IXT2=0                                                            PBNDY   16
      JAY2=0                                                            PBNDY   17
      KMX=0                                                             PBNDY   18
      DO 5 J=1, NPG                                                     PBNDY   19
      NBLJ=NBL(J)                                                       PBNDY   20
      NBL1=NBLJ+1                                                       PBNDY   21
      UNDSP(J)= UNDSP(J)+ DLS(NBL1)*V2(NBLJ,J)/W2(NBLJ,J)               PBNDY   22
      THBDY(J)= Y2(NBL1 )+UNDSP(J)                                      PBNDY   23
      DO 12 IEM=1,MMAX                                                  PBNDY   24
      IF (THBDY(J) .LT. Y2(IEM+1)) GO TO 15                             PBNDY   25
   12 CONTINUE                                                          PBNDY   26
      WRITE(6,103)                                                      PBNDY   27
   15 CONTINUE                                                          PBNDY   28
      IF (IEM.NE.NBL(J)) UNDSP(J)=THBDY(J)-Y2(IEM+1)                    PBNDY   29
      IF (IEM.GT.KMX) KMX=IEM                                           PBNDY   30
      DO 14 LK=1,IEM                                                    PBNDY   31
      IF (LK.GT.NBL(J)) GO TO 17                                        PBNDY   32
      GO TO 16                                                          PBNDY   33
   17 W2(LK,J)=W2(LK-1,J)                                               PBNDY   34
      V2(LK,J)=V2(LK-1,J)                                               PBNDY   35
      IP2(LK,J)=IP2(LK-1,J)                                             PBNDY   36
      RHP2(LK,J)= RHP2(LK-1,J)                                          PBNDY   37
   16 CONTINUE                                                          PBNDY   38
      V(LK,J)= V2(LK,J)                                                 PBNDY   39
      W(LK,J)= W2(LK,J)                                                 PBNDY   40
      IP(LK,J)=IP2(LK,J)                                                PBNDY   41
   11 RHP(LK,J)= RHP2(LK,J)                                             PBNDY   42
   14 CONTINUE                                                          PBNDY   43
      NBL(J)=IEM                                                        PBNDY   44
    5 CONTINUE                                                          PBNDY   45
      WRITE (6,102) S,(THBDY(J),J=1,NPG)                                PBNDY   46
  102 FORMAT( 1H ,33H BOUNDARY OF PARTICLE PHASE AT S= ,F11.5, 1P8E11.3) PBNDY  47
  103 FORMAT(41H  *******NO PARTICLES IN THIS FLOW FIELD  //)           PBNDY   48
      RETURN                                                            PBNDY   49
      END                                                               PBNDY   50


      SUBROUTINE PPUTIN                                                 PPUTIN   2
      COMMON A(25,7),     ,AA(40)     ,ALFA(25,25),ALPHAM    ,ALPHAP    A        2
     1        ,ATOL       ,BETAP      ,BETA      ,C11(25)    ,C(25,40)  A        3
     2        ,C12(25)    ,C2(25,40)  ,CABAR(25) ,CBBAR(25)  ,CP        A        4
     3        ,CPS(25)    ,CPSH       ,CSH(25)   ,CSH1(25)   ,CSTREM(25) A       5
     4        ,MXSTRM     ,D2IF(25,25),DEFF(25)  ,D2EFF(25)  ,DELTA     A        6
     5        ,D11        ,DELSS(40)  ,DELS      ,DELSO      ,DLS(40)   A        7
     6        ,DIM(25,25) ,D12        ,DELY(40)  ,D13        ,DPDY(40)  A        8
     7        ,D14        ,DPHIDS(40) ,EPCON                            A        9
     8        ,EPSLON     ,EXTRA(50)  ,ESTEP     ,EMAX       ,GRAD      A       10
     9        ,H11        ,H(40)      ,HH        ,HJ         ,HPM(25)   A       11
     *        ,H2PM(25)   ,H3PM(25)   ,ICONST    ,ICOUNT     ,IDENT(25) A       12
     1        ,IERROR     ,IEXTRA(50) ,IFLAG     ,IMIND                 A       13
     2        ,IPTOL      ,ISHOCK     ,ITYPE     ,IPD                   A       14
     3        ,IDIFF      ,K          ,KAY       ,KAYS       ,KAY2      A       15
     4        ,KLG        ,KMAX                                         A       16
     5        ,KOP        ,KK         ,LL        ,LPLANE     ,MA        A       17
     6        ,MASH       ,MDOT       ,MMAX      ,MOO        ,MO        A       18
     7        ,MO2        ,MOS        ,MR        ,MW2        ,MWSH      A       19
     8        ,NBOUND     ,NDS        ,NITER     ,NMAX       ,NN        A       20
      COMMON NOCASE       ,OMEGA(25)  ,P11       ,P(40)      ,P12       A       21
     1        ,P2(40)                 ,PO(50)    ,PABAR      ,PBBAR     A       22
     2        ,PHS        ,P15        ,PHI(40)               ,PHIM(50)  A       23
     3        ,PHISH1     ,PHSTRM                ,PHIW(50)   ,P16       A       24
     4        ,PHI2(40)   ,PHIBS      ,PI        ,PM(25)     ,PSH       A       25
     5        ,PSH1       ,PSI        ,PSTREM                ,PW(50)    A       26
     6        ,Q11        ,Q(40)      ,QXTR1     ,QXTR2                 A       27
     7        ,QW(50)     ,R11        ,R(40)                 ,RB(50)    A       28
     8        ,RBS        ,R13        ,RBAR(40)  ,R14        ,R2(40)    A       29
     9        ,RCON       ,R15        ,RE(40)    ,RESH       ,R16       A       30
     *        ,RHO(40)    ,R17        ,RHO2(40)  ,RHS(25)    ,RHSEN     A       31
     1        ,RHSHOK     ,RHABAR     ,RHBBAR    ,RO         ,RSH       A       32
     2        ,RSTREM     ,RW         ,R19       ,RW(100)    ,S         A       33
     3                    ,SM(50)     ,SL(25)                ,SW(50)    A       34
     4        ,S13        ,SX(40)     ,T11       ,T(40)      ,T12       A       35
     5        ,T2(40)     ,TABAR      ,TBBAR     ,T0(25)     ,T14       A       36
     6        ,TAW(40)    ,TXTR1      ,TXTR2     ,TOL        ,TSH       A       37
     7        ,TSH1       ,TSTREM                ,TW(50)     ,TWS       A       38
     8        ,T5         ,U11        ,U(40)     ,U12        ,U2(40)    A       39
      COMMON UXTR1        ,UXTR2      ,U14       ,UBAR(40)   ,USH       A       40
     1        ,USH1       ,USTREM                ,UW(50)     ,UWS       A       41
     2        ,X11        ,X(40)      ,X12       ,X2(40)                A       42
     3        ,XB(50)     ,XBS        ,XABAR(25) ,XBBAR(25)  ,X15       A       43
     4        ,XS(25,40)  ,XSH        ,XSTREM                ,XW(50)    A       44
     5        ,ZMAX(40)               ,Y11       ,Y(40)      ,Y12       A       45
     6        ,Y2(40)     ,YABAR      ,YBBAR     ,ZA(25)     ,Z11(25)   A       46
     7        ,Z3(25,40)  ,ZMF        ,S2X       ,W2SH       ,X2SH      A       47
     8        ,FA(2,40)   ,FR(2,40)   ,FPHI(2,40),FP(2,40)   ,FT(2,40)  A       48
     9        ,FU(2,40)   ,INDL(2,40) ,INDR(2,40),FC(2,40,25),CARD1     A       49
     *        ,M          ,N                                            A       50
      REAL     KAY        ,KAYS(25)   ,KAY2      ,MA         ,MOUT(40)  PPUTIN   4
     *        ,MA(40)     ,MO         ,MOS(25)   , MO(25)    ,MO2       PPUTIN   5
     *        ,MW(25)     ,MW2        ,MASH      ,MASH1      ,MASH      PPUTIN   6
     * ,       MAP                                                      PPUTIN   7
      COMMON/PT1/XMOMV(8), XMOMP(8),ENEP1(8),REP(40,8),V(40,8),W(40,8), PPUTIN   8
     1V2(40,8), W2(40,8), THBDY(8), IP(40,8), IP2(40,8), RP(8),         PPUTIN   9
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),FAL(8),UW(40)                     PPUTIN  10


     3,VOLP(8),WTP(8),HL(8),DLNG(40,8),ICOND(40,8)                      PPUTIN  11
      COMMON/PT2/FFF,FFG,GAMA,OMI,PO,NPG,KMX,UNDSP(8)                   PPUTIN  12
      COMMON/PT3/CL,CS,TPS,RHSS,PT,HTRAN,SIG,EP,IPART,IKIND,IR(40)      PPUTIN  13
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```
     1 ,SUPP,SUMPV,SUMPE
      COMMON/XYZ/IXYZ,JXYZ
      DIMENSION VI(6),AI(6),TPI(6),NMPI(6)  ,DENGI(6)
      NAMELIST/NAM1/ FFF,FFG,UMI   ,CL,CS,IPS,NNBS,AT,MTHAN,SIG,EP,NPG,
     1 NC,KMA,RP,AI,VI,TPI,NMPI
      IXYZ=11
      JXYZ=0
      READ (5,100) FFF,FFG,CL,CS,MTHAN,AT
      READ (5,100) NNBS,SIG,EP      ,TPS   ,UMI
      READ(5,107) NPG,NC
      READ (5,107) (NBL(J),J=1,NPG)
      DO25 J=1,NPG
   25 NBL(J)=NBL(J)-1
      KMA=NBL(1)
      IF (NPG.LE.1) GO TO 245
      DO 241 J=2,NPG
      IF (KMA.LT.NBL(J)) KMA=NBL(J)
  241 CONTINUE
  245 CONTINUE
      READ (5,100) (RP(J),J=1,NPG)
      IF(NC.EQ.1) GO TO 2
      READ(5,100) (AI(J),J=1,NPG)
      READ(5,100) (VI(J),J=1,NPG)
      READ(5,100) (TPI(J),J=1,NPG)
      READ(5,100) (NMPI(J),J=1,NPG)
      READ(5,100) (DENGI(J),J=1,NPG)
      DO 5 J=1,NPG
      KMA=NBL(J)
      DO 4 K=1,KMA
      A(K,J)=AI(J)
      V(K,J)=(K-1)*VI(J)/(KMA-1)
      TP(K,J)=TPI(J)
      NMP(K,J)=NMPI(J)
      DENG(K,J)=DENGI(J)
      A2(K,J)=A(K,J)
      V2(K,J)=V(K,J)
      TP2(K,J)=TP(K,J)
      NMP2(K,J)=NMP(K,J)
    4 CONTINUE
      DADSP(J)=0.0
      TPBDY(J)=Y(KMA+1)
    5 CONTINUE
      DO 21 J=1, NPG
      KMA=NBL(J)
      DO 21 K=1,KMA
      ICOND(K,J)=0
   21 CONTINUE
      GO TO 3
    2 CONTINUE
      DO 1 K=1,KMA
      READ (5,100) (A(K,J),J=1,NPG)
      READ (5,100) (V(K,J),J=1,NPG)
      READ (5,100) (TP(K,J),J=1,NPG)
      READ (5,100) (NMP(K,J),J=1,NPG)
      READ(5,107) (ICOND(K,J),J=1,NPG)
      READ(5,100) (DENG(K,J),J=1,NPG)
      DO 6 J=1,NPG
      A2(K,J)=A(K,J)
      V2(K,J)=V(K,J)
      TP2(K,J)=TP(K,J)
      NMP2(K,J)=NMP(K,J)
    6 CONTINUE
    1 CONTINUE
      READ( 5,100) (TPBDY(J),J=1,NPG)
      READ( 5,100) (DADSP(J),J=1,NPG)
    3 CONTINUE
      WRITE(6,NAM1)
      DO 7 J=1, NPG
      VOLP(J)=1.333333*PI*(RP(J)**3)
      WTP(J)=VOLP(J)*RHSS
    7 WC(J)=WTP(J)    *MTHAN
      DO 12 J=1,NPG
      IF (KMAX-NBL(J)) 12,12,11
   11 KMA1=NBL(J)+1
      DO 10 K=KMA1,KMAX
      A(K,J)=0.0
      V(K,J)=0.0
      TP(K,J)=0.0
      NMP(K,J)=0.0
      A2(K,J)=0.0
      V2(K,J)=0.0
      TP2(K,J)=0.0
      NMP2(K,J)=0.0
      DENG(K,J)=0.0
      ICOND(K,J)=1
   10 CONTINUE
   12 CONTINUE
      DO 22 K=1,KMAX
      WRITE(6,101) K
      WRITE(6,102) ( A(K,J),J=1,NPG)
      WRITE(6,103) ( V(K,J),J=1,NPG)
      WRITE(6,105) ( TP(K,J),J=1,NPG)
      WRITE(6,106) ( NMP(K,J),J=1,NPG)
   22 CONTINUE
  100 FORMAT(8E10.3)
  101 FORMAT(1H ,15HSTREAMLINE NO.  ,I5)
  102 FORMAT(1H ,19HDOWNSTREAM VELOCITY ,2X,1P8E12.3)
  103 FORMAT(1H ,21HCROSS-STREAM VELOCITY ,1P8E12.3)
  105 FORMAT(1H ,20HPARTICLE TEMPERATURE ,1X,1P8E12.3)
  106 FORMAT(1H ,16HPARTICLE DENSITY ,5X,1P8E12.3)
  107 FORMAT(8I5)
      RETURN
      END
```

```
      SUBROUTINE PART
      COMMON A(25,7)     ,AA(40)       ,ALFA(25,25),ALPHAM     ,ALPHAP
     1      ,ATOL        ,BETAP        ,BMIX        ,C11(25)    ,C(25,40)
     2      ,C12(25)     ,C2(25,40)    ,CABAR(25)   ,CBBAR(25)  ,CP
     3      ,CPS(25)     ,CPSM         ,CSM(25)     ,CSM1(25)   ,CSTREM(25)
     4      ,MASTRM      ,D2IM(25,25),DEFF(25)      ,D2EFF(25)  ,DELTA
     5      ,D11         ,DELSS(40)    ,DELS        ,DELSU      ,DLS(40)
     6      ,DIM(25,25)  ,D12          ,DELY(40)    ,D13        ,DPDY(40)
     7      ,D14         ,DPHIDS(40)   ,EPCON
     8      ,EPSLON      ,EXTRA(50)    ,FSTEP       ,FMAX       ,GRAD
     9      ,H11         ,H(40)        ,HH          ,HJ         ,HPM(25)
     *      ,H2PM(25)    ,H3PM(25)     ,ICENBT      ,ICOUNT     ,IDENT(25)
     1      ,IERROR      ,IEXTRA(50)   ,IFLAG       ,IKIND
     2      ,IPTUC       ,ISHOCK       ,ITYPE       ,IPD
     3      ,IDIFF       ,K            ,KAY         ,KAYS       ,KAY2
     4      ,KLO         ,KMAX
     5      ,KUP         ,KW           ,LL          ,LPLANE     ,MA
     6      ,MASM        ,MDOT         ,MMAX        ,MUB        ,MU
     7      ,MU2         ,MUS          ,MW          ,MW2        ,MWSM
     8      ,NBOUND      ,NDS          ,NITER       ,NMAX       ,NN
      COMMON NUCASE      ,OMEGA(25)    ,P11         ,P(40)      ,P12
     1      ,P2(40)                    ,PB(50)      ,PABAR      ,PRBAR
     2      ,PBS         ,P15          ,PHI(40)                 ,PHIH(50)
     3      ,PHISM1      ,PHSTRM                    ,PHIW(50)   ,P18
     4      ,PHI2(40)    ,PHIBS        ,PI          ,PR(25)     ,PSM
     5      ,PSM1        ,PSI          ,PSTREM                  ,PW(50)
     6      ,Q11         ,Q(40)        ,QXTR1       ,QXTR2
     7      ,QW(50)      ,R11          ,R(40)                   ,RH(50)
     8      ,RHS         ,R13          ,RHAR(40)    ,R14        ,R2(40)
     9      ,RCON        ,R15          ,RE(40)      ,RESM       ,R16
     *      ,RHO(40)     ,R17          ,RHO2(40)    ,RHS(25)    ,RHSEN
     1      ,RHSMOM      ,RHABAR       ,RHOBAR      ,RU         ,RSM
     2      ,RSTREM      ,RV           ,R19         ,RW(100)    ,S
     3                   ,SH(50)       ,SC(25)                  ,SW(50)
     4      ,S13         ,SX(40)       ,T11         ,T(40)      ,T12
     5      ,T2(40)      ,TABAR        ,TBBAR       ,TU(25)     ,T14
     6      ,TAW(40)     ,TXTR1        ,TXTR2       ,TUC        ,TSM
     7      ,TSM1        ,TSTREM                    ,TW(50)     ,TWS
     8      ,TS          ,U11          ,U(40)       ,U12        ,U2(40)
      COMMON UXTR1       ,UXTR2        ,U14         ,UBAR(40)   ,USM
     1      ,USM1        ,USTREM                    ,UW(50)     ,UWS
     2      ,X11         ,X(40)        ,X12         ,X2(40)
     3      ,XW(50)      ,XBS          ,XABAR(25)   ,XBBAR(25)  ,X15
     4      ,XS(25,40)   ,XSM          ,XSTREM                  ,XW(50)
     5      ,ZMRK(40)                  ,Y11         ,Y(40)      ,Y12
     6      ,Y2(40)      ,YABAR        ,YBBAR       ,ZA(25)     ,Z11(25)
     7      ,ZJ(25,40)   ,ZMA          ,S2X         ,R2SM       ,X2SM
     8      ,FX(2,40)    ,FR(2,40)     ,FPHI(2,40)  ,FP(2,40)   ,FT(2,40)
     9      ,FU(2,40)    ,INDL(2,40)   ,INDR(2,40)  ,FC(2,40,25),CARD1
     *      ,N           ,N
      REAL   KAY         ,KAYS(25)     ,KAY2        ,KW         ,MDOT(40)
     *      ,MA(40)      ,MU           ,MUS(25)     ,MUU(25)    ,MU2
     *      ,MW(25)      ,MW2          ,MASM        ,MASM1      ,MWSM
     *,     MAP
      COMMON/P11/XPUMV(8), XMOMP(8),ENEP1(8),HEP(40,8),V(40,8),W(40,8),
     1V2(40,8), W2(40,8), TRBOY(8), TP(40,8), TP2(40,8), RP(8),
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),NBL(8),UM(40),
     3,VOLP(8),WTP(8),MC(8),DENG(40,8),ICOND(40,8)
      COMMON/P12/FFF,FFG,GAMA,UMI,PU,NPG,KMX,DNDSP(8)
      COMMON/P13/CL,CS,TFS,HMSS,WT,MIRAN,SIG,EP,IPART,INJNE,IR(40)
     1 ,SUMP,SUMPV,SUMPT
      COMMON/XYZ/IXYZ,JXYZ
      IXYZ=12
      JXYZ=0
      N=K-1
      KZZ=N
      N=K+1
      DEL=(DLS(N)+DLS(N-1))*.5
      DO 1 J=1, NPG
      IF (K.GT. NBL(J)) GO TO 3
    2 CONTINUE
      XX6=DEL *V(K,J)/W(K,J)
      IF(K.EQ.1) GO TO 13
      K1=K-1
      RX1= (.5*(R(K1+1)+R(K1)))**DELTA
      RX2=(.5*(R(K1+2)+R(K1+1)))**DELTA
      DELLY=SQRT((X(K1+2)-X(K1))**2+(R(K1+2)-R(K1))**2)*.5
      THEN=(PHI(K1+2)-PHI(K1))/DELLY *.5
      DWDN=(W(K1+1,J)-W(K1,J))/DELLY
      DVDN=(V(K1+1,J)-V(K1,J))/DELLY
      DTDN=(TP(K1+1,J)-TP(K1,J))/DELLY
      DRRVDN=(RX2  *RHP(K1+1,J)*V(K1+1,J)
     1 -RX1  *RHP(K1,J)*V(K1,J))/DELLY
      GO TO 16
   13 DWDN=0.0
      DELLY=SQRT(R(2)**2+(X(2)-X(1))**2)  *.5
      DVDN=V(1,J)/DELLY
      DTDN=0.0
      DRRVDN=RHP(1,J)*V(1,J)/DELLY*(R(2)/2.)**DELTA
      THEN=PHI(2)/(2.*DELLY)
   16 THES=(PHI2(N)+PHI2(N-1)-PHI(N)-PHI(N-1))/(DLS(N)+DLS(N-1))
      W2(K,J)=W(K,J)-XX6*DWDN
     1        +XX6*V(K,J)*THEN
     2        +DEL *V(K,J)*THES +XMOMP(J)*DEL /W(K,J)
      V2(K,J)= V(K,J)- XX6*DVDN
     1        - DEL *V(K  J)*THEN
     2        - W(K,J)*DEL *THES
     3        - XPUMV(J)*DEL /W(K,J)
```

```
C     ENERGY EQUATION
      CC=CL
      IF(TP(K,J).LE.TPS) CC=CS
      IF (ICOND(K,J).EQ.0) GO TO 14
      XX8= *TP(J)*ENEP2(J)          *DEL /W(K,J)/HJ
      XX9=4.0*PI*HP(J)*HP(J)*EP*SIG*(TPS**4.0)/W(K,J)*DEL/HJ
      DENG(K,J)=DENG(K,J)+XX8+XX9
      IF (ABS(DENG(K,J)).GE.HC(J)) GO TO 15
      GO TO 12
   15 CONTINUE
      ICOND(K,J)=0
      WRITE (6,102) HP(J),S,K,DENG(K,J)
   14 CONTINUE
      XX8=ENEP2(J)/HJ/V(K,J)/CC
      XX9=      EP*SIG*3.0/(R(K,J)   *HP(J)*RHOS*CC) *(TP(K,J)**4.0)/HJ
      TP2(K,J)= TP(K,J)-XX6*DTDN -(XX8+XX9)*DEL


      IF (((TP2(K,J)-TPS)*(TP(K,J)-TPS)).GE.0.0) GO TO 12
      ICOND(K,J)=1
      TP2(K,J)=TPS
      WRITE (6,103) HP(J),S,K
  103 FORMAT (1H ,1PE10.3,43H CM PARTICLE  GROUP START SOLIDIFYING AT S=
     1,0PF10.4,19H CM STREAMTUBE NO. ,I5/)
   12 CONTINUE
C        CONTINUITY EQUATION
      RX1=(.5*(R(K+1)+R(K)))**DELTA
      R2X1=(.5*(R2(K+1)+R2(K)))**DELTA
      XX10=RX1 *RHP(K,J)*U(K,J)
      XX11=RX1 *RHP(K,J)*V(K,J)
      RHP2(K,J)= 1.0/(R2X1 *U2(K,J))*(XX10*(1.0-DEL *THEN)
     1       -DRRVDR*DEL
     2          + XX11*THES*DEL )
      GO TO 1
    3 V2(K,J)=0.0
      U2(K,J)=0.0
      TP2(K,J)=0.0
      RHP2(K,J)= 0.0
      HEP(K,J)=0.0
    1 CONTINUE
  102 FORMAT (1H ,1PE10.3,40H CM SIZE PARTICLE GROUP SOLIDIFIED AT S= ,
     1 0PF10.4,19H CM  STREAMTUBE NO. ,I5, 3X,1PE10.3,3HCAL /)
      K=K+1
      N=K22
      RETURN
      END


      SUBROUTINE PUTOUT(IOUT)
      COMMON A(25,7)       ,AA(40)        ,ALFA(25,25),ALPHAN     ,ALPHAP
     1      ,ATOL          ,BETAP         ,BPIX         ,C11(25)     ,C(25,40)
     2      ,C12(25)       ,C2(25,40)     ,CABAR(25)    ,CHBAR(25)   ,CP
     3      ,CPS(25)       ,CPSH          ,CSH(25)      ,CSH1(25)    ,CSTHEM(25)
     4      ,MXSTHP        ,D2IN(25,25)   ,DEFF(25)     ,D2EFF(25)   ,DELTA
     5      ,D11           ,DELSS(40)     ,DELS         ,DELSU       ,DLS(40)
     6      ,DIN(25,25)    ,D12           ,DELY(40)     ,D13         ,DPDY(40)
     7      ,D14           ,DPHIDS(40)    ,EPCON
     8      ,EPSLON        ,EXTRA(50)     ,FSTEP        ,FMAX        ,GRAD
     9      ,H11           ,H(40)         ,HH           ,HJ          ,HPM(25)
     *      ,H2PM(25)      ,H3PM(25)      ,ICONST       ,ICOUNT      ,IDENT(25)
     1      ,IERROR        ,IEXTRA(50)    ,IFLAG        ,IKIND
     2      ,IPTOC         ,ISHOCK        ,ITYPE        ,IPD
     3      ,IDIFF         ,K             ,KAY          ,KAYS        ,KAY2
     4      ,KLO           ,KMAX
     5      ,KUP           ,KK            ,LL           ,LPLANE      ,MA
     6      ,MASH          ,MOUT          ,MMAX         ,MU0         ,MU
     7      ,MU2           ,MUS           ,MW           ,MW2         ,MWSH
     8      ,NBOUND        ,NOS           ,NITER        ,NMAX        ,NN
      COMMON NUCASE        ,OMEGA(25)     ,P11          ,P(40)       ,P12
     1      ,P2(40)                       ,PB(50)       ,PABAR       ,PBBAR
     2      ,PHS           ,P15           ,PH1(40)                   ,PHIN(50)
     3      ,PHISH1        ,PHSTRM                      ,PHIW(50)    ,P18
     4      ,PHI2(40)      ,PHIBS         ,PI           ,PR(25)      ,PSH
     5      ,PSH1          ,PSI           ,PSTREM                    ,PW(50)
     6      ,Q11           ,Q(40)         ,QXTR1        ,QXTR2
     7      ,QW(50)        ,R11           ,R(40)                     ,RB(50)
     8      ,RHS           ,R13           ,RBAR(40)     ,R14         ,R2(40)
     9      ,RCON          ,R15           ,RE(40)       ,RESH        ,R16
     *      ,RHO(40)       ,R17           ,RHO2(40)     ,RHS(25)     ,RHSEN
     1      ,RHSPOR        ,RHOBAR        ,RHUBAR       ,RU          ,RSH
     2      ,RSTREP        ,RV            ,R19          ,RW(100)     ,S
     3                    ,SH(50)        ,SC(25)                    ,SW(50)
     4      ,S15           ,SX(40)        ,T11          ,T(40)       ,T12
     5      ,T2(40)        ,TABAR         ,TBBAR        ,T0(25)      ,T14
     6      ,TAR(40)       ,TXTR1         ,TXTR2        ,TOL         ,TSH
     7      ,TSH1          ,TSTHEM                      ,TW(50)      ,TWS
     8      ,TS            ,U11           ,U(40)        ,U12         ,U2(40)
      COMMON UXTR1         ,UXTR2         ,U14          ,UBAR(40)    ,USH
     1      ,USH1          ,USTREM                      ,UW(50)      ,UWS
     2      ,X11           ,X(40)         ,X12          ,X2(40)
     3      ,XB(50)        ,XBS           ,XABAR(25)    ,XBBAR(25)   ,X15
     4      ,XS(25,40)     ,XSH           ,XSTHEM                    ,XW(50)
     5      ,ZBAR(40)                     ,Y11          ,Y(40)       ,Y12
     6      ,Y2(40)        ,YABAR         ,YBBAR        ,ZA(25)      ,Z11(25)
     7      ,ZJ(25,40)     ,ZW            ,S2X          ,R2SH        ,X2SH
     8      ,FX(2,40)      ,FR(2,40)      ,FPHI(2,40)   ,FP(2,40)    ,FT(2,40)
     9      ,FU(2,40)      ,INDL(2,40)    ,INDR(2,40)   ,FC(2,40,25),CARD1
     *      ,M             ,N
      REAL   KAY           ,KAYS(25)      ,KAY2         ,KW          ,MOUT(40)
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*          ,MA(40)     ,MU          ,MUS(25)    ,MU0(25)    ,MU2          PUTOUT    5
*          ,MW(25)     ,MW2         ,MASM       ,MASMI      ,MWSM         PUTOUT    6
* ,          MAP                                                           PUTOUT    7
      COMMON/PT1/XMOMV(8), XMOMP(8),ENEP1(8),REP(40,8),V(40,8),W(40,8),   PUTOUT    8
     1V2(40,8), R2(40,8), IRBDY(8), TP(40,8), TP2(40,8), RP(8),            PUTOUT    9
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),NBL(8),UM(40)                        PUTOUT   10

     3,VOLP(8),WTP(8),MC(8),DENS(40,8),ICOND(40,8)                         PUTOUT   11
      COMMON/PT2/FFF,FFG,GAMA,UMI,PB,NPG,KMX,DNDSP(8)                      PUTOUT   12
      COMMON/PT3/CL,CS,TPS,RHSS,RT,HTRAN,SIG,EP,IPANT,IXIAF,TR(40)         PUTOUT   13
     1 ,SUMP,SUMPV,SUMFE                                                   PUTOUT   14
      COMMON/CHEM1/ ZID(5), INR(40),IRT(40),NC(40,3),INNR(40,5),           PUTOUT   15
     1 AV,CM(26,26),FI(26),WP(26),                                         PUTOUT   16
     2 WM(26),WDOT(26,40),CSI(26),BX(26)                                   PUTOUT   17
      COMMON/SHOPUT/ XSHW,RSHW,PSIR,PSHW,TSHW,USHW,CSHW(25)                PUTOUT   18
      COMMON/CFF/IPTO                                                      PUTOUT   19
      COMMON/XYZ/IXYZ,JXYZ                                                 PUTOUT   20
      COMMON/BLFG/ INLFLG,IBL                                              25SEPT    4
      COMMON/WALL/ TWALL                                                   25SEPT   16
      COMMON/BLOUT/ REXI,THETAI,CFI,UFI,CFCCFI,H12,DISP,THETAC(2),DELTI,   PUTOUT   22
     *DELTAC,CFC,QWALL,TAUWAL,ETA(140),TETC(140),UUUFI(140),YDELI(140)     PUTOUT   23
      DIMENSION SUMI(25)                                                   PUTOUT   24
      DATA I01/4HCO  /                                                     PUTOUT   25
      DATA I02/4HCO2 /                                                     PUTOUT   26
      DATA I03/4HH2O /                                                     PUTOUT   27
      DATA I04/4HHCL /                                                     PUTOUT   28
      DATA I05/4HN2  /                                                     PUTOUT   29
      DATA I06/4HH2  /                                                     PUTOUT   30
      DATA I07/4HE   /                                                     PUTOUT   31
      IXYZ=13                                                              PUTOUT   32
      JXYZ=0                                                               PUTOUT   33
      GO TO (50,1300,10), IOUT                                             PUTOUT   34
   10 L=K                                                                  PUTOUT   35
      GO TO 250                                                            PUTOUT   36
   50 L=1                                                                  PUTOUT   37
      SUMDOT=0.0                                                           PUTOUT   38
      DO 75 I=1,NUS                                                        PUTOUT   39
   75 SUMI(I)=0.0                                                          PUTOUT   40
      WRITE (6,100) LL,X2(L),R2(L),PHI2(L)                                 PUTOUT   41
  100 FORMAT ( 1H0,I5,8X,3HX=,   E11.4,3X,3HR=,   E11.4,3X,5HPHI=,         PUTOUT   42
     *E11.4)                                                               PUTOUT   43
      L=2                                                                  PUTOUT   44
  250 IF(LL) 225,260,260                                                   PUTOUT   45
  225 WRITE(6,300) L,X(L),R(L),PHI(L),T(L),P(L),U(L)                       PUTOUT   46
      GO TO 325                                                            PUTOUT   47
  260 WRITE (6,300) L,X2(L),R2(L),PHI2(L),T2(L),P2(L),U2(L)                PUTOUT   48
  300 FORMAT(1H0,5X,I5,3X,2HX=,1PIE11.4,4X,2HR=,1PIE11.4,4X,4HPHI=,1PIE1  PUTOUT   49
     *1.4,2X,2HT=,1PIE11.4,4X,2HP=,1PIE11.4,4X,2HU=,1PIE11.4)              PUTOUT   50
  325 HTK=H(L)+U(L)**2/(2.0*AJ)                                            PUTOUT   51
      PTK=P(L)+RHO(L)*U(L)**2/(2.0*BETAP)                                  PUTOUT   52
      SUMDOT=SUMDOT+MDOT(L)                                                PUTOUT   53
  375 IF(LL) 350,360,360                                                   PUTOUT   54
  350 WRITE (6,400) WA(L),DELY(L),H(L),HTK,TAW(L),Q(L),PTK,RHO(L),SX(L)    PUTOUT   55
     *,SUMDOT                                                              PUTOUT   56
  400 FORMAT(14X,3HMA=,   E11.4,3X,5HDELY=,   E11.4,1X,2HH=,   E11.4,4X,   PUTOUT   57
     *3HHT=,   E11.4,3X,4HTAW=,   E11.4,2X,2HQ=,   E11.4 / 14X,3HPT=,      PUTOUT   58
     *E11.4,3X,4HRHO=,   E11.4,2X,3HSX=,   E11.4,3X,7HSUMDOT=,   E11.4     PUTOUT   59
     *)                                                                    PUTOUT   60
      GO TO 410                                                            PUTOUT   61
  360 WRITE (6,400) WA(L),DELY(L),H(L),HTK,TAW(L),Q(L),PTK,RHO2(L),SX(L)   PUTOUT   62
     *,SUMDOT                                                              PUTOUT   63
      IF(L.LT.KMAX) GO TO 410                                              PUTOUT   64
      WRITE (6,1001)                                                       PUTOUT   65
 1001 FORMAT (///128(***)///)                                              PUTOUT   66

      IF(IBL.EQ.0) GO TO 408                                               25SEPT   11
      WRITE(6,1007) TWALL                                                  25SEPT   12
 1007 FORMAT (50X,17HWALL TEMPERATURE=,1X,F5.0,1X,6HKELVIN///)             25SEPT   13
      WRITE (6,1002)                                                       PUTOUT   67
 1002 FORMAT (50X,25HBOUNDARY LAYER PARAMETERS///)                         25SEPT   14
      WRITE (6,1003) REXI,DELTI,THETAI,CFI,UFI,DISP,DELTAC,THETAC(2),      PUTOUT   69
     *CFC,CFCCFI,H12,QWALL,TAUWAL                                          PUTOUT   70
 1003 FORMAT (T5,*RES= *,E11.4,T24,*DELTAI= *,E11.4,T46,*THETAI= *,        PUTOUT   71
     1E11.4,T66,*CFI= *,E11.4,T87,*UFI= *,E11.4/                           PUTOUT   72
     2T5,*DISP= *,E11.4,T24,*DELTAC= *,E11.4,T46,*THETAC= *,E11.4,         PUTOUT   73
     3T66,*CFC= *,E11.4,T87,*CFC/CFI= *E11.4/                              PUTOUT   74
     4T5,*H12= *,E11.4,T24,*QWALL= *,E11.4,T46,*TAUWALL= *,E11.4)          PUTOUT   75
      IF(INLFLG) 1004,410,1004                                             PUTOUT   76
 1004 WRITE (6,1005)                                                       PUTOUT   77
 1005 FORMAT (///T53,*BOUNDARY LAYER PROFILES*///T28,*U/UE*,T47,           PUTOUT   78
     1*  T/TE*,T67,*U/UF IAC*,T88,*Y/DEL*)                                 PUTOUT   79
      WRITE (6,1006) (ETA(J),TETC(J),UUUFI(J),YDELI(J),J=5,140,5)          PUTOUT   80
 1006 FORMAT (T25,E11.4,T45,E11.4,T65,E11.4,T85,E11.4)                     PUTOUT   81
  408 WRITE(6,409)                                                         25SEPT   15
  409 FORMAT (45X,27HBOUNDARY LAYER NOT COMPUTED///)                       25SEPT   16
  410 WRITE (6,1000)                                                       PUTOUT   82
 1000 FORMAT(1H0)                                                          PUTOUT   83
      IF (NOS-1) 450,450,1050                                              PUTOUT   84
 1050 DO 1299 I=1,NOS                                                      PUTOUT   85
      IF (IEXTRA(I)) 1120,1110,1120                                        PUTOUT   86
 1110 IF (LL) 1105,1115,1115                                               PUTOUT   87
 1105 WRITE (6,1200) IDENT(I),C(I,L),XS(I,L),WDOT(I,L)                     PUTOUT   88
      GO TO 1299                                                           PUTOUT   89
 1115 WRITE (6,1200) IDENT(I),C2(I,L),XS(I,L),WDOT(I,L)                    PUTOUT   90
 1200 FORMAT(14X,6HSPECIE,2X, A4,7X,2HC=,   E11.4,4X,2HX=,   E11.4,4X,     PUTOUT   91
     * 5HWDOT=,E11.4)                                                      PUTOUT   92
      GO TO 1299                                                           PUTOUT   93
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1120 SUMI(I)=SUMI(I)+MDOT(L)*C(I,L)
1150 IF (LL) 1125,1160,1160
1125 WRITE (6,1225) IDENT(I),C(I,L),XB(I,L),MDOT(I,L),SUMI(I),ZJ(I,L)
1225 FORMAT(14X,6HSPECIE,2X, A6,7X,2HC=,1PIE11.4,4X,2HX=,1PIE11.4,4X,
    * 5HMDOT=,E11.4,3X,3HF1=,
    *1PIE11.4,3X,3HZJ=,1PIE11.4)
     GO TO 1299
1160 WRITE (6,1225) IDENT(I),C2(I,L),XS(I,L),MDOT(I,L),SUMI(I),ZJ(I,L)
1299 CONTINUE
 450 IF (IPTO .EQ. 0) GO TO 457
     XL=X2(L)/REX
     RL=R2(L)/REX
     I22=25
     I23=25
     I24=25
     I25=25
     I26=25
     I27=25
     DO 60 J=1,NOS
     IF (IDENT(J) .EQ. 101) I21=J
     IF (IDENT(J) .EQ. 102) I22=J
     IF (IDENT(J) .EQ. 103) I23=J
     IF (IDENT(J) .EQ. 104) I24=J
     IF (IDENT(J) .EQ. 105) I25=J
     IF (IDENT(J) .EQ. 106) I26=J
     IF (IDENT(J) .EQ. 107) I27=J
  60 CONTINUE
     ENE=0.733E22*P2(L)/T2(L)*C2(I27,L)
     VEE=6.21E5*SQRT(T(L))
     SPG=C2(I21,L)*(2.06E-23*VEE+2.46E-16)+C2(I22,L)*4.7E-8/VEE+C2(I23,
    1L)*5.9/(VEE**2)+C2(I24,L)*1.05/(VEE*VEE)+C2(I25,L)*3.29E-23*VEE+
    2C2(I26,L)*(1.45E-23*VEE+8.9E-16)
     ENUE=4.57E27*P2(L)/SQRT(T2(L))*SPG
     SGM=7.14509E-4*ENE/ENUE
     IF(IPTO.GT.4) GO TO 61
     WRITE (6,1400) XL,RL,ENE,ENUE,SGM
1400 FORMAT (2X,6HX/REX=,1PE11.4,5X,6HR/REX=,E11.4,5X,3HNE=,E11.4,5X,
    1 4HNUE=,E11.4,5X,6HSIGMA=,E11.4)
     IF (IPTO .EQ. 1 .OR. IPTO .EQ. 3)
    1WRITE (7,1600) XL,RL,ENE,ENUE,SGM
1600 FORMAT (4E19.12/3E19.12)
     IF (IPTO .EQ. 2 .OR. IPTO .EQ. 4)
    1WRITE (8,1601) XL,RL,ENE,ENUE,SGM
1601 FORMAT (7E19 [illegible]
  61 WRITE (6, [illegible] L,T2(L),P2(L),XS(I22,L),XS(I23,L),XS(I21,L)
1500 FORMAT (5 [illegible] X=,1PE11.4,5X,6HR/REX=,E11.4,4X,2HT=,E11.4,9X,
    1 2HP=,E11.4/10X,6H(CO2)=,E11.4,6X,6H(H2O)=,E11.4,7X,5H(CO)=,E11.4)
     IF (IPTO .EQ. 5 . R. IPTO .EQ. 3)
    1WRITE (7,160 ) XL,RL,T2(L),P2(L),XS(I22,L),XS(I23,L),XS(I21,L)
     IF (IPTO  [illegible] 6 .OR. IPTO .EQ.3)
    1WRITE [illegible] XL,RL,T2(L),P2(L),XS(I22,L),XS(I23,L),XS(I21,L)
 457 IF ( [illegible] ,600,600
 500 L=L [illegible]
     GO TO 250
1300 IF (NBOUND) 1320,1310,1320
1310 K=1
     DELPHI=PHI(K)-PHISH
     WRITE (6,1401) LL,K,X2(K),R2(K),PHI2(K),PSIK,DELPHI
     K=2
     GO TO 600
1320 DELPHI=PHI(KMAX)-PHISH
     WRITE (6,1401) LL,KMAX,X(KMAX),R(KMAX),PHI(KMAX),PSI,DELPHI
1401 FORMAT (1H0,5HSHOCK,2X,3HLL=,I4,2X,2HK=,I2,2X,2HX=,1PIE11.4,2X,2HR
    *=,1PIE11.4,2X,4HPHI=,1PIE11.4,2X,4HPSI=,1PIE11.4,2X,7HDELPHI=,1PIE
    *11.4)
 600 RETURN
     END
```

```
      SUBROUTINE PPTOUT(KKKK)
      COMMON A(25,7)      ,AA(40)      ,ALFA(25,25),ALPHAM     ,ALPHAP
     1        ,ATOL        ,BETAP       ,BMIX       ,C11(25)    ,C(25,40)
     2        ,C12(25)     ,C2(25,40)   ,CAHAR(25)  ,CBHAR(25)  ,CP
     3        ,CPS(25)     ,CPSH        ,CSH(25)    ,CSH1(25)   ,CSTHEM(25)
     4        ,CYSTAR      ,D21H(25,25) ,DEFF(25)   ,D2EFF(25)  ,DELTA
     5        ,D11         ,DELSS(40)   ,DELS       ,DELSU      ,DLS(40)
     6        ,DIM(25,25)  ,D12         ,DELY(40)   ,D13        ,DPDY(40)
     7        ,D14         ,DPHIDS(40)  ,EPCON
     8        ,EPSLON      ,EXTRA(50)   ,FSTEP      ,FMAX       ,GRAD
     9        ,H11         ,H(40)       ,HH         ,HJ         ,HPM(25)
     *        ,H2PM(25)    ,H3PM(25)    ,ICONST     ,ICOUNT     ,IDENT(25)
     1        ,IERROR      ,IEXTRA(50)  ,IFLAG      ,IKIND
     2        ,IPTOC       ,ISHOCK      ,ITYPE      ,IPD
     3        ,IDIFF       ,K           ,KAY        ,KAYS       ,KAY2
     4        ,KLL         ,KMAX
     5        ,KOP         ,KK          ,LL         ,LPLANE     ,MA
     6        ,MASH        ,MDOT        ,MMAX       ,MUO        ,MU
     7        ,MU2         ,MUS         ,MM         ,MM2        ,MMSH
     8        ,NBOUND      ,NOS         ,NITER      ,NMAX       ,NN
      COMMON NUCASE       ,CMFGA(25)   ,P11        ,P(40)      ,P12
     1        ,P2(40)                   ,PH(50)     ,PMBAR      ,PMHAM
```

```
     2         ,PBS        ,P15        ,PHI(40)                  ,PHIN(50)
     3         ,PHISHI     ,PHSTRM                 ,PHIW(50)     ,P18
     4         ,PHI2(40)   ,PHIUS      ,PI         ,PW(25)       ,PBM
     5         ,PSHI       ,PSI        ,PSTREM                   ,PW(50)
     6         ,Q11        ,Q(40)      ,QXTR1      ,QXTR2
     7         ,QW(50)     ,R11        ,R(40)                    ,RW(50)
     8         ,RBS        ,R13        ,RBAR(40)   ,R14          ,R2(40)
     9         ,RCON       ,R15        ,RE(40)     ,RESH         ,R16
     *         ,RHO(40)    ,R17        ,RHO2(40)   ,RHS(25)      ,RHSEN
     1         ,RHSMUM     ,RHABAR     ,RHUBAR     ,RU           ,RSH
     2         ,RSTREM     ,RV         ,R19        ,RW(100)      ,S
     3.                    ,SB(50)     ,SC(25)                   ,SW(50)
     4         ,S12        ,SX(40)     ,T11        ,T(40)        ,T12
     5         ,T2(40)     ,TABAR      ,TBBAR      ,T0(25)       ,T14
     6         ,TAW(40)    ,TXTR1      ,TXTR2      ,TOL          ,TSH
     7         ,TSH1       ,TSTREM                 ,TW(50)       ,TWS
     8         ,TS         ,U11        ,U(40)      ,U12          ,U2(40)
      COMMON UXTR1     ,UXTR2      ,U14        ,UBAR(40)     ,USH
     1         ,USH1       ,USTREM                 ,UW(50)       ,UWS
     2         ,X11        ,X(40)      ,X12        ,X2(40)
     3         ,XB(50)     ,XBS        ,XABAR(25)  ,XBBAR(25)    ,X15
     4         ,XS(25,40)  ,XSH        ,XSTREM                   ,XW(50)
     5         ,ZMMR(40)               ,Y11        ,Y(40)        ,Y12
     6         ,Y2(40)     ,YABAR      ,YBBAR      ,Z5(25)       ,Z11(25)
     7         ,ZJ(25,40)  ,ZFW        ,S2X        ,W2SH         ,X2SH
     8         ,FX(2,40)   ,FN(2,40)   ,FPHI(2,40) ,FP(2,40)     ,FT(2,40)
     9         ,FU(2,40)   ,INDL(2,40) ,INDH(2,40) ,FC(2,40,25),CAND1
     *         ,M          ,N
      REAL      KAY        ,KAYS(25)   ,KAY2       ,KW           ,MDOT(40)
     *         ,MA(40)     ,MU         ,MUS(25)    ,MUO(25)      ,MU2
     *         ,MW(25)     ,MW2        ,MASH       ,MASH1        ,MWSH
     * ,        MAP
      COMMON/PT1/XMOMV(8), XMOMP(8),ENEP1(8),HEP(40,8),V(40,8),W(40,8),
     1V2(40,8), W2(40,8), TRBOY(8), TP(40,8), TP2(40,8), RP(8),
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),NBL(8),UM(40)


     3,VOLP(8),WIP(8),FC(8),DENG(40,8),ICOND(40,8)
      COMMON/PT2/FF3,FFG,GAMA,UM1,PU,NPG,KMX,DNDSP(8)
      COMMON/PT3/CL,CS,IPS,RHSS,WT,HIRAN,SIG,EM,IPART,IKINE,IR(40)
     1 ,SUMP,SUMPV,SUMPE
      COMMON/XYZ/IXYZ,JXYZ
      DIMENSION PIP(8)
      IXYZ=13
      JXYZ=0
      IF(KKKK.EQ.1) GO TO 3
      LKI=K-1
      LKMAX=K-1
      GO TO 4
    3 LKI=1
      LKMAX=KMX+2
    4 CONTINUE
      DO 2 LK=LKI,LKMAX
      LKI=LK+1
      PIPP=0.0
      DO 6 J=1,NPG
      PIP(J)=RHP2(LK,J)*W2(LK,J)**2/(2.*BETAP)
      PIPP=PIPP+PIP(J)
    6 CONTINUE
      WRITE(6,101) LK,S,U2(LK1),T2(LK1),RHO(LK1),RE(LK1),Y2(LK1)
     1 ,W2(LK1)
      WRITE (6,99)
      WRITE(6,107) (J,J=1,NPG)
      WRITE(6,102) (W2(LK,J),J=1,NPG)
      WRITE(6,103) (V2(LK,J),J=1,NPG)
      WRITE(6,104) (REP(LK,J),J=1,NPG)
      WRITE(6,105) (TP2(LK,J),J=1,NPG)
      WRITE(6,106) (RHP2(LK,J),J=1,NPG)
      WRITE(6,108) PIPP
    2 CONTINUE
   99 FORMAT (1H ,39H===== PARTICLE PHASE PROPERTIES =====     )
  101 FORMAT (1H ,15H===STREAMLINE= ,I5,4H  S=,F12.5/,2X,23H== LOCAL GAS
     1 PROPERTIES /,2X,2HU=,1PE10.3,2X,2HT=,E10.3,2X,8HDENSITY=,E10.3,
     2 2X,13HREYNOLDS NO.=,E10.3,2X,3HY2=,E10.3,2X,3HW2=,E10.3)
  102 FORMAT (1H ,19HDOWNSTREAM VELOCITY ,2X,1P8E12.3)
  103 FORMAT(1H ,21HCROSS-STREAM VELOCITY,1P8E12.3)
  104 FORMAT(1H ,21HPARTICLE REYNOLDS NO.,1P8E12.3)
  105 FORMAT(1H ,20HPARTICLE TEMPERATURE,1X,1P8E12.3)
  106 FORMAT(1H ,16HPARTICLE DENSITY,5X,1P8E12.3)
  107 FORMAT(1H ,14HPARTICLE GROUP,8(7X,I5))
  108 FORMAT(1H,24H PARTICLE MOMENTUM FLUX  ,2X,1P8E12.3  )
      RETURN
      END


      SUBROUTINE SHOCKE
      RETURN
      END


      SUBROUTINE COMBO(L)
      RETURN
      END


      SUBROUTINE STEP
C     THIS SUBROUTINE CALCULATES STATE PROPERTIES IN A STREAMTUBE
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```
      COMMON A(25,7)    ,AA(40)         ,ALFA(25,25),ALPHAM   ,ALPHAP
     1      ,ATOL       ,BETAP          ,BMIX         ,C11(25)       ,C(25,40)
     2      ,C12(25)    ,C2(25,40)      ,CBAR(25)     ,CBBAR(25)     ,CP
     3      ,CPS(25)    ,CPSH           ,CSH(25)      ,CSH1(25)      ,CSTHEM(25)
     4      ,CSTHP      ,D2IR(25,25),DEFF(25)         ,D2EFF(25)     ,DELTA
     5      ,D11        ,DELSS(40)      ,DELS         ,DELSO         ,DLS(40)
     6      ,DIR(25,25) ,D12            ,DELY(40)     ,D13           ,DPDTX(40)
     7      ,D14        ,DPHIDS(40)     ,EPCON
     8      ,EPSLON     ,EXTRA(50)      ,FSTEP        ,FMAX          ,GRAD
     9      ,H11        ,H(40)          ,HH           ,HJ            ,HPH(25)
     A      ,H2PH(25)   ,H3PH(25)       ,ICONST       ,ICOUNT        ,IDENT(25)
     1      ,IERROR     ,IEXTRA(50)     ,IFLAG        ,IKIND
     2      ,IPTOC      ,ISHOCK         ,ITYPE        ,IPO
     3      ,IDIFF      ,K              ,KAY          ,KAYS          ,KAY2
     4      ,KLO        ,KMAX
     5      ,KUP        ,KK             ,LL           ,LPLANE        ,MA
     6      ,MASH       ,MDOT           ,MMAX         ,MUO           ,MU
     7      ,MU2        ,MUS            ,MW           ,MW2           ,MWSH
     8      ,NBOUND     ,NCS            ,NITER        ,NMAX          ,NN
      COMMON NOCASE      ,OMEGA(25)      ,P11          ,P(40)         ,P12
     1      ,P2(40)                     ,PB(50)       ,PBBAR         ,PBBAR
     2      ,PBS        ,P15            ,PHI(40)                     ,PHIB(50)
     3      ,PHISH1     ,PHSTHM                       ,PHIW(50)      ,P10
     4      ,PHI2(40)   ,PHIUS          ,PI           ,PW(25)        ,PSH
     5      ,PSH1       ,PSI            ,PSTHEM                      ,PW(50)
     6      ,Q11        ,Q(40)          ,QXTR1        ,QXTR2
     7      ,QW(50)     ,R11            ,R(40)                       ,RB(50)
     8      ,RHS        ,R13            ,RBAR(40)     ,R14           ,R2(40)
     9      ,RCON       ,R15            ,RE(40)       ,RESH          ,R16
     A      ,RHO(40)    ,R17            ,RHO2(40)     ,RHB(25)       ,RHSEN
     1      ,RHSWCH     ,RHABAR         ,RHBBAR       ,RU            ,RSH
     2      ,RSTHEM     ,RV             ,R19          ,RW(100)       ,S
     3                  ,SE(50)         ,SC(25)                      ,SW(50)
     4      ,S13        ,SX(40)         ,T11          ,T(40)         ,T12
     5      ,T2(40)     ,TABAR          ,TBBAR        ,T0(25)        ,T14
     6      ,TAN(40)    ,TXTR1          ,TXTR2        ,TOL           ,TSH
     7      ,TSH1       ,TSTHEM                       ,TW(50)        ,TWS
     8      ,TS         ,U11            ,U(40)        ,U12           ,U2(40)
      COMMON UXTR1      ,UXTR2          ,U14          ,UBAR(40)      ,USH
     1      ,USH1       ,USTHEM                       ,UW(50)        ,UWS
     2      ,X11        ,X(40)          ,X12          ,X2(40)
     3      ,XB(50)     ,XBS            ,XABAR(25)    ,XBBAR(25)     ,X15
     4      ,XS(25,40)  ,XSH            ,XSTHEM                      ,XW(50)
     5      ,ZMAR(40)                   ,Y11          ,Y(40)         ,Y12
     6      ,Y2(40)     ,YABAR          ,YBBAR        ,ZA(25)        ,Z11(25)
     7      ,ZJ(25,40)  ,ZMR            ,S2X          ,R2SH          ,X2SH
     8      ,FX(2,40)   ,FR(2,40)       ,FPHI(2,40)   ,FP(2,40)      ,FT(2,40)
     9      ,FU(2,40)   ,INDL(2,40)     ,INDR(2,40)   ,FC(2,40,25),CARD1
     A      ,W          ,N
      REAL   KAY        ,KAYS(25)       ,KAY2         ,KA            ,MDOT(40)
     *      ,MA(40)     ,MU             ,MUS(25)      ,MUO(25)       ,MU2
     *      ,MW(25)     ,MW2            ,MASH         ,MASH1         ,MWSH
     * ,    MAP
      COMMON/PT1/XMOMS(8), XMOMP(8),ENEP1(8),REP(40,8),V(40,8),R(40,8),
     1V2(40,8), R2(40,8), THBDY(8), TP(40,8), TP2(40,8), NP(8),
     2RHP(40,8), RHP2(40,8) ,ENEP2(8),NBL(8),UM(40)
     3,VOLF(8),AIP(8),HL(8),DENG(40,8),ICOND(40,8)
      COMMON/PT2/FFF,FFG,GAMA,UMI,P0,NPG,KPX,DNOSP(8)
      COMMON/PT3/CL,CS,TPS,RHSS,AT,HIRAN,SIG,EF,IPART,IKINE,IR(40)
     1 ,SUPP,SUPPV,SUPPE
      COMMON/IBUGS1/ IBUGSH
      COMMON/CHEM1/ ZIO(5), IRR(40),IRT(40),RC(40,3),IRRR(40,5),
     1 AV,CM(26,26),FT(26),AP(26),
     2 RM(26),ROUT(26,40),CSI(26),QX(26)
      COMMON/XYZ/IXYZ,JXYZ
      DIMENSION ZAO(25)
      EQUIVALENCE (IVISC,IEXTRA(1))
      EQUIVALENCE (RALAMK,IEXTRA(20))
      IXYZ=17
      JXYZ=0
C     EVALUATION OF TRANSPORT TERMS
C     FOR IVISC=1 (ITURB=1), CALL VISCO IMMEDIATELY
C     THIS RUNS PROGRAM WITH VISCOSITY
      IF (IVISC) 50,50,200
   50 RHSFUN=0.0
      RHSENE=0.0
      DO 100 I=1,NOS
  100 RHS(I)=0.0
      IF (IFLAG) 125,150,125
  125 UBAR(K)=U2(K)
C     FOR NO VISCOSITY CALL VISCO ONLY AT BOUNDARY TO CALC BOUNDARY LAYE
      IF (NBOUND) 300,300,200
  150 UBAR(K)=U(K)
      IF (NBOUND) 300,300,200
  200 CALL VISCO
      MULT=IEXTRA(48)
      IHIG=IEXTRA(49)
      IF (K.LT.KMAX) GO TO 250
      TABAR=TABAR
      RHBAR=RABAR
      DO 225 I=1,NOS
  225 YBBAR(I)=XABAR(I)
  250 AP=ALPHAT
  300 AEL=PI*(R(K)+R(K-1))*DELTA*(Y(K)-Y(K-1))
      AHAR=.5*(AA(K)+AL(0))
      IF(IRIPE.NE.0.AND.IFLAG.EQ.1) GO TO 401
  350 DO 400 I=1,NOS
  400 C2(I,K)=C(I,K)+RHS(I)/MDOT(K)
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```
      GO TO 402
  401 CALL CHEM(IKINE)
  402 CONTINUE
      DO 403 I=1,NDS
      IF(C2(I,K)) 404,403,403
  403 CONTINUE
      GO TO 405
  404 DELS=DELS*.5
      ICOUNT=ICOUNT+1
      KALARM=2
      GO TO 10000
  405 ZM=0.0
      DO 500 I=1,NDS
  500 ZM=ZM+C2(I,K)/W(I)


      ZM=1.0/ZM
      ZMW(K)=ZM
      DO 600 J=1,NN
      ZA(J)=0.0
      ZAO(J)=0.
      DO 600 I=1,NDS
      ZAO(J)=ZAO(J)+A(I,J)*C(I,K)
  600 ZA(J)=ZA(J)+A(I,J)*C2(I,K)
      ITER=0
  700 US=UMAX(K)
      CP=0.0
      CPOLD=0.
      DO 702 J=2,NN
      CPOLD=CPOLD+FLOAT(J-2)*ZAO(J)*T(K)**(J-3)
  702 CP=CP+ZA(J)*FLOAT(J-2)*T   (K)**(J-3)
      B1=(RHSNGM+MDOT(K)*U(K))/(BETAP*ABAR)+P(K)
      B1= B1-DELS(K)*SUMP/BETAP
      B2=MDOT(K)/(BETAP*ABAR)
  706 B3=ZM*AA(K)/RV/MDOT(K)
      IF (IHUGSH.EQ.0) GO TO 703
      WRITE (6,2001) ALLD,B1,B2,B3
 2001 FORMAT (1H0,5HALLD=,1P1E11.4,5H  B1=,1P1E11.4,5H  B2=,1P1E11.4,5H
     * B3=,1P1E11.4,6E10.3)
  703 IF (MA(K)-1.002) 1400,1400,704
  704 IF (ICONST)  705,710,705
  705 IF(MA(K)-5.0) 800,710,710
C     CONSTANT GAMMA
  710 B5=HJ*CP*B3*B1
      B6=2.0*HJ*CP*B3*B2-1.0
      B4=U(K)**2+2.0*HJ*(RHSEN/MDOT(K)+CPOLD*T(K)+ZAO(2)-ZA(2))
      B4=B4+SUMPE*ABAR*DLS(K)/MDOT(K)
      DISCR=B5**2-B6*B4
      IF (IHUGSH.NE.0) WRITE (6,2001) B4,B5,B6,DISCR
     1  ,SUMPE,ZA(1),ZAO(1),T(K),RHSEN
      IF (DISCR) 730,750,750
  730 IF (ICOUNT-9) 740,740,9800
  740 ICOUNT=ICOUNT+1
      DELS=DELS/2.0
      KALARM=2
      GO TO 10000
  750 US=(B5+SQRT(DISCR))/B6
      IF (IHUGSH.NE.0) WRITE (6,2001) US,T(K),P(K),U(K)
      GO TO 1200
C     VARIABLE HEAT CAPACITY
  800 ITER=ITER+1
      B4=2.0*HJ*RHSEN/MDOT(K)+2.0*HJ*H(K)+U(K)**2
      B4=B4+SUMPE*ABAR*DLS(K)/MDOT(K)
      DUM1=0.0
      DUM2=0.0
      DO 900 I=1,NN
      DUM1=DUM1+ZA(I)*(B3*(B1-B2*US)*US)**(I-2)
  900 DUM2=DUM2+ZA(I)*FLOAT(I-2)*    (B1*US-B2*US**2) **(I-3)*B3**(I-2)
      G=2.0*HJ*DUM1+US**2-B4
      DGDU=2.0*US+2.0*HJ*DUM2*(B1-2.0*B2*US)
      DELTAU=-G/DGDU
      IF (ABS(DELTAU/US)-TOL) 1200,1000,1000
 1000 IF (ITER-NITER) 1100,1010,1010


 1010 IF (ICOUNT-9) 1020,1020,9500
 1020 ICOUNT=ICOUNT+1
      KALARM=2
      DELS=DELS/2.0
      GO TO 10000
 1100 US=US+DELTAU
      GO TO 800
 1200 U2(K)=US
      P2(K)=B1-B2*US
      T2(K)=B3*P2(K)*US
 1300 RHO2(K)=ZM*P2(K)/(RV*T2(K))
      IF (P2(K)) 1301,1301,1304
 1301 IF (ICOUNT.LT.9) GO TO 1020
      WRITE (6,1302)
 1302 FORMAT(26H1 PRESSURE BECAME NEGATIVE)
 1303 CALL PDUMP(A(1,1),A,1)
      CALL EXIT
 1304 IF (T2(K)) 1305,1305,1307
 1305 IF (ICOUNT.LT.9) GO TO 1020
      WRITE (6,1306)
 1306 FORMAT(29H1 TEMPERATURE BECAME NEGATIVE)
      GO TO 1303
C     STAGNATION MACH AND REYNOLDS NUMBERS
 1307 MAX=1.0
      IF (K.LT.KMAX) GO TO 1309
      ...
      KAY=KAY
      DO 1308 I=1,NES
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      D2EFF(I)=DEFF(I)
      DO 1308 J=1,NOS
      D2IN(I,J)=DIN(I,J)
 1308 CONTINUE
 1309 CP=0.
      DO 1310 I=1,NN
 1310 CP=CP+FLOAT(I-2)*ZA(I)*T2(K)**(I-3)
      IF (IVISC) 1315,1360,1315
 1315 IF (KAY2-MU2*CP) 1330,1330,1320
 1320 FMAX=KAY2/(CP*MU2)
 1330 IF (MULT.NE.0.AND.XS(IHIG,K+1).GT.0.75) GO TO 1352
      JMAX=NOS-1
      DO 1350 I=1,JMAX
      J=I
 1335 J=J+1
      IF (D2IN(I,J)*RHO2(K)/MU2-FMAX) 1345,1345,1340
 1340 IF (MULT.NE.0.AND.XS(IHIG,K+1).GT.0.75) GO TO 1342
      FMAX=D2IN(I,J)*RHO2(K)/MU2
      GO TO 1345
 1342 FMAX=D2EFF(J)*RHO2(K)/MU2
 1345 IF (J.LT.NOS) GO TO 1335
 1350 CONTINUE
      GO TO 1355
 1352 DO 1353 I=1,NOS
      IF (D2EFF(I)*RHO2(K)/MU2.GT.FMAX) FMAX=D2EFF(I)*RHO2(K)/MU2
 1353 CONTINUE
 1355 IF (IHUGSH.NE.0) WRITE (6,1375) RHO2(K),U2(K),DELY(K),MU2,KAY2,FMA
     1X,CP
 1375 FORMAT (6H RHO2=,E11.4,5H  U2=,E11.4,7H  DELY=,E11.4/5H MU2=,E11.4


     1,7H  KAY2=,E11.4,7H  FMAX=,E11.4,5H  CP=,E11.4)
      RE(K)=RHO2(K)*U2(K)*DELY(K)/(MU2*FMAX)
      IF (IHUGSH.NE.0) WRITE (6,1358) RE(K)
 1358 FORMAT (4H RE=,E11.4)
 1360 MA(K)=U2(K)*SQRT((CP*ZMA-RCON)/(CP*T2(K)*RO))
      GAMA=CP/(CP-RCON/ZMA )
      MU= 4.0*GAMA/(9.*GAMA-5.0)
      GO TO 10000
 1400 CONTINUE
C     ERROR MESSAGES
 9300 NUCASE=2250
      GO TO 9900
 9400 NUCASE=730
      WRITE (6,8888) NUCASE
      GO TO 9900
 9500 NUCASE=1010
      WRITE (6,8888) NUCASE
 8888 FORMAT (1H1,15X,* ------------- NUCASE=*,I5//)
 9900 IERROR=3
10000 RETURN
      END

      FUNCTION  ERF(X)
C     ----- THIS CALCULATES THE ERROR FUNCTION AND ITS COMPLEMENT -----
      DATA EPSILN/1.0E-10/,N/100/,CONST/1.128379167955/
      NORMAL=1
      GO TO 5
      ENTRY ERFC
      NORMAL=-1
    5 IF (X) 10,55,15
   10 Z=-X
      GO TO 20
   15 Z= X
   20 IF (Z-5.) 25,25,45
   25 ZSQ=Z*Z
      TERM=CONST*Z*EXP(-ZSQ)
      ERF=TERM
      I=0
      R=1.0
   30 I=I+1
      R=R+2.0
      TERM=2.0*ZSQ*TERM/R
      ERF=ERF+TERM
      IF (I-N) 35,40,40
   35 IF (TERM-EPSILN*ERF) 40,30,30
   40 IF (ERF-1.0) 50,50,45
   45 ERF=1.0
   50 IF (X) 60,55,65
   55 ERF=0.0
      GO TO 65
   60 ERF=-ERF
   65 IF (NORMAL) 70,99,99
C     ----- COMPUTE COMPLEMENTARY ERROR FUNCTION ERF -----
   70 ERF=1.0-ERF
   99 RETURN
      END


      SUBROUTINE TRANSP (TT,PP,KKK,MULT,IHIG)
C     -- THIS SUBROUTINE CALCULATES THE TURBULENT TRANSPORT PROPERTIES -
      COMMON A(25,7)     ,AA(40)      ,ALFA(25,25),ALPHAN     ,ALPHAP
     1      ,ATOL        ,BETAP       ,BMIX       ,C1(25)     ,C(25,40)
     2      ,C12(25)     ,T2(25,40)   ,CAMAR(25)  ,CMMAR(25)  ,CP
     3      ,CPS(25)     ,CPSN        ,CSM(25)    ,CSM1(25)   ,CSIMPP(25)
     4      ,CXSIMP      ,D2IN(25,25),DEFF(25)   ,D2EFF(25)  ,DELTA
     5      ,D11         ,DELSS(40)   ,DELS       ,DELSN      ,DLS(40)
     6      ,DIN(25,25)  ,D12         ,DELY(40)   ,D1I        ,DPDX(40)
     7      ,E,V         ,EPMIDS(40)  ,EP(40)                 
     8      ,EP,XES      ,EXTRA(50)   ,FSTEP      ,FMAX       ,GMAX
     9      ,H11         ,H(40)       ,HH         ,HJ         ,HP(25)
     *      ,H2PS(25)    ,HSPS(25)    ,ICCSS1     ,ICON1      ,IDENT(25)
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```
     1       ,IERROR       ,IEXTRA(50) ,IFLAG        ,IKIND                          A         13
     2       ,IPTUC        ,ISHOCK     ,ITYPE        ,IPO                            A         14
     3       ,IDIFF        ,K          ,KAY          ,KAYS         ,KAY2             A         15
     4       ,KLU          ,KMAX                                                     A         16
     5       ,KUP          ,KW         ,LL           ,LPLANE       ,MA               A         17
     6       ,MASH         ,MDOT       ,MMAX         ,MUO          ,MU               A         18
     7       ,MU2          ,MUS        ,MW           ,MW2          ,MASH             A         19
     8       ,NBOUND       ,NDS        ,NITER        ,NMAX         ,NN               A         20
      COMMON NCASE         ,OMEGA(25)  ,P11          ,P(40)        ,P12              A         21
     1       ,P2(40)                   ,PB(50)       ,PAHAR        ,PBHAR            A         22
     2       ,PHS          ,P15        ,PHI(40)                    ,PHIW(50)         A         23
     3       ,PHISH1       ,PHSTRM                   ,PHIW(50)     ,P18              A         24
     4       ,PHI2(40)     ,PHIBS      ,PI           ,PR(25)       ,PSH              A         25
     5       ,PSH1         ,PS1        ,PSTREM                     ,PW(50)           A         26
     6       ,Q11          ,Q(40)      ,QXTR1        ,QXTR2                          A         27
     7       ,QW(50)       ,R11        ,R(40)                      ,RB(50)           A         28
     8       ,RBS          ,R13        ,RBAR(40)     ,R14          ,R2(40)           A         29
     9       ,RCON         ,R15        ,RE(40)       ,RESH         ,R16              A         30
     *       ,RHO(40)      ,R17        ,RHO2(40)     ,RHS(25)      ,RHSEN            A         31
     1       ,RHSMOM       ,RHAHAR     ,RHBBAR       ,RU           ,RSH              A         32
     2       ,RSTREM       ,RV         ,R19          ,RW(100)      ,S                A         33
     3                     ,SB(50)     ,SL(25)                     ,SW(50)           A         34
     4       ,S13          ,SX(40)     ,T11          ,T(40)        ,T12              A         35
     5       ,T2(40)       ,TAHAR      ,TBBAR        ,TO(25)       ,T14              A         36
     6       ,TAW(40)      ,TXTR1      ,TXTR2        ,TOL          ,TSH              A         37
     7       ,TSH1         ,TSTREM                   ,TW(50)       ,TWS              A         38
     8       ,TS           ,U11        ,U(40)        ,U12          ,U2(40)           A         39
      COMMON UXTR1         ,UXTR2      ,U14          ,UBAR(40)     ,USH              A         40
     1       ,USH1         ,USTREM                   ,UW(50)       ,UWS              A         41
     2       ,X11          ,X(40)      ,X12          ,X2(40)                         A         42
     3       ,XB(50)       ,XB2        ,XAHAR(25)    ,XBBAR(25)    ,X15              A         43
     4       ,XS(25,40)    ,XSH        ,XSTREM                     ,XW(50)           A         44
     5       ,ZBAR(40)                 ,Y11          ,Y(40)        ,Y12              A         45
     6       ,Y2(40)       ,YAHAR      ,YBBAR        ,ZA(25)       ,Z11(25)          A         46
     7       ,ZJ(25,40)    ,ZBA        ,S2X          ,R2SH         ,X2SH             A         47
     8       ,FX(2,40)     ,FR(2,40)   ,FPHI(2,40)   ,FP(2,40)     ,FT(2,40)         A         48
     9       ,FU(2,40)     ,INDL(2,40) ,INDR(2,40)   ,FC(2,40,25),CARD1              A         49
     *       ,M            ,N                                                        A         50
      REAL    KAY          ,KAYS(25)   ,KAY2         ,KW           ,MDOT(40)     TRANSP         5
     *       ,MA(40)       ,MU         ,MUS(25)      ,MUO(25)      ,MU2          TRANSP         6
     *       ,MW(25)       ,MW2        ,MASH         ,MASH1        ,MASH         TRANSP         7
     * ,      KAP                                                              TRANSP         8
      COMMON/RHELE/RHEE(40)                                                    TRANSP         9
      COMMON/TURBUL/TLE,TPR,EDDYK,ITURB,DELMIX                                 TRANSP        10


      COMMON/INPUX/ITI,XO,YO,FRAC  ,KFL                                        TRANSP        11
      COMMON/XYZ/IXYZ,JXYZ                                                     TRANSP        12
      COMMON/PERGFF/PERGF                                                      TRANSP        13
      IXYZ=18                                                                  TRANSP        14
      JXYZ=0                                                                   TRANSP        15
      KAY2=KAY                                                                 TRANSP        16
      MU2=MU                                                                   TRANSP        17
      D2IM(1,2)=DIM(1,2)                                                       TRANSP        18
      IF (IROUGH.NE.0)                                                         TRANSP        19
     1 WRITE(6,700) KKK,LL,MDOT(KKK),U(KKK),RHO(KKK),RHO(KKK+1),IFLAG          TRANSP        20
      IF (KKK-2) 100,100,450                                                   TRANSP        21
  100 IF (LL .LT. 0) GO TO 400                                                 TRANSP        22
      IF (ITURB -2) 301,302,400                                                TRANSP        23
  302 ROMAX=RHO(2)*U(2)                                                        TRANSP        24
      ROMIN=RHO(2)*U(2)                                                        TRANSP        25
      DO 300 L=2,KMAX                                                          TRANSP        26
      TEST = RHO(L)*U(L)                                                       TRANSP        27
      IF (TEST .GT. ROMAX) GO TO 200                                           TRANSP        28
      IF (TEST .GE. ROMIN) GO TO 300                                           TRANSP        29
      ROMIN = TEST                                                             TRANSP        30
      GO TO  300                                                               TRANSP        31
  200 ROMAX=TEST                                                               TRANSP        32
  300 CONTINUE                                                                 TRANSP        33
      DELMIX=Y(KMAX)                                                           TRANSP        34
      MU=          (DELMIX/EDDYK)*(ROMAX-ROMIN)     *.087896                   TRANSP        35
      WRITE(6,11) ROMAX,ROMIN,DELMIX,MU,RHO(KMAX),U(KMAX),RHAHAR               TRANSP        36
      GO TO 450                                                                TRANSP        37
  301 KKW=KMAX-1                                                               TRANSP        38
C     ***** DETERMINE DIVIDING STREAMLINE *****                                TRANSP        39
      TAMM=TAW(2)                                                              TRANSP        40
      KDSL=2                                                                   TRANSP        41
      DO 800 IF=2,KKW                                                          TRANSP        42
      IF (ABS(TAW(IF+1)).LE.ABS(TAMM)) GO TO 800                               TRANSP        43
      KDSL=IF+1                                                                TRANSP        44
      TAMM=TAW(KDSL)                                                           TRANSP        45
  800 CONTINUE                                                                 TRANSP        46
      RDY=R(KDSL)                                                              TRANSP        47
C     ***** COMPUTE DELMIX AND MU *****                                        TRANSP        48
      PERG=PERGF*ABS(TAMM)                                                     TRANSP        49
      INN=2                                                                    TRANSP        50
      DO 810 IF=3,KDSL                                                         TRANSP        51
      IF (ABS(TAW(IF)).LT.PERG) INN=IF                                         TRANSP        52
  810 CONTINUE                                                                 TRANSP        53
      RINN=R(INN)                                                              TRANSP        54
      DELMIX=RDY-RINN                                                          TRANSP        55
      MU=0.5*DELMIX*RHO(KKK)*ABS(U(1)-U(KMAX))/EDDYK                           TRANSP        56
      IF (DELMIX.EQ.0.0)  MU=1.0E-5                                            TRANSP        57
      WRITE(6,10) KDSL,INN,MU,DELMIX                                           TRANSP        58
   10 FORMAT (1H ,10X,26HDIVIDING STREAMLINE=I3,5X,15HINNER BOUND SL=,         TRANSP        59
     *  I3,/X,5HMU=,1PE10.3,5X,7HDELMIX=,E10.3)                                TRANSP        60
      GO TO 450                                                                TRANSP        61
  400 MU=EDDYK                                                                 255EP1        17
  450 CP=1.0                                                                   TRANSP        63
      DO 810 I=1,NCS                                                           TRANSP        64
      CPS(I)=0.0                                                               TRANSP        65
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      DO 500 J=1,NN                                                     TRANSP   66
  500 CPS(I)=CPS(I)+FLOAT(J-2)*A(I,J)*TT**(J-3)                         TRANSP   67


      IF (LL .LT. 0) GO TO 550                                          TRANSP   68
      CP=CP+CPS(I)*CABAR(I)                                             TRANSP   69
      GO TO 600                                                         TRANSP   70
  550 CP=CP+CPS(I)*C(I,KKK)                                             TRANSP   71
  600 CONTINUE                                                          TRANSP   72
      KAY=CP*MU/IPR                                                     TRANSP   73
      IF (IBUGSH.NE.0)                                                  TRANSP   74
     1WRITE(6,702) CP,KAY,RHABAR                                        TRANSP   75
      IF (LL .LT. 0) GO TO 650                                          TRANSP   76
      DIM(1,2)=KAY*ILE/(RHABAR*CP)                                      TRANSP   77
      GO TO 10000                                                       TRANSP   78
  650 DIM(1,2)=KAY*ILE/(RHO(KKK)*CP)                                    TRANSP   79
   11 FORMAT(1H ,6HPUMAX=,1PE9.2,2X,6HPUMIN=,E9.2,2X,7HDELMIX=,E9.2,2X  TRANSP   80
     1 ,3HPU=,E9.2,2X,4HRHO=,E9.2,2X,2HU=,E9.2,2X,7HRHMABAR=,E9.2)      TRANSP   81
  700 FORMAT(1H ,4HKKK=,I3,2X,3HLL=,I3,2X,5HMDOT=,1PE9.2,2X,2HU=,E9.2,  TRANSP   82
     * 2X,7HRHO(K)=,E9.2,2X,9HRHO(K+1)=,E9.2,2X,6HIFLAG=,I2)            TRANSP   83
  702 FORMAT(1H ,3HCP=,1PE9.2,2X,4HKAY=,E9.2,2X,7HRHABAR=,E9.2)         TRANSP   84
10000 RETURN                                                            TRANSP   85
      END                                                               TRANSP   86


      SUBROUTINE VISCO                                                  VISCO     2
C     THIS SUBROUTINE CALCULATES THE FLUX CONTRIBUTIONS TO THE          VISCO     3
C     CONSERVATION EQUATIONS                                            VISCO     4
      COMMON A(25,7)      ,AA(40)     ,ALFA(25,25),ALPHAM    ,ALPHAP    A         2
     1         ,ATOL      ,BETAP      ,BMIX       ,C11(25)   ,C(25,40)  A         3
     2         ,C12(25)   ,C2(25,40)  ,CABAR(25)  ,CBBAR(25) ,CP        A         4
     3         ,CPS(25)   ,CPSH       ,CSH(25)    ,CSH1(25)  ,CSTREM(25) A        5
     4         ,CXSTRM    ,D2IM(25,25),DEFF(25)   ,D2EFF(25) ,DELTA     A         6
     5         ,D11       ,DELSS(40)  ,DELS       ,DELSO     ,DLS(40)   A         7
     6         ,DIM(25,25) ,D12       ,DELY(40)   ,D13       ,DPDY(40)  A         8
     7         ,D14       ,EPHIDS(40) ,EPCON                            A         9
     8         ,EPSLON    ,FXTRA(50)  ,FSTEP      ,FMAX      ,GRAD      A        10
     9         ,H11       ,H(40)      ,HH         ,HJ        ,HPM(25)   A        11
     *         ,H2PM(25)  ,H3PM(25)   ,ICONST     ,ICOUNT    ,IDENT(25) A        12
     1         ,IERROR    ,IFXTRA(50) ,IFLAG      ,IKIND                A        13
     2         ,IPTOC     ,ISHOCK     ,ITYPE      ,IPD                  A        14
     3         ,IDIFF     ,K          ,KAY        ,KAYS      ,KAY2      A        15
     4         ,KLO       ,KMAX                                         A        16
     5         ,KUP       ,KK         ,LL         ,LPLANE    ,MA        A        17
     6         ,MASH      ,MDOT       ,MMAX       ,MUO       ,MU        A        18
     7         ,MU2       ,MUS        ,MM         ,MM2       ,MASH      A        19
     8         ,NBOUND    ,NDS        ,NITER      ,NMAX      ,NN        A        20
      COMMON NUCASE       ,OMEGA(25)  ,P11        ,P(40)     ,P12       A        21
     1         ,P2(40)                ,PB(50)     ,PABAR     ,PBBAR     A        22
     2         ,PHS       ,P15        ,PHI(40)               ,PHIN(50)  A        23
     3         ,PHISH1    ,PHSTRM                 ,PHIN(50)  ,P18       A        24
     4         ,PH12(40)  ,PHIBS      ,PI         ,PR(25)    ,PSH       A        25
     5         ,PSH1      ,PSI        ,PSTREM                ,PN(50)    A        26
     6         ,Q11       ,Q(40)      ,QXTR1      ,QXTR2                A        27
     7         ,QN(50)    ,R11        ,R(40)                 ,RB(50)    A        28
     8         ,RHS       ,R13        ,RBAR(40)   ,R14       ,R2(40)    A        29
     9         ,RCON      ,R15        ,RE(40)     ,RESH      ,R16       A        30
     *         ,RHO(40)   ,R17        ,RHO2(40)   ,RHS(25)   ,RHSEN     A        31
     1         ,RHSHCH    ,RHABAR     ,RHSBAR     ,RU        ,RSH       A        32
     2         ,RSTREM    ,RV         ,R19        ,RN(100)   ,S         A        33
     3                    ,SB(50)     ,SC(25)                ,SN(50)    A        34
     4         ,S13       ,SX(40)     ,T11        ,T(40)     ,T12       A        35
     5         ,T2(40)    ,TAPAY      ,TBBAR      ,T0(25)    ,T14       A        36
     6         ,TAP(40)   ,TXTR1      ,TXTR2      ,TOL       ,TSH       A        37
     7         ,TSH1      ,TSTREM                 ,TN(50)    ,TNS       A        38
     8         ,TS        ,U11        ,U(40)      ,U12       ,U2(40)    A        39
      COMMON UXTR1        ,UXTR2      ,U14        ,UBAR(40)  ,USH       A        40
     1         ,USH1      ,USTREM                 ,UN(50)    ,UNS       A        41
     2         ,X11       ,X(40)      ,X12        ,X2(40)               A        42
     3         ,XN(50)    ,XNS        ,XABAR(25)  ,XBBAR(25) ,X15       A        43
     4         ,XS(25,40) ,XSH        ,XSTREM                ,XN(50)    A        44
     5         ,ZBAR(40)              ,Y11        ,Y(40)     ,Y12       A        45
     6         ,Y2(40)    ,YABAR      ,YBBAR      ,ZA(25)    ,Z11(25)   A        46
     7         ,Z2(25,40) ,ZKA        ,S2X        ,R2SH      ,X2SH      A        47
     8         ,FX(2,40)  ,FN(2,40)   ,FPHI(2,40) ,FP(2,40)  ,FT(2,40)  A        48
     9         ,FU(2,40)  ,INDL(2,40) ,INDR(2,40) ,FC(2,40,25),CANDI    A        49
     *         ,N         ,N                                            A        50
      REAL     KAY        ,KAYS(25)   ,KAY2       ,KK        ,MDOT(40)  VISCO     6
     *         ,MA(40)    ,MU         ,MUS(25)    ,MUO(25)   ,MU2       VISCO     7
     *         ,MN(25)    ,MM2        ,MASH       ,MASH1     ,MNSH      VISCO     8
     *  ,        MAP                                                    VISCO     9
      COMMON/RMEFE/MREF(40)                                             VISCO    10


      COMMON/IBUGS1/ IBUGSH                                             VISCO    11
      COMMON/XYZ/IXYZ,JXYZ                                              VISCO    12
      IXYZ=19                                                           VISCO    13
      JXYZ=0                                                            VISCO    14
      IF (P(K)) 100,400,400                                             VISCO    15
  100 WRITE (6,150)                                                     VISCO    16
  150 FORMAT(28H1NEGATIVE PRESSURE IN VISCO. )                          VISCO    17
      CALL FDUMP(A(1,1),N,1)                                            VISCO    18
  400 CALL FLUX                                                         VISCO    19
  500 IF (IFLAG) 600,700,600                                            VISCO    20
  600 RBAR(K)=.5*(R(K)+R2(K))                                           VISCO    21
      GO TO 800                                                         VISCO    22
  700 RBAR(K)=R(K)                                                      VISCO    23
  800 IF (RBAR(K-1)) 900,1000,900                                       VISCO    24
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```
  900 DUMM=RBAR(K-1)**DELTA                                          VISCO
      GO TO 1200                                                     VISCO
 1000 IF (DELTA) 900,1100,900                                        VISCO
 1100 DUMM=1.0                                                       VISCO
C     MOMENTUM TRANSFER                                              VISCO
 1200 RHSMOM=(RBAR(K)**DELTA*TAU(K)*DLS(K)-DUMM*TAU(K-1)*DLS(K-1))   VISCO
     **PI*2.0**DELTA                                                 VISCO
C     KINETIC ENERGY TRANSFER                                        VISCO
      IF (K-2) 1300,1300,1400                                        VISCO
 1300 DSSPIN=RBAR(K)**DELTA*TAU(K)*(UBAR(K)+UBAR(K+1))/2.0*DLS(K)-DUMM*VISCO
     *AZ(K)*UPS*DLS(K-1)                                             VISCO
      GO TO 1500                                                     VISCO
 1400 DSSPIN=RBAR(K)**DELTA*TAU(K)*(UBAR(K)+UBAR(K+1))/2.0*DLS(K)-DUMM*VISCO
     *AU(K-1)*(UBAR(K)+UBAR(K-1))/2.0*DLS(K-1)                       VISCO
C     ENERGY TRANSFER BY DIFFUSION                                   VISCO
 1500 DFFLX=0.0                                                      VISCO
      DO 1700 I=1,NDS                                                VISCO
      H3PM(I)=H2PM(I)                                                VISCO
      H2PM(I)=HPM(I)                                                 VISCO
      HPM(I)=0.0                                                     VISCO
      IF(K+1-KMAX)1550,1650,1650                                     VISCO
 1550 IF (IFLAG) 1570,1560,1570                                      VISCO
 1560 HPM(I)=CPS(I)*T(K+1)                                           VISCO
      GO TO 1650                                                     VISCO
 1570 HPM(I)=CPS(I)*.5*(T(K+1)+T2(K+1))                              VISCO
 1650 DFFLX=DFFLX+.5*RBAR(K)**DELTA*ZJ(I,K)*DLS(K)*(HPM(I)+H2PM(I))  VISCO
     *-.5*DUMM*ZJ(I,K-1)*DLS(K-1)*(H2PM(I)+H3PM(I))                  VISCO
C     SPECIES TRANSFER                                               VISCO
 1700 RHS(I)=(RBAR(K)**DELTA*ZJ(I,K)*DLS(K)-DUMM*ZJ(I,K-1)*DLS(K-1))*PI  VISCO
     **2.0**DELTA                                                    VISCO
C     TOTAL ENERGY TRANSFER                                          VISCO
      RHSEN=(DFFLX+DSSPIN/HJ+RBAR(K)**DELTA*Q(K)*DLS(K)-DUMM*Q(K-1)*DLS(  VISCO
     *K-1))*PI*2.0**DELTA                                            VISCO
      RHEE(K)=ABS(RHSMOM)+RHEE(K)                                    VISCO
      IF (IHUGSN.EQ.0) GO TO 10000                                   VISCO
      WRITE (6,2001)                                                 VISCO
 2001 FORMAT (1H0,7HRHSSUM1)                                         VISCO
      DO 2100 I=1,NDS                                                VISCO
      WRITE (6,2002) RHS(I)                                          VISCO
 2100 CONTINUE                                                       VISCO
 2002 FORMAT (3X,1P1E11.4)                                           VISCO
      WRITE (6,2003) RHSMOM,DFFLX,DSSPIN,RHSEN                       VISCO
 2003 FORMAT (1H0,7HRHSMOM=,1P1E11.4,8H  DFFLX=,1P1E11.4,9H  DSSPIN=,1P1 VISCO


     *E11.4,8H  RHSEN=,1P1E11.4)                                     VISCO
10000 RETURN                                                         VISCO
      END                                                            VISCO
      SUBROUTINE SLOP(X,A,N)                                         SLOP
C     THIS PROGRAM FINDS THE SOLUTIONS TO A SET OF N SIMULTANEOUS LINEAR SLOP
C     EQUATIONS BY USING THE GAUSS-JORDAN REDUCTION ALGORITHM WITH THE  SLOP
C      DIAGONAL PIVOT STRATEGY                                       SLOP
      DIMENSION A(26,26),X(26)                                       SLOP
      DO 9 K=1,N                                                     SLOP
      IF (ABS(A(K,K)) .GT. 1.E-10) GO TO 5                           SLOP
      WRITE (6,101)   K,A(K,K)                                       SLOP
      DO 10 IR=1,N                                                   SLOP
      WRITE(6,100)(A(IR,JR),JR=1,N),X(IR)                            SLOP
   10 CONTINUE                                                       SLOP
  100 FORMAT(1X,      10F12.3)                                       SLOP
  101 FORMAT(22H ERROR--- SMALL PIVOT  ,I5,  E12.5)                  SLOP
      STOP                                                           SLOP
    5 KP1= K+1                                                       SLOP
      DO 6 J= KP1, N                                                 SLOP
    6 A(K,J)= A(K,J)/A(K,K)                                          SLOP
      X(K)= X(K)/A(K,K)                                              SLOP
      A(K,K)= 1.0                                                    SLOP
      DO 9 I=1,N                                                     SLOP
      IF (I.EQ.K .OR. A(I,K).EQ.0.) GO TO 9                          SLOP
      DO 8 J=KP1,N                                                   SLOP
    8 A(I,J)= A(I,J)- A(I,K)*A(K,J)                                  SLOP
      X(I)= X(I)- A(I,K)*X(K)                                        SLOP
      A(I,K)=0.                                                      SLOP
    9 CONTINUE                                                       SLOP
   99 CONTINUE                                                       SLOP
      RETURN                                                         SLOP
      END                                                            SLOP


      SUBROUTINE MODEL                                               MODEL
      COMMON A(25,7)    ,AA(40)     ,ALFA(25,25),ALPHAM     ,ALPHAP     A
     1       ,ATOL      ,BETAP      ,BMIX       ,C11(25)    ,C(25,40)   A
     2       ,C12(25)   ,C2(25,40)  ,CABAR(25)  ,CBBAR(25)  ,CP         A
     3       ,CPS(25)   ,CPSM       ,CSM(25)    ,CSM1(25)   ,CSTREM(25) A
     4       ,DASTRN    ,D2IM(25,25),DEFF(25)   ,D2EFF(25)  ,DELTA      A
     5       ,D11       ,DELSS(40)  ,DELS       ,DELSO      ,DLS(40)    A
     6       ,DIM(25,25),D12        ,DELY(40)   ,D13        ,DPDY(40)   A
     7       ,D14       ,DPHIDS(40) ,EPCON                              A
     8       ,EPSLON    ,EXTRA(50)  ,FSTEP      ,FMAX       ,GRAD       A
     9       ,H11       ,H(40)      ,HH         ,HJ         ,HPM(25)    A
     *       ,H2PM(25)  ,H3PM(25)   ,ICONST     ,ICOUNT     ,IDENT(25)  A
     1       ,IERROR    ,IEXTRA(50) ,IFLAG      ,IKIND                  A
     2       ,IPLOC     ,ISHOCK     ,ITYPE      ,IPO                    A
     3       ,IDIFF     ,K          ,KAY        ,KAYS       ,KAY2       A
     4       ,KLO       ,KMAX                                           A
     5       ,KUP       ,KP         ,LL         ,LPLACE     ,MA         A
     6       ,MASH      ,MLOT       ,MMAX       ,MMU        ,MN         A
     7       ,MUE       ,MUS        ,MW         ,MY2        ,MASH       A
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      8      ,NBOUND      ,NDS         ,NITER       ,NMAX        ,NN          A        20
      COMMON NUCASE       ,OMEGA(25)   ,P11         ,P(40)       ,P12         A        21
      1      ,P2(40)                   ,PB(50)      ,PABAR       ,PBBAR       A        22
      2      ,PBS         ,P15         ,PHI(40)                  ,PHIB(50)    A        23
      3      ,PHISH1      ,PHSTRM                   ,PHIW(50)    ,P1W         A        24
      4      ,PH12(40)    ,PHIHS       ,P1          ,PR(25)      ,PSH         A        25
      5      ,PSH1        ,PS1         ,PSTREM                   ,PW(50)      A        26
      6      ,Q11         ,Q(40)       ,QXTR1       ,QXTR2                    A        27
      7      ,QW(50)      ,R11         ,R(40)                    ,RB(50)      A        28
      8      ,RBS         ,R13         ,RBAR(40)    ,R14         ,R2(40)      A        29
      9      ,RCON        ,R15         ,RE(40)      ,RESH        ,R16         A        30
      *      ,RHO(40)     ,R17         ,RHO2(40)    ,RHS(25)     ,RHSEN       A        31
      1      ,RHSHOM      ,RHABAR      ,RHBBAR      ,RU          ,RSH         A        32
      2      ,RSTREM      ,RV          ,R19         ,RW(100)     ,S           A        33
      3                   ,SB(50)      ,SC(25)                   ,SW(50)      A        34
      4      ,S13         ,SX(40)      ,T11         ,T(40)       ,T12         A        35
      5      ,T2(40)      ,TABAR       ,TBBAR       ,TO(25)      ,T14         A        36
      6      ,TAA(40)     ,TXTR1       ,TXTR2       ,TOL         ,TSH         A        37
      7      ,TSH1        ,TSTREM                   ,TW(50)      ,TW3         A        38
      8      ,TS          ,U11         ,U(40)       ,U12         ,U2(40)      A        39
      COMMON UXTR1        ,UXTR2       ,U14         ,UBAR(40)    ,USH         A        40
      1      ,USH1        ,USTREM                   ,UW(50)      ,UWS         A        41
      2      ,X11         ,X(40)       ,X12         ,X2(40)                   A        42
      3      ,XB(50)      ,XBS         ,XABAR(25)   ,XBBAR(25)   ,X15         A        43
      4      ,XS(25,40)   ,XSH         ,XSTREM                   ,XW(50)      A        44
      5      ,ZMAR(40)                 ,Y11         ,Y(40)       ,Y12         A        45
      6      ,Y2(40)      ,YABAR       ,YBBAR       ,ZA(25)      ,Z11(25)     A        46
      7      ,ZJ(25,40)   ,ZMR         ,S2X         ,R2SH        ,X2SH        A        47
      8      ,FX(2,40)    ,FR(2,40)    ,FPHI(2,40)  ,FP(2,40)    ,FT(2,40)    A        48
      9      ,FU(2,40)    ,INDL(2,40)  ,INDR(2,40)  ,FC(2,40,25),CARD1        A        49
      *      ,M           ,N                                                  A        50
      COMMON/WALL/ TWALL                                                      BOUNDL    4
      COMMON/BLOUT/ REXI,THETAI,CFI,UFI,CFCCFI,M12,DISP,THETAC(2),DELTI,      BOUNDL    5
     *DELTAC,CFC,QWALL,TAUWAL,ETA(140),TETC(140),UBUFI(140),YDELI(140)        BOUNDL    6
      DIMENSION U1INT(140),U2INT(140)                                         BOUNDL    7
      REAL   KAY          ,KAYS(25)    ,KAY2        ,KW          ,MDOT(40),   BOUNDL    8
      *      ,MA(40)      ,MU          ,MUS(25)     ,MUO(25)     ,MU2         BOUNDL    9
      *      ,MW(25)      ,MW2         ,MASH        ,MASH1       ,MWSH        BOUNDL   10


      * ,        MAP                                                          BOUNDL   11
      REAL MUEREF                                                             BOUNDL   12
      IF (LL) 90,90,91                                                        BOUNDL   13
   90 QWALL=0.0                                                               BOUNDL   14
      TAUWAL=0.0                                                              BOUNDL   15
      GO TO 500                                                               BOUNDL   16
   91 CONTINUE                                                                BOUNDL   17
      MUEREF=491.E-06                                                         BOUNDL   18
      TE=T2(KMAX)                                                             BOUNDL   19
      UE=U2(KMAX)                                                             BOUNDL   20
      RHOE=RHO2(KMAX)                                                         BOUNDL   21
      PE=P2(KMAX)                                                             BOUNDL   22
      XE=X2(KMAX)                                                             BOUNDL   23
      RAD=R2(KMAX)                                                            BOUNDL   24
      SE=SX(KMAX)                                                             BOUNDL   25
      ANE=1.2                                                                 BOUNDL   26
      AMUE=MUEREF*SQRT(TE/1034.)                                              BOUNDL   27
      AMUW=MUEREF*SQRT(TWALL/1034.)                                           BOUNDL   28
      REXI=UE*SE*RHOE/AMUE                                                    BOUNDL   29
      THETAI=.036*SE/(REXI**.2)                                               BOUNDL   30
      DELTI=10.286*THETAI                                                     BOUNDL   31
C....CALC SKIN FRICTION: K-S EQ., FLAT PLATE, ZERO PRES GRAD                   BOUNDL   32
      RETHI=UE*THETAI*RHOE/AMUE                                               BOUNDL   33
      CFI=1./(17.08*(ALOG10(RETHI))**2+25.11*ALOG10(RETHI)+6.012)             BOUNDL   34
C....CALC FRICTION VELOCITY                                                   BOUNDL   35
      RC=82.1                                                                 BOUNDL   36
C........REPLACE ZMW(I) WITH CONST MOLECULAR WGT FOR NOW                      BOUNDL   37
      RHOW=TE*RHOE/TWALL                                                      BOUNDL   38
      UFI=(.5*RHOE*UE*UE*CFI/RHOW)**.5                                        BOUNDL   39
C....GENERATE TABLE OF TE/T VS U/UE                                           BOUNDL   40
      CONST=UE*UE*4.973E-08                                                   BOUNDL   41
      TTOTE=TE+CONST                                                          BOUNDL   42
      AC=-(TTOTE/TE-1.)                                                       BOUNDL   43
      CC=TWALL/TE                                                             BOUNDL   44
      B=TTOTE/TE-CC                                                           BOUNDL   45
C....FINER RESOLUTION FOR DELTA<.1                                            BOUNDL   46
      I1=50                                                                   BOUNDL   47
      I2=140                                                                  BOUNDL   48
      I3=I1+1                                                                 BOUNDL   49
      DO 100 J=1,I1                                                           BOUNDL   50
  100 ETA(J)=J/(I1*10.)                                                       BOUNDL   51
      DO 101 J=I3,I2                                                          BOUNDL   52
  101 ETA(J)=ETA(I1)+(J-I1)/100.                                              BOUNDL   53
      DETA1=ETA(1)                                                            BOUNDL   54
      DETA2=ETA(I3)-ETA(I1)                                                   BOUNDL   55
      DO 102 J=1,I2                                                           BOUNDL   56
  102 TETC(J)=(1./(AC*ETA(J)*ETA(J)+B*(ETA(J)**ANE)+CC))**.5                  BOUNDL   57
C....CALC COMP CF/INCOMP CF                                                   BOUNDL   58
      SUMI=0.0                                                                BOUNDL   59
      DO 110 J=1,I1                                                           BOUNDL   60
  110 SUMI=SUMI+TETC(J)*DETA1                                                 BOUNDL   61
      DO 111 J=I3,I2                                                          BOUNDL   62
  111 SUMI=SUMI+TETC(J)*DETA2                                                 BOUNDL   63
      CFCCFI=SUMI*SUMI                                                        BOUNDL   64
      CFC=CFCCFI*CFI                                                          BOUNDL   65
C....WALL HEAT TRANSFER AND SHEAR STRESS                                      BOUNDL   66
      STAR=.35*CFC                                                            BOUNDL   67
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      QWALL=-STANARHOE*UE*CP*(TTOTE-TWALL)                              BOUNDL  68
      TAUWALL=.5*RHOE*UE*UE*CFL                                         BOUNDL  69
C.....RETURN POINT FROM FIRST PASS                                      BOUNDL  70
      IF (IFLAG) 112,500,112                                            BOUNDL  71
C.....CALC U INCOMP/U FRICT INCOMP                                      BOUNDL  72
  112 UBUFI(1)=SQRT(2./CFC)*TETC(1)*DETA1                               BOUNDL  73
      DO 120 J=2,11                                                     BOUNDL  74
  120 UBUFI(J)=UBUFI(J-1)+SQRT(2./CFC)*TETC(J)*DETA1                    BOUNDL  75
      DO 121 J=13,I2                                                    BOUNDL  76
  121 UBUFI(J)=UBUFI(J-1)+SQRT(2./CFC)*TETC(J)*DETA2                    BOUNDL  77
C.....CALC CORRESPONDING Y/DELTA, INCOMP                                 BOUNDL  78
      FACT=1./(EXP((UBUFI(12)-5.05)/2.5))                               BOUNDL  79
      DO 132 J=1,I2                                                     BOUNDL  80
      IF (UBUFI(J).LT.5.0) GO TO 130                                    BOUNDL  81
      IF(UBUFI(J).LT.13.96) GO TO 131                                   BOUNDL  82
      YDELI(J)=EXP((UBUFI(J)-5.05)/2.5)*FACT                            BOUNDL  83
      GO TO 132                                                         BOUNDL  84
  130 YDELI(J)=UBUFI(J)*FACT                                            BOUNDL  85
      GO TO 132                                                         BOUNDL  86
  131 YDELI(J)=EXP((UBUFI(J)+3.05)/5.0)*FACT                            BOUNDL  87
  132 CONTINUE                                                          BOUNDL  68
C.....NOW HAVE Y/DELTA INCOMP = Y/DELTA COMP VS U/UE & TE/T COMP        BOUNDL  89
C                                                                       BOUNDL  90
C.....CALC THETA/DELTA & DISP/DELTA BY TRAPEZOIDAL INTEGRATION          BOUNDL  91
C.....OF U/UE(1-U/UE): (1-U/UE) & Y/DELTA                               BOUNDL  92
      SUMD2=0.0                                                         BOUNDL  93
      SUMD1=0.0                                                         BOUNDL  94
      I4=I2-1                                                           BOUNDL  95
      DO 140 J=1,I2                                                     BOUNDL  96
      D1INT(J)=1.-ETA(J)                                                BOUNDL  97
  140 D2INT(J)=D1INT(J)*ETA(J)                                          BOUNDL  98
      DO 141 J=1,I4                                                     BOUNDL  99
      SUMD1=SUMD1+(YDELI(J+1)-YDELI(J))*.5*(D1INT(J)+D1INT(J+1))        BOUNDL 100
  141 SUMD2=SUMD2+(YDELI(J+1)-YDELI(J))*.5*(D2INT(J)+D2INT(J+1))        BOUNDL 101
      H12=SUMD1/SUMD2                                                   BOUNDL 102
C.....CALC THETAC FROM MOMENTUM INTEGRAL                                 BOUNDL 103
      IF (LL.EQ.0) GO TO 142                                            BOUNDL 104
      THETAC(1)=THETAL(2)                                               BOUNDL 105
      GO TO 143                                                         BOUNDL 106
  142 THETAC(1)=.1                                                      BOUNDL 107
  143 DELX=SQRT((X2(KMAX)-X(KMAX))**2+(R2(KMAX)-R(KMAX))**2)            BOUNDL 108
      DUDX=(UE-U(KMAX))/DELX                                            BOUNDL 109
      DRHODX=(RHOE-RHO(KMAX))/DELX                                      BOUNDL 110
      DRDX=(RAD-R(KMAX))/DELX                                           BOUNDL 111
      AD=(H12+2.)/UE*DUDX+DRHODX/RHOE+DRDX/RAD                          BOUNDL 112
      THETAC(2)=(CFC/2.*DELX+THETAC(1))/(1.+AD*DELX)                    BOUNDL 113
      DELTAC=THETAC(2)/SUMD2                                            BOUNDL 114
      DISP=SUMD1*DELTAC                                                 BOUNDL 115
      DO 150 J=1,I2                                                     BOUNDL 116
  150 TETC(J)=1./(TETC(J)*TETC(J))                                      BOUNDL 117
  500 RETURN                                                            BOUNDL 118
      END                                                               BOUNDL 119
      SUBROUTINE STABLE                                                 STABLE   2
C     THIS SUBROUTINE DETERMINES STABLE STEPPING DISTANCE AND PUNCHES   STABLE   3
C     OUTPUT DATA WHEN CALLED FOR                                       STABLE   4
C                                                                       STABLE   5
      COMMON A(25,7)     ,AA(40)      ,ALFA(25,25),ALPHAR     ,ALPHAP   A        2
     1       ,ATOL       ,BETAP       ,BMIX       ,C11(25)    ,C(25,40) A        3
     2       ,C12(25)    ,C2(25,40)   ,CABAR(25)  ,CBBAR(25)  ,CP       A        4
     3       ,CFS(25)    ,CFSH        ,CSH(25)    ,CSH1(25)   ,CSTREM(25) A      5
     4       ,CSTRM      ,D21M(25,25),DEFF(25)    ,D2EFF(25)  ,DELTA    A        5
     5       ,D11        ,DELSS(40)   ,DELS       ,DELSO      ,DLS(40)  A        7
     6       ,D1M(25,25) ,D12         ,DELY(40)   ,D13        ,DPDY(40) A        8
     7       ,D14        ,DPHIDS(40)  ,EPCON                            A        9
     8       ,EPSLON     ,EXTRA(50)   ,FSTEP      ,FMAX       ,GRAD     A       10
     9       ,H11        ,H(40)       ,HH         ,HJ         ,HPM(25)  A       11
     *       ,H2PM(25)   ,H3PM(25)    ,ICONST     ,ICOUNT     ,IDENT(25) A      12
     1       ,IERROR     ,IEXTRA(50)  ,IFLAG      ,IKIND                A       13
     2       ,IPIOC      ,ISHOCK      ,ITYPE      ,IPD                  A       14
     3       ,IDIFF      ,K           ,KAY        ,KAYS       ,KAY2     A       15
     4       ,KLO        ,KMAX                                          A       16
     5       ,KUP        ,KP          ,LL         ,LPLANE     ,MA       A       17
     6       ,MASH       ,MDOT        ,MMAX       ,MU0        ,MU       A       18
     7       ,MU2        ,MUS         ,MW         ,MW2        ,MWSH     A       19
     8       ,NMODED     ,NLS         ,NITER      ,NMAX       ,NS       A       20
      COMMON NUCASE      ,OMEGA(25)   ,P11        ,P(40)      ,P12      A       21
     1       ,P2(40)                  ,PB(50)     ,PABAR      ,PBBAR    A       22
     2       ,PHS        ,P15         ,PHI(40)                ,PHIB(50) A       23
     3       ,PHISH1     ,PHSTRM                  ,PHIW(50)   ,P18      A       24
     4       ,PHI2(40)   ,PHIBS       ,PI         ,PR(25)     ,PSH      A       25
     5       ,PSH1       ,PS1         ,PSTREM                 ,PW(50)   A       26
     6       ,Q11        ,Q(40)       ,QXTR1      ,QXTR2                A       27
     7       ,QW(50)     ,R11         ,R(40)                  ,RB(50)   A       28
     8       ,RBS        ,R13         ,RBAR(40)   ,R14        ,R2(40)   A       29
     9       ,RCON       ,R15         ,RE(40)     ,RESH       ,R16      A       30
     *       ,RHO(40)    ,R17         ,RHO2(40)   ,RHS(25)    ,RHSFN    A       31
     1       ,RHSFLP     ,RHABAR      ,RHBBAR     ,RO         ,RSH      A       32
     2       ,RSTREM     ,RV          ,R19        ,RW(100)    ,S        A       33
     3                   ,SH(50)      ,SC(25)                 ,SW(50)   A       34
     4       ,S13        ,SX(40)      ,T11        ,T(40)      ,T12      A       35
     5       ,T2(40)     ,TABAR       ,TBBAR      ,T0(25)     ,T14      A       36
     6       ,TAW(40)    ,TXTR1       ,TXTR2      ,TOL        ,TSH      A       37
     7       ,TSH1       ,TSTREM                  ,TW(50)     ,TWS      A       38
     8       ,T5         ,U11         ,U(40)      ,U12        ,U2(40)   A       39
      COMMON UXTR1       ,UXTR2       ,U14        ,UBAR(40)   ,USH      A       40
     1       ,USH1       ,USTREM                  ,UW(50)     ,UWS      A       41
     2       ,X11        ,X(40)       ,X12        ,X2(40)               A       42
     3       ,XB(50)     ,XBS         ,XABAR(25)  ,XBBAR(25)  ,X15      A       43
     4       ,XS(25,40)  ,XSH         ,XSTREM                 ,XW(50)   A       44
     5       ,ZBAR(40)                ,Y11        ,Y(40)      ,Y12      A       45
     6       ,Y2(40)     ,YABAR       ,YBBAR      ,ZA(25)     ,Z11(25)  A       46
     7       ,ZJ(25,40)  ,ZMW         ,S2X        ,R2SH       ,X2SH     A       47
     8       ,FX(2,40)   ,FR(2,40)    ,FPHI(2,40) ,FP(2,40)   ,FT(2,40) A       48
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     9      ,FU(2,40)    ,INDL(2,40)  ,INDR(2,40)  ,FC(2,40,25),CARD1
     *      ,M           ,N
      REAL   KAY         ,KAYS(25)    ,KAY2        ,KM         ,MDOT(40)
     *      ,MA(40)      ,MU          ,MUB(25)     ,MUO(25)    ,MU2
     *      ,MW(25)      ,MW2         ,MASH        ,MASH1      ,MWSH
     * ,      MAP


      COMMON/P11/XMOMV(8), XMOMP(8),ENEP1(8),HEP(40,8),V(40,8),W(40,8),
     1V2(40,8), W2(40,8), TBODY(8), TP(40,8), TP2(40,8), RP(8),
     2RMP(40,8), RMP2(40,8) ,ENEP2(8),NBL(8),UM(40)
     3,VOLP(8),WTP(8),HC(8),DENG(40,8),ICOND(40,8)
      COMMON/P12/FFF,FFG,GAMA,UMI,PO,NPG,KMX,DNOSP(8)
       COMMON/P13/CL,CS,IFS,RHSS,WT,HTRAN,SIG,EP,IPART,IKINE,TK(40)
     1 ,SUMP,SUMPV,SUMPE
      COMMON/IBUGS1/ IBUGSH
      DIMENSION INDEX2(120)
      COMMON/INIL/XLX,IKI,REX
      COMMON/XYZ/IXYZ,JXYZ
      DIMENSION CA(30)
      IXYZ=20
      JXYZ=0
      IF (LL) 10,10,40
C     INDEXING
   10 IEXTRA(6)=0
      INI=0
      DO 20 I=1,KMAX
   20 INDEX2(I)=I
      MAX=KMAX+1
      DO 30 I=MAX,120
   30 INDEX2(I)=0
   40 K=2
      I=2
      DELS=1.0E10
   45 IF (IEXTRA(5)-LPLANE) 50,50,90
   50 IF (INDEX2(I)) 75,90,90
   75 I=I+1
      GO TO 50
C     VISCOUS STABILITY CRITERION
   90 DEL1=DELY(K)*RE(K)/2.0
      IF (IBUGSH.NE.0) WRITE (6,95) DEL1
   95 FORMAT (6H DEL1=,E11.4)
C     INERTIAL STABILITY CRITERION
      IF (MA(K)-1.0-EPSLON) 100,100,600
  100 WRITE (6,200) K
  200 FORMAT (25H1FLOW IS SUBSONIC IN TUBE,I5)
      CALL PDUMP(A(1,1),N,1)
      CALL EXIT
  600 DEL2=.5*DELY(K)*(MA(K)**2-1.0)**(.5)
  500 FORMAT (6H DEL2=,E11.4)
      IF (IBUGSH.NE.0) WRITE (6,500) DEL2
      IF (DEL1.EQ.0.0)  GO TO 590
      DELSS(K)=ALPHAM/(1.0/DEL1+1.0/DEL2)
      GO TO 595
  590 DELSS(K)=ALPHAM*DEL2
  595 CONTINUE
C     COMBINING SMALL TUBES
      IF (LL) 608,602,602
  602 FL=LL
      FPLANE=LPLANE
      FMULT=FL/FPLANE
      GSTEP=FSTEP
      IF (EXTRA(4).LT.1.E-5) GO TO 604
       FSTEP=GSTEP-(GSTEP-EXTRA(3))*(1.-FMULT)/EXTRA(4)
      GO TO 606


  604 FSTEP=GSTEP
  606 L=K
      CALL COMBO(L)
      FSTEP=GSTEP
      IF (L-K) 610,690,620
  610 K=L
      IF (IEXTRA(5)-LPLANE) 630,630,90
  620 K=L-1
      I=I+1
      IF (IEXTRA(5)-LPLANE) 630,630,90
  630 IJ=I
  640 IJ=IJ-1
      IF (INDEX2(IJ)) 640,650,650
  650 INDEX2(IJ)=-1
      IEXTRA(6)=IEXTRA(6)+1
      GO TO 50
C     AREA CHANGE LIMITATION
  690 DLNA=(SIN(.5*(PHI(K)+PHI(K-1)))/(.5*(R(K)+R(K-1)))*DELTA+(PHI(K)-
     *PHI(K-1))/(DELY(K))*DELSS(K)
      IF (IBUGSH.NE.0) WRITE (6,695) DLNA,ATOL
  695 FORMAT (6H DLNA=,E11.4,7H  ATOL=,E11.4)
      IF (ABS(DLNA)-ATOL)  800,800,700
  700 DELSS(K)=DELSS(K)*ATOL/ABS(DLNA)
  800 IF (DELSS(K)-DELS) 900,1000,1000
  900 DELS=DELSS(K)
      IEXTRA(7)=K
 1000 IF (IEXTRA(5)-LPLANE) 1025,1025,1050
 1025 INDEX2(I)=K
      IEXTRA(6)=I
      I=I+1
 1050 K=K+1
      IF (K-KMAX) 45,45,1055
 1055 IF (KMAX-38) 1057,1057,1060
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C     COMBINING SMALLEST TUBE WHEN NUMBER OF TUBES GETS TOO LARGE          STABLE   101
 1057 ITUBE=FSTEP                                                          STABLE   102
      IF (KMAX-ITUBE) 1400,1400,1060                                       STABLE   103
 1060 L=IEXTRA(7)                                                          STABLE   104
      K=L                                                                  STABLE   105
      STORE1=GRAD                                                          STABLE   106
      STORE2=FSTEP                                                         STABLE   107
      STORE3=Y(KMAX)                                                       STABLE   108
      GRAD=10.**10                                                         STABLE   109
      FSTEP=10.**(-10)                                                     STABLE   110
      Y(KMAX)=10.**20                                                      STABLE   111
      CALL COMBO(L)                                                        STABLE   112
      GRAD=STORE1                                                          STABLE   113
      FSTEP=STORE2                                                         STABLE   114
      Y(KMAX)=STORE3                                                       STABLE   115
      K=KMAX+1                                                             STABLE   116
 1063 IF (IEXTRA(5)-LPLANE) 1065,1065,2000                                 STABLE   117
 1065 IF (L-IEXTRA(7)) 1085,1080,1080                                      STABLE   118
 1080 I=IEXTRA(8)                                                          STABLE   119
      GO TO 1090                                                           STABLE   120
 1085 I=IEXTRA(8)-1                                                        STABLE   121
 1090 IEXTRA(6)=IEXTRA(6)+1                                                STABLE   122
      JMAX=KMAX+IEXTRA(6)                                                  STABLE   123
      JMIN=I+1                                                             STABLE   124


      J=JMAX                                                               STABLE   125
 1095 INDEX2(J)=INDEX2(J-1)                                                STABLE   126
      J=J-1                                                                STABLE   127
      IF (J-JMIN) 1097,1095,1095                                           STABLE   128
 1097 INDEX2(I)=-1                                                         STABLE   129
 1400 IF (IEXTRA(5).GT.LPLANE) GO TO 2000                                  STABLE   130
      IF (X2(2).LT. XLX) GO TO 2000                                        STABLE   131
      IF  (X2(2).EQ. XLX) GO TO 1500                                       STABLE   132
      IF (MOD(LL,IEXTRA(5))) 2000,1500,2000                                STABLE   133
C     PUNCHING OUTPUT CARDS                                                STABLE   134
 1500 I=1                                                                  STABLE   135
      IF(IKI.EQ.0)                                                         STABLE   136
     *WRITE(7,1600)  X(I),R(I),PHI(I),P(I),T(I),U(I),1,I                   STABLE   137
      IF(IKI.EQ.0.OR.IKI.NE.0)                                             STABLE   138
     *WRITE(10,1600) X(I),R(I),PHI(I),P(I),T(I),U(I),1,I                   STABLE   139
 1600 FORMAT(6E12.5,2I4)                                                   STABLE   140
      IF(IKI.EQ.0)                                                         STABLE   141
     *WRITE(7,1700)  (C(J,I),J=1,NDS)                                      STABLE   142
      IF(IKI.EQ.0.OR.IKI.NE.0)                                             STABLE   143
     *WRITE(10,1700) (C(J,I),J=1,NDS)                                      STABLE   144
 1700 FORMAT(8F10.3)                                                       STABLE   145
      KMXX=KMAX+IEXTRA(6)                                                  STABLE   146
      IF (IMART.LE.1) GO TO 1802                                           STABLE   147
      DO 1701 I=2,KMAX                                                     STABLE   148
      XMV=0.0                                                              STABLE   149
      XM=0.0                                                               STABLE   150
      XMM=0.0                                                              STABLE   151
      RHTT=0.0                                                             STABLE   152
      EU=0.0                                                               STABLE   153
      EE=0.0                                                               STABLE   154
      II=I+1                                                               STABLE   155
      DO 31 J=1,NPG                                                        STABLE   156
      XM=XM+RHP2(II,J)*W2(II,J)**2                                         STABLE   157
      XMM=XMM+RHP2(II,J)*(W2(II,J)+V2(II,J))                               STABLE   158
      XMV=XMV+RHP2(II,J)*V2(II,J)**2                                       STABLE   159
      EU=EU+RHP2(II,J)*(W2(II,J)**3/2.0+V2(II,J)**3/2.0)                   STABLE   160
      RHTT=RHTT+RHP2(II,J)                                                 STABLE   161
   31 EE=EE+RHP2(II,J)*TP2(II,J)*CS*(W2(II,J)     +V2(II,J)  )             STABLE   162
      UPI=(XM+RHO (I)*U(I)**2)/(XMM+RHO (I)*U(I))                          STABLE   163
      VPI=SQRT(XMV/(XM+RHO (I)*U(I)**2))                                   STABLE   164
      VP=UPI*(VPI+VPI**2)                                                  STABLE   165
      UP=UPI*(1+VPI)                                                       STABLE   166
      RHOP=(XMM+RHO (I)*U(I))**2/(1.+VPI)/(XM+RHO (I)*U(I)**2)             STABLE   167
      HP=(RHO (I)*U(I)*(H(I)+U(I)**2/(2.*HJ))+EU/HJ+EE)/(XMM+RHO (I)*U(I   STABLE   168
     1))-.5/HJ*((XM+RHO (I)*U(I)**2)/(XMM+RHO (I)*U(I)))**2*(1.+VPI)**2*   STABLE   169
     2((1+VPI)**2-3.*VPI)                                                  STABLE   170
      PHIA=PHI(I)+ATAN(VP/UP)                                              STABLE   171
      UA=SQRT(UP**2+VP**2)                                                 STABLE   172
      RHTOT=RHO (I)+RHTT                                                   STABLE   173
      WRITE(6,202) UP,VP,RHOP,HP,RHTOT,RHTT                                STABLE   174
  202 FORMAT(6E12.5)                                                       STABLE   175
      NDSP=NDS+NPG                                                         STABLE   176
      NDOP=NDS+1                                                           STABLE   177
      DO 102 J=NDOP,NDSP                                                   STABLE   178
      JJ=J-NDS                                                             STABLE   179
  102 CA(J)=RHP2(I-1,JJ)/RHTOT                                             STABLE   180
      DO 103 J=1,NDS                                                       STABLE   181


  103 CA(J)=C(J,I)*RHO(I)/RHTOT                                            STABLE   182
      TL=1.E-4*HP                                                          STABLE   183
      TA=T(K)                                                              STABLE   184
      DO 104 II=1,100                                                      STABLE   185
      HA=0.0                                                               STABLE   186
      CGM=0.0                                                              STABLE   187
      DO 105 J=1,NDS                                                       STABLE   188
      DO 105 JJ=1,IN                                                       STABLE   189
      HA=HA+A(J,JJ)*TA**(JJ-2)*CA(J)                                       STABLE   190
  105 CGM=CGM+A(J,JJ)*FLOAT(JJ-2)*TA**(JJ-3)*CA(J)                         STABLE   191
      HPP=0.0                                                              STABLE   192
      CPP=0.0                                                              STABLE   193
      DO 106 J=NDOP,NDSP                                                   STABLE   194
      HPP=HPP+CS*TA*CA(J)                                                  STABLE   195
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  106 DHP=DHP+CS*CA(J)                                                  STABLE   196
      G=HA+HPP-HP                                                       STABLE   197
      IF (ABS(G) .LT. TL) GO TO 107                                     STABLE   198
      DG=HP+DGH                                                         STABLE   199
      TA=TA-G/DG                                                        STABLE   200
  104 CONTINUE                                                          STABLE   201
      WRITE (6,108) IT,HA,HPP,DGH,DHP                                   STABLE   202
  108 FORMAT(8X,50HITERATION DOES NOT CONVERGE TO CORRECT TEMPERATURE  ,  STABLE   203
     1  I4,2X,4HHA= ,1PE10.3,5X,4HHPP=,E10.3,5X,4HDGH=,E10.3,5X,4HDHP=,  STABLE   204
     2 E10.3)                                                           STABLE   205
  107 CONTINUE                                                          STABLE   206
      ZM=0.0                                                            STABLE   207
      DO 109 J=1,EOS                                                    STABLE   208
  109 ZM=ZM+CA(J)/FF(J)                                                 STABLE   209
      [illegible]                                                       STABLE   210
      WRITE(10,1600)X(I),R(I),PHIA,PA,TA,UA,I,I                         STABLE   211
      WRITE(10,1700)(CA(J),J=1,NOSP)                                    STABLE   212
 1701 CONTINUE                                                          STABLE   213
      GO TO 1960                                                        STABLE   214
 1802 DO 1950 I=2,KMAX                                                  STABLE   215
      IF (INDEX2(I)) 1800,1800,1850                                     STABLE   216
 1800 JJ=I                                                              STABLE   217
 1825 JJ=JJ+1                                                           STABLE   218
      II=INDEX2(JJ)                                                     STABLE   219
      IF (II) 1825,1825,1900                                            STABLE   220
 1850 II=INDEX2(I)                                                      STABLE   221
 1900 IF(INT.EQ.0.OR.IPT.NE.0)                                          STABLE   222
     *WRITE(10,1600) X(II),R(II),PHI(II),P(II),T(II),U(II),I,INDEX2(I)  STABLE   223
      IF(INT.EQ.0)                                                      STABLE   224
     *WRITE(7,1600)  X(II),R(II),PHI(II),P(II),T(II),U(II),I,INDEX2(I)  STABLE   225
      IF(INT.EQ.0)                                                      STABLE   226
     *WRITE(7,1700) (C(J,II),J=1,NS)                                    STABLE   227
      IF(INT.EQ.0.OR.IPT.NE.0)                                          STABLE   228
     *WRITE(10,1700)(C(J,II),J=1,NOS)                                   STABLE   229
 1950 CONTINUE                                                          STABLE   230
 1960 IEXTRA(6)=0                                                       STABLE   231
      DO 1970 I=2,KMAX                                                  STABLE   232
 1970 INDEX2(I)=1                                                       STABLE   233
      KMAX=KMAX+1                                                       STABLE   234
      DO 1980 I=KMAX,121                                                STABLE   235
 1980 INDEX2(I)=0                                                       STABLE   236
 2000 IF (IHOGSH.EQ.0) RETURN                                           STABLE   237
      DO 2200 K=2,KMAX                                                  STABLE   238


      WRITE (6,2100) EELSS(K)                                           STABLE   239
 2100 FORMAT (7H EELSS=,E11.4)                                          STABLE   240
 2200 CONTINUE                                                          STABLE   241
      RETURN                                                            STABLE   242
      END                                                               STABLE   243

      SUBROUTINE PUTIN                                                  PUTIN      2
C     THIS SUBROUTINE READS IN AND INITIALIZES ALL DATA EXCEPT THAT     PUTIN      3
C     HAVING TO DO WITH AN EXTERNAL NON-UNIFORM FLOW FIELD              PUTIN      4
      COMMON A(25,7)     ,AA(40)       ,ALFA(25,25),ALPHAN      ,ALPHAP      A          2
     1        ,AIOL        ,BETAP       ,BMIX        ,C11(25)     ,C(25,40)    A          3
     2        ,C12(25)     ,C2(25,40)   ,CABAR(25)   ,CBBAR(25)   ,CP          A          4
     3        ,CPS(25)     ,CPSH        ,CSH(25)     ,CSH1(25)    ,CSTREM(25)  A          5
     4        ,DASTAR      ,D2IN(25,25),DEFF(25)    ,D2EFF(25)   ,DELTA       A          6
     5        ,DI1         ,EELSS(40)   ,DELS        ,DELSU       ,DLS(40)     A          7
     6        ,DIM(25,25) ,DI2         ,DELY(40)    ,DI3         ,DPDY(40)    A          8
     7        ,DI4         ,DPHIDS(40) ,EPCON                                 A          9
     8        ,EPSLON      ,EXTRA(50)   ,FSTEP       ,FMAX        ,GRAD        A         10
     9        ,H11         ,H(40)       ,HH          ,HJ          ,HPM(25)     A         11
     *        ,H2FM(25)    ,HSPR(25)    ,ICONST      ,ICOUNT      ,IDENT(25)   A         12
     1        ,IERROR      ,IEXTRA(50) ,IFLAG       ,ININD                    A         13
     2        ,IPLOC       ,ISHOCK      ,ITYPE       ,IPO                      A         14
     3        ,IWIFF       ,K           ,KAY         ,KAYS        ,KAY2        A         15
     4        ,KLO         ,KMAX                                              A         16
     5        ,KOP         ,KS          ,LL          ,LPLANE      ,MA          A         17
     6        ,NASH        ,NEQ         ,NMAX        ,NOD         ,NU          A         18
     7        ,NU2         ,NUS         ,NA          ,NV2         ,NASH        A         19
     8        ,ONEDEC      ,NCS         ,OMTEM       ,OMAX        ,OK          A         20
      COMMON  NOCASE      ,OMEGA(25)   ,P11         ,P(40)       ,P12         A         21
     1        ,P2(40)                   ,PB(50)      ,PABAR       ,PBBAR       A         22
     2        ,PBS         ,P15         ,PHI(40)                  ,PHIB(50)    A         23
     3        ,PHISH1      ,PHSTRM                   ,PHIA(50)    ,PIB         A         24
     4        ,PHI2(40)    ,PHIBS       ,PI          ,PR(25)      ,PSH         A         25
     5        ,PSH1        ,PS1         ,PSTREM                   ,PW(50)      A         26
     6        ,Q11         ,Q(40)       ,QXTR1       ,QXTR2                    A         27
     7        ,QW(50)      ,R11         ,R(40)                    ,RB(50)      A         28
     8        ,RBS         ,R13         ,RBAR(40)    ,R14         ,R2(40)      A         29
     9        ,RCON        ,R15         ,RE(40)      ,RESH        ,RIB         A         30
     *        ,RHO(40)     ,R17         ,RHO2(40)    ,RHS(25)     ,RHSEB       A         31
     1        ,RHSWB       ,RHABAR      ,RHBBAR      ,RO          ,RSH         A         32
     2        ,RSTREM      ,RV          ,R19         ,RW(100)     ,S           A         33
     3                     ,SB(50)      ,SC(25)                   ,SW(50)      A         34
     4        ,S13         ,SX(40)      ,T11         ,T(40)       ,T12         A         35
     5        ,T2(40)      ,TABAR       ,TBBAR       ,TO(25)      ,T14         A         36
     6        ,TAA(40)     ,TXTR1       ,TXTR2       ,TOL         ,TSH         A         37
     7        ,TSH1        ,TSTREM                   ,TW(50)      ,TWS         A         38
     8        ,TS          ,U11         ,U(40)       ,U12         ,U2(40)      A         39
      COMMON  UXTR1       ,UXTR2       ,U14         ,UBAR(40)    ,USH         A         40
     1        ,USH1        ,USTREM                   ,UW(50)      ,UWS         A         41
     2        ,X11         ,X(40)       ,X12         ,X2(40)                   A         42
     3        ,XB(50)      ,XBS         ,XABAR(25)   ,XBBAR(25)   ,X15         A         43
     4        ,XS(25,40)   ,XSH         ,XSTREM                   ,XW(50)      A         44
     5        ,ZMAX(40)                 ,Y11         ,Y(40)       ,Y12         A         45
     6        ,Y2(40)      ,YABAR       ,YBBAR       ,ZA(25)      ,Z11(25)     A         46
     7        ,Z3(25,40)   ,ZPW         ,S2X         ,R2SH        ,X2SH        A         47
     8        ,FX(2,40)    ,FR(2,40)    ,FPHI(2,40) ,FP(2,40)    ,FT(2,40)    A         48
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     *        ,FU(2,40)    ,INCL(2,40) ,INDR(2,40) ,EC(2,40,25),CARD1        A       49
     *        ,M           ,N                                                A       50
      REAL     KAY         ,KAYS(25)    ,KAY2        ,KM          ,MOUT(40)  PUTIN    6
     *        ,MA(40)      ,MU          ,MUS(25)     ,MUO(25)     ,MU2       PUTIN    7
     *        ,MM(25)      ,MM2         ,MASH        ,MASH1       ,MMSH      PUTIN    8
     * ,        MAP                                                          PUTIN    9
      COMMON/PT1/SHOMV(8), XMOMP(8),ENEP1(8),HEP(40,8),Y(40,8),R(40,8),      PUTIN   10

     1V2(40,8), X2(40,8), IRHO1(8), TP(40,8), TP2(40,8), RP(8),              PUTIN   11
     2XMP(40,8), RHP2(40,8) ,ENEP2(8),RHL(8),UM(40)                          PUTIN   12
     3,VOLP(8),WTP(8),RC(8),DENG(40,8),ICORD(40,8)                           PUTIN   13
      COMMON/PT2/FFF,FFG,GAMA,OMI,PO,RPG,RMX,UNDSP(8)                        PUTIN   14
       COMMON/PT3/CL,CS,TPS,RMS9,RT,HTRAN,SIG,EP,IPART,IKINE,TR(40)          PUTIN   15
     1 ,SUMP,SUMPV,SUMPE                                                     PUTIN   16
      COMMON/IBUGS1/ IBUGSH                                                  PUTIN   17
      COMMON/CHEM1/ ZIG(5), IRR(40),IRI(40),RC(40,3),IRRR(40,5),             PUTIN   18
     1 AV,CM(26,26),FI(26),RP(26),                                           PUTIN   19
     2 RM(26),MOUT(26,40),CSI(26),OX(26)                                     PUTIN   20
      COMMON/INPUX/IID,X0,Y0,FRAC  ,KFL                                      PUTIN   21
      COMMON/TRNSP1/ ALFTO(25),DEXP(25)                                      PUTIN   22
      COMMON/INPHO/ ICSH,IIN                                                 PUTIN   23
      EQUIVALENCE (IVISC,IEXTRA(1)),(IPCH,IEXTRA(5))                         PUTIN   24
      COMMON/IGSHOP/ FLO,TOO,UOO,PHOO,COO(25)                                PUTIN   25
      COMMON/SHOPOT/ XSHR,RSHR,PSIR,PSHR,TSHR,USHR,CSHR(25)                  PUTIN   26
      COMMON/INIL/ XEX,INI,REX                                               PUTIN   27
      COMMON/TURBUL/ILE,TPR,EDDYR,ITURB,DELMIX                               PUTIN   28
      COMMON/CFF/IPTO                                                        PUTIN   29
      COMMON/ALM/XLMD                                                        PUTIN   30
      COMMON/XYZ/IXYZ,JXYZ                                                   PUTIN   31
      COMMON/PERGFF/PERGF                                                    PUTIN   32
      COMMON/BLFG/ IBLFLG,IBL                                                255EPT  18
      COMMON/WALL/ TWALL                                                     PUTIN   34
      DIMENSION AR(7)                                                        PUTIN   35
      EQUIVALENCE (PASE,EXTRA(11)),(ITAPES,IEXTRA(2))                        PUTIN   36
      IXYZ=21                                                                PUTIN   37
      JXYZ=0                                                                 PUTIN   38
      IIN=0                                                                  PUTIN   39
C     INTEGRAL PARAMETERS,LIMITS,AND SWITCHES                                PUTIN   40
      CARD1 = 1.                                                             PUTIN   41
      READ (5,100) ITYPE,IKIND,IPO,IPTOC,ISHOCK,IBUGSH,IIO,ICSH,             PUTIN   42
     *  ITAPES,IPART,INI,ITURB,IPTO                                          PUTIN   43
      READ (5,100) KMAX,NN,KP,MMAX,NMAX,NDS,NITER,LPLANE,IKINE,IPCH,KMN      PUTIN   44
  100 FORMAT (16I5)                                                          PUTIN   45
      WRITE (6,610) KMAX,NN,KP,IP,ITYPE,IKIND,MMAX,NMAX,NDS,IPO,NITER,       PUTIN   46
     2  ICIFF,LPLANE,IPTOC,IPCH,ISHOCK,IBUGSH,IIO,ICSH,ITAPES,IKINE,         PUTIN   47
     3  IPART,INI,ITURB,IPTO                                                 PUTIN   48
  151 IF (INI.EQ.0) GO TO 150                                                PUTIN   49
      REWIND 9                                                               PUTIN   50
      REWIND 10                                                              PUTIN   51
      DO 5565 I=1,NDS                                                        PUTIN   52
 5565 READ (9,201) (A(I,J),J=1,NN),CSI(I)                                    PUTIN   53
      DO 5566 I=1,NDS                                                        PUTIN   54
 5566 READ (9,400) IDENT(I),MUO(I),TO(I),OMEGA(I),PR(I),SC(I),MA(I)          PUTIN   55
      READ(9,3) XLMD                                                         PUTIN   56
    3 FORMAT(E12.5)                                                          PUTIN   57
      READ (9,101) KMAX,DELMIX                                               PUTIN   58
  101 FORMAT (I2,2E12.5)                                                     PUTIN   59
  150 EXTRA(3)=KMAX                                                          PUTIN   60
      KFL=KMAX                                                               PUTIN   61
      ALPHAP=KP                                                              PUTIN   62
C     PHYSICAL CONSTANTS AND CONVERSIONS                                     PUTIN   63
      RJ=4.162E07                                                            PUTIN   64
      BETAP=1.013E06                                                         PUTIN   65
      RCON=1.9871                                                            PUTIN   66
      WRITE (6,611) BETAP,RJ,RCON                                            PUTIN   67

  400 FORMAT(6E12.4)
C     READ WALL TEMP AND PRINT FLAG FOR NOZZLE                               PUTIN   68
      READ(5,202) TWALL,IBLFLG,IBL                                           PUTIN   69
  202 FORMAT (F5.0,2X,I1,2X,I1)                                              255EPT  19
C     NON-INTEGRAL PARAMETERS                                                255EPT  20
      READ (5,250) ALPHAR,EPSLON,TOL,DELTA,ATOL,FSTEP,GRAD,FRAC,FRACTN       PUTIN   72
      WRITE(6,612) ALPHAR,EPSLON,TOL,DELTA,ATOL,FSTEP,GRAD,FRAC,FRACTN       PUTIN   73
  250 FORMAT (8F9.4,1F8.4)                                                   PUTIN   74
      EXTRA(4)=FRACTN                                                        PUTIN   75
      IF (IIO) 200,270,200                                                   PUTIN   76
  200 READ (5,1600) (ALFTO(I),I=1,NDS)                                       PUTIN   77
      READ (5,1600) ( DEXP(I),I=1,NDS)                                       PUTIN   78
      WRITE (6,613)                                                          PUTIN   79
      DO 614 I=1,NDS                                                         PUTIN   80
  614 WRITE (6,615) I,ALFTO(I),DEXP(I)                                       PUTIN   81
  270 PI=3.1415926S                                                          PUTIN   82
      RU=RCON*RJ                                                             PUTIN   83
      RV=RU/BETAP                                                            PUTIN   84
C     ENTHALPY POLYNOMIAL CONSTANTS                                          PUTIN   85
      IF (INI.NE.0) GO TO 5563                                               PUTIN   86
      DO 300 I=1,NDS                                                         PUTIN   87
      READ (5,201) (A(I,J),J=1,NN),CSI(I)                                    PUTIN   88
  300 WRITE(9,201) (A(I,J),J=1,NN),CSI(I)                                    PUTIN   89
 5563 CONTINUE                                                               PUTIN   90
  201 FORMAT(4E13.5/3E13.5)                                                  PUTIN   91
      DO 401 IK=1,6                                                          PUTIN   92
  401 AR(IK)=0.0                                                             PUTIN   93
C     TRANSPORT PROPERTIES                                                   PUTIN   94
      IVISC=0                                                                PUTIN   95
      WRITE (6,616)                                                          PUTIN   96
      DO 350 I=1,NDS                                                         PUTIN   97
      IF (IPTO.GT.0) GO TO 5562                                              PUTIN   98
                                                                             PUTIN   99
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      READ (5,400) IDENT(I),MUO(I),TO(I),OMEGA(I),PR(I),SC(I),MW(I)     PUTIN    100
      WRITE(9,400) IDENT(I),MUO(I),TO(I),OMEGA(I),PR(I),SC(I),MW(I)     PUTIN    101
 5502 WRITE(6,617) IDENT(I),MUO(I),TO(I),OMEGA(I),PR(I),SC(I),MW(I)     PUTIN    102
      DO 5501 JN=1,6                                                    PUTIN    103
      AN(JN)=A(I,JN)                                                    PUTIN    104
 5501 CONTINUE                                                          PUTIN    105
      A(I,1)=-AN(5)*1.0E+6/MW(I)                                        PUTIN    106
      A(I,2)=AN(6)/MW(I)*1000.0                                         PUTIN    107
      A(I,3)=AN(1)/MW(I)                                                PUTIN    108
      A(I,4)=AN(2)/(2.0E3*MW(I))                                        PUTIN    109
      A(I,5)=AN(3)/(3.0E6*MW(I))                                        PUTIN    110
      A(I,6)=AN(4)/(4.0E9*MW(I))                                        PUTIN    111
      CSI(I)=CSI(I)/MW(I)                                               PUTIN    112
  350 CONTINUE                                                          PUTIN    113
      DO 340 J=4,NN                                                     PUTIN    114
      DO 340 I=1,NOS                                                    PUTIN    115
      IF(A(I,1)) 330,351,330                                            PUTIN    116
  351 IF (A(I,J)) 330,340,330                                           PUTIN    117
  330 ICONSI=1                                                          PUTIN    118
  340 CONTINUE                                                          PUTIN    119
  400 FORMAT(A4,A8),5E12.4,1E8.2)                                       PUTIN    120
      DELNI=0.0                                                         PUTIN    121
      IF(ITURB.EQ.0) GO TO 450                                          PUTIN    122
      READ(5,6900) ILE,IPR,EDDYK,PERGF                                  PUTIN    123
      WRITE(6,618) ILE,IPR,EDDYK,PERGF                                  PUTIN    124

  425 FORMAT(4E12.5)                                                    PUTIN    125
      IVISC=1                                                           PUTIN    126
      GO TO 650                                                         PUTIN    127
  450 DO 600 I=1,NOS                                                    PUTIN    128
      IF (MUO(I)) 500,600,500                                           PUTIN    129
  500 IVISC=1                                                           PUTIN    130
  600 CONTINUE                                                          PUTIN    131
      IF(ITURB.EQ.0.AND.IPART.NE.0) IVISC =0                            PUTIN    132
  650 MU=10.0**(-20)                                                    PUTIN    133
      MU2=10.0**(-20)                                                   PUTIN    134
C     INNER STREAMLINE POSITION                                         PUTIN    135
 1100 K=1                                                               PUTIN    136
      IF (INI.EQ.0) READ (5,200) X(K),R(K),PHI(K)                       PUTIN    137
      WRITE(6,619)                                                      PUTIN    138
      IF (INI.NE.0) READ (9,200) X(K),R(K),PHI(K)                       PUTIN    139
      WRITE(6,620) K,X(K),R(K),PHI(K)                                   PUTIN    140
      X0=X(K)                                                           PUTIN    141
      Y(K)=0.0                                                          PUTIN    142
C     OTHER STREAMLINE POSITION AND STREAMTUBE PROPER                   PUTIN    143
      K=2                                                               PUTIN    144
 1200 CONTINUE                                                          PUTIN    145
      IF (INI.EQ.0) READ(5,200) X(K),R(K),PHI(K),P(K),T(K),U(K)         PUTIN    146
      IF (INI.NE.0) READ(9,200) X(K),R(K),PHI(K),P(K),T(K),U(K)         PUTIN    147
      WRITE(6,620) K,X(K),R(K),PHI(K),P(K),T(K),U(K)                    PUTIN    148
      H=SQRT((X(K)-X(K-1))**2+(R(K)-R(K-1))**2)                         PUTIN    149
      IF (ABS(PHI(K)-PHI(K-1))-1.0E-06) 1300,1300,1400                  PUTIN    150
 1300 DELY(K)=H                                                         PUTIN    151
      GO TO 1500                                                        PUTIN    152
 1400 DELY(K)=(PHI(K)-PHI(K-1))*H/(2.0*SIN(.5*(PHI(K)-PHI(K-1))))       PUTIN    153
 1500 AA(K)=PI*(R(K)+R(K-1))**DELTA*DELY(K)                             PUTIN    154
      Y(K)=Y(K-1)+DELY(K)                                               PUTIN    155
C     STREAMTUBE COMPOSITION (SPECIES MASS FRACTIONS)                   PUTIN    156
      IF (INI.EQ.0) READ(5,1600) (C(I,K),I=1,NOS)                       PUTIN    157
      IF (INI.NE.0) READ(9,1600) (C(I,K),I=1,NOS)                       PUTIN    158
 1600 FORMAT(8E10.3)                                                    PUTIN    159
C     SETUP CALCULATIONS                                                PUTIN    160
 1900 ZMR=0.0                                                           PUTIN    161
      DO 2000 I=1,NOS                                                   PUTIN    162
 2000 ZMR=ZMR+C(I,K)/MW(I)                                              PUTIN    163
      ZMW=1.0/ZMR                                                       PUTIN    164
      ZMWK(K)=ZMW                                                       PUTIN    165
      DO 2100 I=1,NOS                                                   PUTIN    166
 2100 XS(I,K)=C(I,K)*ZMW/MW(I)                                          PUTIN    167
 2400 RHO(K)=ZMW*P(K)/(RU*T(K))                                         PUTIN    168
      RMA=RHO*RHO(K)                                                    PUTIN    169
      MDOT(K)=RHO(K)*U(K)*AA(K)                                         PUTIN    170
      MAX=1.0                                                           PUTIN    171
      MAY=0.0                                                           PUTIN    172
      DO 2403 I=1,NOS                                                   PUTIN    173
      DO 2405 J=1,M                                                     PUTIN    174
      DIM(I,J)=0.0                                                      PUTIN    175
 2405 CONTINUE                                                          PUTIN    176
 2403 CONTINUE                                                          PUTIN    177
      IF (IVISC) 2406,2402,2406                                         PUTIN    178
 2402 DO 2404 I=1,NOS                                                   PUTIN    179
      CPS(I)=0.0                                                        PUTIN    180
      DO 2404 J=1,NN                                                    PUTIN    181

 2404 CPS(I)=CPS(I)+FLOAT(J-2)*A(I,J)*T(K)**(J-3)                       PUTIN    182
      GO TO 2408                                                        PUTIN    183
 2406 INIG=1                                                            PUTIN    184
      MULT=0                                                            PUTIN    185
      CALL TRANSP(T(K),P(K),K,MULT,IBIG)                                PUTIN    186
 2408 CP=0.0                                                            PUTIN    187
      DO 2410 I=1,NOS                                                   PUTIN    188
 2410 CP=CP+CPS(I)*C(I,K)                                               PUTIN    189
      IF (MAY-MAC(F)) 2430,2430,2420                                    PUTIN    190
 2420 MAX=MAY/(CP*MU)                                                   PUTIN    191
 2430 DO 2450 I=1,NOS                                                   PUTIN    192
      MAX=1                                                             PUTIN    193
      DO 2450 J=1,MAX                                                   PUTIN    194
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      IF (UIH(I,J)*RHO(K)/MU-FMAX) 2450,2450,2440
 2440 FMAX=UIH(I,J)*RHO(K)/MU
 2450 CONTINUE
      RE(K)=RHO(K)*U(K)*DELY(K)/(MU*FMAX)
      MA(K)=U(K)*SQRT((CP*ZMW-RCON)/(CP*T(K)*RCON))
      GAMA=CP/(CP-RCON/ZMW )
      PU= 4.0*GAMA/(9.*GAMA-5.0)
      H(K)=0.0
      DO 2500 I=1,NOS
      DO 2500 J=1,NN
 2500 H(K)=H(K)+A(I,J)*C(I,K)*T(K)**(J-2)
      IF (K-KMAX) 2600,2700,2700
 2600 K=K+1
      GO TO 1200
 2700 YO=Y(KMAX)
      REX=R(KMAX)
C     WALL CONDITIONS
      IF (IKI.NE.0) GO TO 2801
      WRITE(6,621)
      DO 2800 I=1,MMAX
      READ  (5,200) XW(I),RW(I),PHIW(I),PW(I),SW(I)
 2800 WRITE (6,620) I,XW(I),RW(I),PHIW(I),PW(I),SW(I)
      GO TO 3700
 2801 READ (9,200) XW(1),RW(1),XW(2),RW(2)
 3700 SWA=0.0
      PHSWA=0.0
      M=1
      PWSW=PW(M)
      IPHIW=PHIW(M)
      IF(IPHIW    ) 3900,3800,3900
 3800 PHIW(M)=PHI(M)
 3900 M=M+1
      IPHIW=PHIW(M)
      IF(IPHIW    ) 4300,4000,4300
 4000 IF (M-MMAX) 4100,4200,4200
 4100 PHIW(M)=ATAN((RW(M+1)-RW(M-1))/(XW(M+1)-XW(M-1)))
      GO TO 4300
 4200 PHIW(M)=2.0*ATAN((RW(M)-RW(M-1))/(XW(M)-XW(M-1)))
      PHIW(M)=PHIW(M)-PHIW(M-1)
 4300 ISW=SW(M)
      IF(ISW    ) 4800,4400,4800
 4400 FKW=(SIN(PHIW(M))-SIN(PHIW(M-1)))/(XW(M)-XW(M-1))
      IF (ABS(FKW/(XW(M)-XW(M-1)))-1.E-06) 4600,4600,4500
 4500 DELSWA=(PHIW(M)-PHIW(M-1))/FKW

      GO TO 4700
 4600 DELSWA=SQRT((XW(M)-XW(M-1))**2+(RW(M)-RW(M-1))**2)
 4700 SWA=SWA+DELSWA
      SW(M)=SWA
 4800 IF (M-MMAX) 3900,4900,4900
 4900 IF (IKI.NE.0) GO TO 4901
      WRITE (6,623)
      DO 5000 [illegible]1,NMAX
      READ (5,200) XB(N),RB(N),PHIB(N),PB(N),SB(N)
 5000 WRITE (6,620) N,XB(N),RB(N),PHIB(N),PB(N),SB(N)
      GO TO 5700
 4901 READ (9,200) XB(1),RB(1),XB(2),RB(2)
 5700 SBA=0.0
C     INNER BOUNDARY CONDITIONS
      N=1
      IPHIB=PHIB(N)
      IF(IPHIB    ) 5900,5800,5900
 5800 PHIB(N)=PHI(KMAX)
 5900 N=N+1
      IPHIB=PHIB(N)
      IF(IPHIB    ) 6300,6000,6300
 6000 IF (N-NMAX) 6100,6200,6200
 6100 PHIB(N)=ATAN((RB(N+1)-RB(N-1))/(XB(N+1)-XB(N-1)))
      GO TO 6300
 6200 PHIB(N)=2.0*ATAN((RB(N)-RB(N-1))/(XB(N)-XB(N-1)))
      PHIB(N)=PHIB(N)-PHIB(N-1)
 6300 ISB=SB(N)
      IF(ISB    ) 6750,6400,6750
 6400 FKB=(SIN(PHIB(N))-SIN(PHIB(N-1)))/(XB(N)-XB(N-1))
      IF (ABS(FKB/(XB(N)-XB(N-1)))-1.E-06) 6600,6600,6500
 6500 DELSBA=(PHIB(N)-PHIB(N-1))/FKB
      GO TO 6700
 6600 DELSBA=SQRT((XB(N)-XB(N-1))**2+(RB(N)-RB(N-1))**2)
 6700 SBA=SBA+DELSBA
      SB(N)=SBA
 6750 IF (N-NMAX) 5900,6800,6800
 6800 IF (IKIND-3) 6905,6850,6850
C     CONDITIONS BEHIND OUTER SHOCK
 6850 CONTINUE
      IF (IKI.EQ.0) READ(5,200) XSH,RSH,PSI,PSH,TSH,USH
      IF(IKI.EQ.0) READ(5,1600)(CSH(I),I=1,NOS)
      IF (IKI.NE.0) READ(9,200) XSH,RSH,PSI,PSH,TSH,USH
      WRITE (6,624) XSH,RSH,PSI,PSH,TSH,USH
      IF(IKI.NE.0) READ(9,1600)(CSH(I),I=1,NOS)
 6900 FORMAT(8E10.3)
      PHS=PSH
C     EXTERNAL FLOW PROPERTIES AT FIRST SHOCK POINT
 6901 READ (5,200) XSTREM,RSTREM,PHSTRM,PSTREM,TSTREM,USTREM
      WRITE (6,625) XSTREM,RSTREM,PHSTRM,PSTREM,TSTREM,USTREM
      READ (5,6900) (CSTREM(I),I=1,NOS)
 6905 IF (ITYPE-3) 7000,6910,6910
C     CONDITIONS BEHIND INNER SHOCK
 6910 CONTINUE
      IF (IKI.EQ.0) READ (5,200) XSHI,RSHI,PSIA,[illegible],TSHA,USHA
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      IF (DIM(I,J)*RHO(K)/MU-FMAX) 2450,2450,2440
 2440 FMAX=DIM(I,J)*RHO(K)/MU
 2450 CONTINUE
      RE(K)=RHO(K)*U(K)*DELY(K)/(MU*FMAX)
      MA(K)=U(K)*SQRT((CP*ZMW-RCON)/(CP*T(K)*RU))
      GAMA=CP/(CP-RCON/ZMW )
      PR= 4.0*GAMA/(9.*GAMA-5.0)
      H(K)=0.0
      DO 2500 I=1,NOS
      DO 2500 J=1,NN
 2500 H(K)=H(K)+A(I,J)*C(I,K)*T(K)**(J-2)
      IF (K-KMAX) 2600,2700,2700
 2600 K=K+1
      GO TO 1200
 2700 YO=Y(KMAX)
      HE=H(KMAX)
C     WALL CONDITIONS
      IF (IRI.NE.0) GO TO 2801
      WRITE(6,621)
      DO 2800 I=1,MMAX
      READ  (5,200) XW(I),RW(I),PHIW(I),PW(I),SW(I)
 2800 WRITE (6,620) I,XW(I),RW(I),PHIW(I),PW(I),SW(I)
      GO TO 3700
 2801 READ (9,200) XW(1),RW(1),XW(2),RW(2)
 3700 SWA=0.0
      PHSWA=0.0
      M=1
      PWSW=PW(M)
      IPHIW=PHIW(M)
      IF(IPHIW   ) 3900,3800,3900
 3800 PHIW(M)=PHI(M)
 3900 M=M+1
      IPHIW=PHIW(M)
      IF(IPHIW   ) 4300,4000,4300
 4000 IF (M-MMAX) 4100,4200,4200
 4100 PHIW(M)=ATAN((RW(M+1)-RW(M-1))/(XW(M+1)-XW(M-1)))
      GO TO 4300
 4200 PHIW(M)=2.0*ATAN((RW(M)-RW(M-1))/(XW(M)-XW(M-1)))
      PHIW(M)=PHIW(M)-PHIW(M-1)
 4300 ISW=SW(M)
      IF(ISW   ) 4800,4400,4800
 4400 FKW=(SIN(PHIW(M))-SIN(PHIW(M-1)))/(XW(M)-XW(M-1))
      IF (ABS(FKW/(XW(M)-XW(M-1)))-1.E-06) 4600,4600,4500
 4500 DELSWA=(PHIW(M)-PHIW(M-1))/FKW

      GO TO 4700
 4600 DELSWA=SQRT((XW(M)-XW(M-1))**2+(RW(M)-RW(M-1))**2)
 4700 SWA=SWA+DELSWA
      SW(M)=SWA
 4800 IF (M-MMAX) 3900,4900,4900
 4900 IF (IRI.NE.0) GO TO 4901
      WRITE (6,623)
      DO 5000 N=1,NMAX
      READ (5,200) XB(N),RB(N),PHIB(N),PB(N),SB(N)
 5000 WRITE (6,620) N,XB(N),RB(N),PHIB(N),PB(N),SB(N)
      GO TO 5700
 4901 READ (9,200) XB(1),RB(1),XB(2),RB(2)
 5700 SBA=0.0
C     OUTER BOUNDARY CONDITIONS
      N=1
      IPHIB=PHIB(N)
      IF(IPHIB   ) 5900,5800,5900
 5800 PHIB(N)=PHI(KMAX)
 5900 N=N+1
      IPHIB=PHIB(N)
      IF(IPHIB   ) 6300,6000,6300
 6000 IF (N-NMAX) 6100,6200,6200
 6100 PHIB(N)=ATAN((RB(N+1)-RB(N-1))/(XB(N+1)-XB(N-1)))
      GO TO 6300
 6200 PHIB(N)=2.0*ATAN((RB(N)-RB(N-1))/(XB(N)-XB(N-1)))
      PHIB(N)=PHIB(N)-PHIB(N-1)
 6300 ISB=SB(N)
      IF(ISB   ) 6750,6400,6750
 6400 FKB=(SIN(PHIB(N))-SIN(PHIB(N-1)))/(XB(N)-XB(N-1))
      IF (ABS(FKB/(XB(N)-XB(N-1)))-1.E-06) 6600,6600,6500
 6500 DELSBA=(PHIB(N)-PHIB(N-1))/FKB
      GO TO 6700
 6600 DELSBA=SQRT((XB(N)-XB(N-1))**2+(RB(N)-RB(N-1))**2)
 6700 SBA=SBA+DELSBA
      SB(N)=SBA
 6750 IF (N-NMAX) 5900,6800,6800
 6800 IF (IRIND-3) 6905,6850,6850
C     CONDITIONS BEHIND OUTER SHOCK
 6850 CONTINUE
      IF (IRI.EQ.0) READ(5,200) XSH,RSH,PSI,PSH,TSH,USH
      IF(IRI.EQ.0) READ(5,1600)(CSH(I),I=1,NOS)
      IF (IRI.NE.0) READ(9,200) XSH,RSH,PSI,PSH,TSH,USH
      WRITE (6,624) XSH,RSH,PSI,PSH,TSH,USH
      IF(IRI.NE.0) READ(9,1600)(CSH(I),I=1,NOS)
 6900 FORMAT(8E10.3)
      PHS=PSH
C     EXTERNAL FLOW PROPERTIES AT FIRST SHOCK POINT
 6901 READ (5,200) XSTREM,RSTREM,PHSTRM,PSTREM,TSTREM,USTREM
      WRITE (6,625) XSTREM,RSTREM,PHSTRM,PSTREM,TSTREM,USTREM
      READ (5,6900) (CSTREM(I),I=1,NOS)
 6905 IF (ITYPE-3) 7000,6910,6910
C     CONDITIONS BEHIND INNER SHOCK
 6910 CONTINUE
      IF (IRI.EQ.0) READ (5,200) XSHI,RSHI,PSII,PSHI,TSHI,USHI
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