20/1/18/80

Uh. 535

LA-8129-MS

Informal Report

MASTER

CONCHAS:

An Arbitrary Lagrangian-Eulerian Computer Code for Multicomponent Chemically Reactive Fluid Flow at all Speeds

University of California

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545

This report was not edited by the Technical Information staff.

This work was supported by the Department of Energy, Division of Fossil Fuel Utilization.

UNITED STATES
DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36

LA-8129-MS
Informal Report
UC-32
Issued: November 1979

CONCHAS:
An Arbitrary Lagrangian-Eulerian Computer Code for Multicomponent Chemically Reactive Fluid Flow at all Speeds

T. D. Butler
L. D. Cloutman
J. K. Dukowicz
J. D. Ramshaw

CONCHAS: AN ARBITRARY LAGRANGIAN-EULERIAN COMPUTER CODE FOR MULTICOMPONENT CHEMICALLY REACTIVE FLUID FLOW AT ALL SPEEDS

by

T. D. Butler, L. D. Cloutman, J. K. Dukowicz, and J. D. Ramshaw

ABSTRACT

This report describes the CONCHAS computer code, which solves the equations of transient multicomponent chemically reactive fluid dynamics in two space dimensions. CONCHAS is a time-marching finite-difference code that utilizes a partially implicit numerical scheme and a generalized mesh. Both planar and axisymmetric problems may be solved. Spatial differences are formed with respect to a two-dimensional mesh whose cells are arbitrary quadrilaterals. The location of the cell corners, or vertices, may be arbitrarily specified as functions of time, thereby allowing a Lagrangian, Eulerian, or mixed description. This capability is particularly useful for representing curved and or moving boundary surfaces. Arbitrary numbers of species and chemical reactions are allowed. Discussions are given of the governing equations, the numerical scheme, and the code structure. A FORTRAN listing of the code is also provided.

I. INTRODUCTION

During the past several years there has been a steadily increasing interest in numerical computations of chemically reactive fluid flow. Areas of current interest in which reactive flow plays a fundamental role include chemical lasers,[1,2] internal combustion engines,[3] and industrial burners and furnaces.[4] With few exceptions, reactive flow problems of practical significance are far too complex to be solved analytically. Quantitative theoretical analyses therefore require the use of numerical methods. This report describes a new computer code, called CONCHAS, which may be used to generate numerical solutions to multicomponent reactive fluid flow problems.

CONCHAS is a time-marching code that solves finite-difference approximations to the governing partial differential equations. The transient solution is marched out in a sequence of finite time increments called cycles or time steps. Values of the dependent variables on each cycle are calculated from those on the previous cycle.

CONCHAS is a two-dimensional code, which assumes that the dependent variables depend on only two of the three spatial coordinates because of symmetry. The option is provided to select either rectangular or cylindrical coordinates, corresponding to linear or axial symmetry, respectively. In the latter case, the option is provided to retain all three velocity components, so that axisymmetric swirling flows may be dealt with. The velocity component normal to the plane of calculation is called the swirl velocity; like the other dependent variables, it is assumed independent of displacements normal to the plane, so that a two-dimensional formulation is applicable.

The effects of turbulence are represented by a simple sub-grid-scale (SGS) turbulence model, whose use is optional. Chemical reactions are treated by a new procedure in which a distinction is made between slow and fast reactions. The former proceed kinetically, while the latter are assumed to be in equilibrium.

CONCHAS utilizes a partially implicit numerical scheme which is a variant of the ICE method.[5-7] The primary stability limitation of the ICE method is that the fluid cannot traverse more than one spatial increment per cycle. At low Mach number, the ICE method allows the use of much larger time steps than could otherwise be taken. The implicit part of the ICE scheme is solved by a pointwise iterative procedure similar to the method of successive over-relaxation.

Spatial differences are formed with respect to a generalized finite-difference mesh or grid, which subdivides the region of interest into a number of small quadrilateral cells, or zones. The corners of the cells are called the vertices. The positions of the vertices may be arbitrarily specified as functions of time, thereby allowing a Lagrangian, Eulerian, or mixed description. Since the locations of the vertices are arbitrary, the cells are arbitrary quadrilaterals.

This type of mesh is called an ALE (arbitrary Lagrangian-Eulerian) mesh,[8-13] and is particularly useful for representing curved and/or moving boundary surfaces. The spatial differencing is made conservative wherever possible. The procedure used is to difference the basic equations in integral form, with the area of a typical cell used as the control area, and with divergence terms transformed into surface integrals using the divergence theorem.[10,14,15]

The numbers of species and chemical reactions that can be represented in CONCHAS are arbitrary; they are limited only by computer time and storage considerations. Chemical rate expressions for the kinetic reactions are evaluated by a partially implicit procedure similar to that used in the RICE[16-19] and APACHE[20] codes. In contrast to these earlier codes, however, the reactions in CONCHAS are not assumed to be elementary. The rate coefficients are assumed to be of a generalized Arrhenius form. The equilibrium reactions are treated by an iterative procedure. Sufficient accuracy in transient calculations is frequently obtained by choosing the associated convergence criterion so that only about five iterations per cell per cycle are required.

The input and setup philosophy of CONCHAS is similar to that of APACHE and of the SOLA series of programs.[21,22] Geometrical specifications, initial conditions, and boundary conditions are inserted directly into the appropriate user-input subroutines, thereby preserving both simplicity and flexibility. An option is provided to insert a single obstacle somewhere in the computing mesh. The obstacle must be rectangular in logical space.

Much of the numerical methodology upon which CONCHAS is based has been described elsewhere. These descriptions will not be repeated here; they will simply be cited where appropriate.

CONCHAS has been developed with applications to internal combustion engines in mind, and for this reason it contains several features designed to facilitate such applications. However, the basic code structure is modular and quite general, and the code is therefore applicable to a wide variety of problems in fluid dynamics, with and without chemical reactions.

II. THE GOVERNING EQUATIONS

The governing equations are written in a two-dimensional form that may be specialized to either rectangular or cylindrical coordinates (linear or axial symmetry). In either case, the plane of calculation is taken to be the xy-plane. For compactness, the equations are written in two-dimensional vector notation. The unit vectors in the x- and y-directions are denoted by $\underset{\sim}{i}$ and $\underset{\sim}{j}$ respectively. The two-dimensional vector operator $\underset{\sim}{\nabla}$ is given by

$$\underset{\sim}{\nabla} = \underset{\sim}{i}\frac{\partial}{\partial x} + \underset{\sim}{j}\frac{\partial}{\partial y} \quad , \tag{1}$$

and the two-dimensional fluid velocity vector $\underset{\sim}{u}$ is given by

$$\underset{\sim}{u} = u(x,y,t)\underset{\sim}{i} + v(x,y,t)\underset{\sim}{j} \quad , \tag{2}$$

where t is the time. It is convenient to define

$$R = x^{\delta} \quad , \tag{3}$$

where $\delta = 0$ for rectangular coordinates and $\delta = 1$ for cylindrical coordinates. When $\delta = 1$, the symmetry axis is the y-axis.

A. Differential Form

The partial mass density of species k is denoted by ρ_k, and the total mass density ρ is given by

$$\rho = \sum_k \rho_k \quad . \tag{4}$$

The continuity equation for species k is

$$\frac{\partial\rho_k}{\partial t} + \frac{1}{R}\underset{\sim}{\nabla}\cdot(R\rho_k\underset{\sim}{u}) = \frac{1}{R}\underset{\sim}{\nabla}\cdot[R\rho D\underset{\sim}{\nabla}(\rho_k/\rho)] + (\dot{\rho}_k) \quad , \tag{5}$$

where D is the species diffusivity (assumed the same for all species), and $(\dot{\rho}_k)$ is the rate of change of ρ_k due to chemical reactions (defined later). The total density ρ satisfies the equation

$$\frac{\partial \rho}{\partial t} + \frac{1}{R} \underset{\sim}{\nabla} \cdot (R \rho \underset{\sim}{u}) = 0 \quad , \tag{6}$$

which is obtained by summing Eq. (5) over k.

The momentum equation for the mixture is

$$\frac{\partial}{\partial t} (\rho \underset{\sim}{u}) + \frac{1}{R} \underset{\sim}{\nabla} \cdot (R \rho \underset{\sim\sim}{uu}) = - \underset{\sim}{\nabla} p + \frac{1}{R} \underset{\sim}{\nabla} \cdot (R \underset{\approx}{\sigma}) - \frac{(\sigma_o - \rho w^2)}{R} \underset{\sim}{\nabla} R + \rho \underset{\sim}{G} \quad , \tag{7}$$

where p is the fluid pressure, w is the swirl velocity (i.e., the velocity normal to the xy plane) , $\underset{\approx}{\sigma}$ is the two-dimensional viscous stress, σ_o is the cylindrical viscous stress, and $\underset{\sim}{G}$ is the external force per unit mass. The viscous stresses are given by

$$\underset{\approx}{\sigma} = \mu [(\underset{\sim\sim}{\nabla u}) + (\underset{\sim\sim}{\nabla u})^T] + (\lambda / R) \; \underset{\sim}{\nabla} \cdot (R \underset{\sim}{u}) \underset{\approx}{I} \quad , \tag{8}$$

$$\sigma_o = (2\mu / R) \underset{\sim}{u} \cdot \underset{\sim}{\nabla} R + (\lambda / R) \; \underset{\sim}{\nabla} \cdot (R \underset{\sim}{u}) \quad , \tag{9}$$

where μ and λ are the first and second viscosity coefficients,[23] $\underset{\approx}{I}$ is the two-dimensional unit dyadic, and superscript T denotes the transpose. CONCHAS assumes that $\lambda = - 2\mu/3$, which is equivalent to assuming the bulk viscosity to be zero.

The angular momentum equation, which determines the swirl velocity w, is given by

$$\frac{\partial}{\partial t} (R \rho w) + \frac{1}{R} \underset{\sim}{\nabla} \cdot (R^2 \rho w \underset{\sim}{u}) = \frac{1}{R} \underset{\sim}{\nabla} \cdot (R \underset{\sim}{\tau}) \quad , \tag{10}$$

where the swirl stress vector $\underset{\sim}{\tau}$ is given by

$$\underset{\sim}{\tau} = \mu R^2 \underset{\sim}{\nabla}(w/R) \quad . \tag{11}$$

Of course, these swirl equations are meaningful only when $\delta = 1$.

The internal energy equation is

$$\frac{\partial}{\partial t}(\rho I) + \frac{1}{R}\underset{\sim}{\nabla}\cdot(R\rho I\underset{\sim}{u}) = -\frac{p}{R}\underset{\sim}{\nabla}\cdot(R\underset{\sim}{u}) + \underset{\approx}{\sigma}:\underset{\sim}{\nabla}\underset{\sim}{u} + \underset{\sim}{\tau}\cdot\underset{\sim}{\nabla}(w/R)$$
$$+ \frac{\sigma_o}{R}\underset{\sim}{u}\cdot\underset{\sim}{\nabla}R - \frac{1}{R}\underset{\sim}{\nabla}\cdot(R\underset{\sim}{J}) + \dot{Q} \quad , \tag{12}$$

where I is the specific internal energy (exclusive of chemical energy), $\underset{\sim}{J}$ is the heat flux vector, and $\dot{Q}$ is the rate of chemical heat release (defined later). The heat flux is given by

$$\underset{\sim}{J} = -K\underset{\sim}{\nabla}T - \rho D \sum_k h_k \underset{\sim}{\nabla}(\rho_k/\rho) \quad , \tag{13}$$

where K is the thermal conductivity, T is the absolute temperature, and h_k is the partial specific enthalpy of species k.

CONCHAS permits the use of arbitrary equations of state. For our application, however, the state relations are assumed to be those of an ideal gas mixture. Therefore

$$p = R_g T \sum_k (\rho_k/\mu_k) \quad , \tag{14}$$

$$I(T) = \sum_k (\rho_k/\rho) I_k(T) \quad , \tag{15}$$

$$c_v(T) = \sum_k (\rho_k/\rho)\ c_{vk}(T) \quad , \tag{16}$$

$$h_k(T) = I_k(T) + R_g T/\mu_k \quad , \tag{17}$$

where $I_k(T)$ is the partial specific internal energy for species k, $c_{vk}(T)$ is the specific heat at constant volume for species k, c_v is the mixture specific heat at constant volume, R_g is the universal gas constant, and μ_k is the molecular weight of species k.

The chemical reactions occurring in the system are symbolized by

$$\sum_k a_{kr} X_k \rightleftharpoons \sum_k b_{kr} X_k \quad , \tag{18}$$

where X_k represents one mole of species k, and a_{kr} and b_{kr} are the dimensionless stoichiometric coefficients for the <u>r</u>th reaction. It is assumed that a_{kr} and b_{kr} are integers.

The chemical source term in the species continuity equation is given by

$$(\dot{\rho}_k) = \mu_k \sum_r (b_{kr} - a_{kr})\dot{\omega}_r \quad , \tag{19}$$

where $\dot{\omega}_r$ is the rate of progress of the <u>r</u>th reaction. The chemical heat release term in the energy equation is given by

$$\dot{Q} = \sum_r q_r \dot{\omega}_r \quad , \tag{20}$$

where q_r is the negative of the heat of reaction for the <u>r</u>th reaction at absolute zero.

If r is a kinetic reaction then $\dot{\omega}_r$ is computed by

$$\dot{\omega}_r = k_{fr} \prod_k (\rho_k/\mu_k)^{a'_{kr}} - k_{br} \prod_k (\rho_k/\mu_k)^{b'_{kr}} \quad . \tag{21}$$

Here k_{fr} and k_{br} are the forward and backward rate coefficients for reaction r, and the exponents a'_{kr} and b'_{kr} specify the order of the reaction. For an elementary reaction $a'_{kr} = a_{kr}$ and $b'_{kr} = b_{kr}$. The coefficients k_{fr} and k_{br} are assumed to be of a generalized Arrhenius form:

$$\begin{aligned} k_{fr} &= A_{fr} \, T^{\zeta_{fr}} \exp\{-E^{+}_{fr}/T\} \quad , \\ k_{br} &= A_{br} \, T^{\zeta_{br}} \exp\{-E^{+}_{br}/T\} \quad , \end{aligned} \tag{22}$$

where E^{+}_{fr} and E^{+}_{br} are activation temperatures (Kelvin).

If r is an equilibrium reaction then $\dot{\omega}_r$ is implicitly determined by the constraint condition

$$\prod_k (\rho_k/\mu_k)^{b_{kr}-a_{kr}} = K^r_c(T) \quad , \tag{23}$$

where $K^r_c(T)$ is the concentration equilibrium constant for equilibrium reaction r. The equilibrium constant depends only on temperature, and is assumed to be of the form

$$K^r_c = \exp\{A_r \ln T_A + B_r/T_A + C_r + D_r T_A + E_r T_A^2\} \quad , \tag{24}$$

where $T_A = T/1000$.

B. Integral Form

The spatial differencing is simplified by writing the conservation equations in integral form, using the divergence theorem and the Reynolds transport theorem.[24] If we multiply Eq. (5) by R and integrate over a control area A, whose boundary may be moving, we obtain

$$\frac{d}{dt}\int_A R\rho_k dA + \oint_P R\rho_k(\underset{\sim}{u}-\underset{\sim}{b})\cdot\underset{\sim}{n}ds = \oint_P R\rho D\underset{\sim}{\nabla}(\rho_k/\rho)\cdot\underset{\sim}{n}ds + \int_A R(\dot{\rho}_k)dA \quad , \tag{25}$$

where $dA = dxdy$, $\oint_P ds$ is a line integral over the perimeter P of A, $\underset{\sim}{b}$ is the boundary velocity, and $\underset{\sim}{n}$ is the outward unit normal to P. Similarly, Eq. (6) becomes

$$\frac{d}{dt}\int_A R\rho dA + \oint_P R\rho(\underset{\sim}{u}-\underset{\sim}{b})\cdot\underset{\sim}{n}ds = 0 \quad . \tag{26}$$

A similar treatment of the momentum equation, Eq. (7), yields

$$\frac{d}{dt}\int_A R\rho\underset{\sim}{u}dA + \oint_P R\rho\underset{\sim}{u}(\underset{\sim}{u}-\underset{\sim}{b})\cdot\underset{\sim}{n}ds = -\int_A R\underset{\sim}{\nabla}pdA + \oint_P R\underset{\approx}{\sigma}\cdot\underset{\sim}{n}ds + \int_A (\rho w^2 - \sigma_o)\underset{\sim}{\nabla}RdA + \int_A R\rho\underset{\sim}{G}dA \quad . \tag{27}$$

The swirl equation, Eq. (10), becomes

$$\frac{d}{dt}\int_A R^2\rho wdA + \oint_P R^2\rho w(\underset{\sim}{u} - \underset{\sim}{b})\cdot\underset{\sim}{n}ds = \oint_P R\underset{\sim}{\tau}\cdot\underset{\sim}{n}ds \quad . \tag{28}$$

Finally, the energy equation, Eq. (12), becomes

$$\frac{d}{dt}\int_A R\rho I dA + \oint_P R\rho I(\underset{\sim}{u}-\underset{\sim}{b})\cdot\underset{\sim}{n}ds = -\int_A p\nabla\cdot(R\underset{\sim}{u})dA + \int_A R\underset{\approx}{\sigma}:\nabla\underset{\sim\sim}{u}dA$$

$$+\int_A R\underset{\sim}{\tau}\cdot\underset{\sim}{\nabla}(w/R)dA + \int_A \sigma_o\underset{\sim}{u}\cdot\underset{\sim}{\nabla}R dA - \oint_P R\underset{\sim}{J}\cdot\underset{\sim}{n}\, ds$$

$$+\int_A R\dot{Q}\, dA \quad . \tag{29}$$

III. THE NUMERICAL SCHEME

CONCHAS solves finite-difference approximations to the governing equations summarized in Sect. II. The equations are discretized in both space and time. Before specifying the numerical scheme in detail, it is desirable to discuss some of its general features.

A. Temporal Differencing

The temporal part of the difference scheme is based on the ICE method,[5-7] a partially implicit method that eliminates the sound-speed stability restriction of purely explicit schemes.[25,26] The temporal differencing is performed with respect to a sequence of discrete times t^n ($n = 0,1,2,\ldots$). The time interval $\Delta t^n = t^{n+1} - t^n$ is the time step and the integer n is the cycle number. The latter is displayed as a superscript, so that Q^n denotes the difference approximation to the quantity Q at time t^n. When Δt appears without a superscript, Δt^n is understood. The difference approximation to the derivative $\partial Q/\partial t$ is the first-order expression $(Q^{n+1} - Q^n)/\Delta t$.

Most quantities are not advanced from time t^n to time t^{n+1} in a single step. A cycle is performed in three stages, or phases, and it is convenient to define intermediate quantities that have been partially but not fully updated. Such quantities will be identified by superscripts A and B, corresponding to phases I and II, respectively.

B. Spatial Differencing

The spatial differencing is based on the ALE method,[8-13] which uses a mesh made up of arbitrary quadrilaterals. Spatial difference approximations are constructed by the control-volume or integral-balance approach,[10,14,15] which largely preserves the local conservation properties of the differential equations.

The combined use of the ICE and ALE methods is sometimes signified by the term ICED-ALE. Earlier ICED-ALE codes include YAQUI[11] and BAAL.[13]

The spatial region of interest in the xy-plane is subdivided into a number of small quadrilateral cells, or zones, the corners of which are the vertices. Together, the cells constitute the mesh with respect to which spatial differences are formed. The vertices need not be stationary, but may move in an arbitrarily prescribed manner. This capability includes the Lagrangian and Eulerian descriptions as special cases. In the general case, the cells are asymmetrical; a typical cell is shown in Fig. 1. The vertices are conventionally numbered in counterclockwise order as shown.

The cells are indexed by integers (i,j), which may be regarded as horizontal and vertical coordinates in logical space. The indices (i,j) also label the vertices, with the understanding that vertex (i,j) is the (logical) lower left corner of cell (i,j). The Cartesian coordinates of vertex (i,j) are (x_{ij},y_{ij}), which in general depend on the time t. The "center" of cell (i,j) is defined to be the point with coordinates

$$
\begin{aligned}
x_{ij}^{c} &= \frac{1}{4}\left(x_{ij} + x_{i+1,j} + x_{i,j+1} + x_{i+1,j+1}\right) \quad , \\
y_{ij}^{c} &= \frac{1}{4}\left(y_{ij} + y_{i+1,j} + y_{i,j+1} + y_{i+1,j+1}\right) \quad .
\end{aligned}
\tag{30}
$$

In general, the point (x_{ij}^{c}, j_{ij}^{c}) is not the geometrical center of cell (i,j).

It is convenient to define auxiliary cells centered about the vertices. These cells are called the momentum cells; momentum cell (i,j) is centered about vertex (i,j). The relation of a typical momentum cell to its associated regular cells is shown in Fig. 2. Each momentum cell contains four triangular subcells, one from each of the four associated regular cells. Note that the momentum cells overlap each other, while the regular cells do not.

Figure 1 shows that cell (i,j) may be regarded as the union of triangles 123 and 134, whose areas are given respectively by

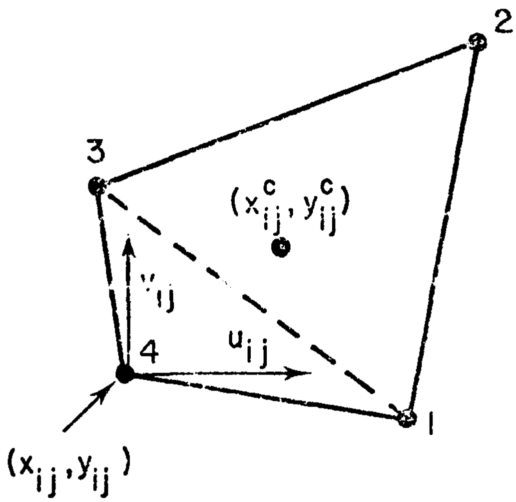

Fig. 1. Typical finite-difference cell. Also shown are the location of velocity components u_{ij} and v_{ij}, the conventional vertex labelling, and the conventional division into triangles.

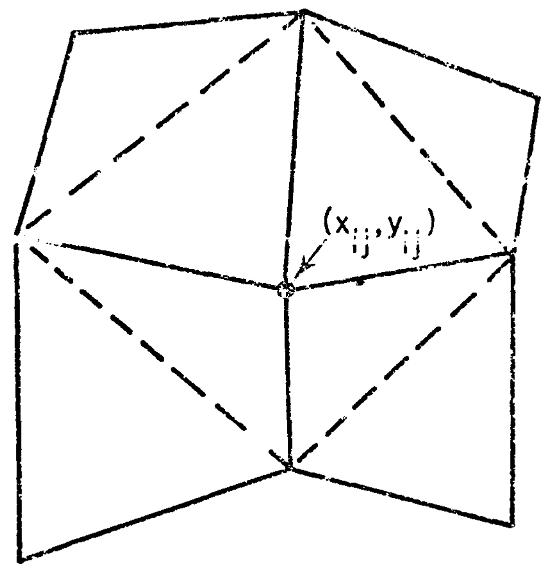

Fig. 2. Momentum cell (i,j), shown in dashed lines, and its associated regular cells.

$$\text{ATR} = \frac{1}{2}\left[x_1(y_2-y_3) + x_2(y_3-y_1) + x_3(y_1-y_2)\right] \quad ,$$
$$\text{ABL} = \frac{1}{2}\left[x_1(y_3-y_4) + x_3(y_4-y_1) + x_4(y_1-y_3)\right] \quad . \tag{31}$$

The area of cell (i,j) is then given by

$$A_{ij} = \text{ATR} + \text{ABL} \quad . \tag{32}$$

The volumes corresponding to triangles 123 and 134 may be shown to be

$$VTR = \int_{\Delta(123)} R dx dy = \frac{1}{3}(R_1 + R_2 + R_3) ATR \quad ,$$

$$VBL = \int_{\Delta(134)} R dx dy = \frac{1}{3}(R_1 + R_3 + R_4) ABL \quad , \tag{33}$$

which reduce to ATR and ABL when $\delta = 0$. These volumes assume a depth of one length unit when $\delta = 0$ and one radian when $\delta = 1$. The total cell volume is then given by

$$V_{ij} = \int_{A_{ij}} R dx dy = VTR + VBL \quad . \tag{34}$$

Spatial differences are performed by identifying the control area A of Sect. II.B with the area of a typical cell (or, in the case of the momentum equation, a typical momentum cell). Spatial integrals are then performed under the assumption that the dependent variables are uniform within each cell and/or on each cell face. Thermodynamic variables are regarded as uniform within each regular cell with the values they have at the center of the cell. Velocities are regarded as uniform within each momentum cell, with the values they have at the vertex on which the cell is centered. On cell faces, all quantities are regarded as uniform with their values at the center of the face in question, obtained by averaging. Thus line integrals over cell perimeters are approximated as sums over cell faces,

$$\oint_P \underset{\sim}{F} \cdot \underset{\sim}{n} ds \cong \sum_{\alpha=1}^{4} \underset{\sim}{F}_\alpha \cdot \underset{\sim}{n}_\alpha \Delta s_\alpha \quad , \tag{35}$$

where $\underset{\sim}{F}_\alpha$ is the value of $\underset{\sim}{F}$ at the center of cell face α, $\underset{\sim}{n}_\alpha$ is the outward unit normal to the cell face, Δs_α is its length, and the faces are assumed to be numbered in a counterclockwise order. Let $\underset{\sim}{k}$ be the unit vector out of the plane, and let $\underset{\sim}{\ell}_\alpha$ be the vector of length Δs_α along cell face α in the counterclockwise direction. Then

$$\underset{\sim}{n}_\alpha \Delta s_\alpha = \underset{\sim}{\ell}_\alpha \times \underset{\sim}{k} = \ell_{\alpha y} \underset{\sim}{i} - \ell_{\alpha x} \underset{\sim}{j} \quad , \tag{36}$$

where $\ell_{\alpha x}$ and $\ell_{\alpha y}$ are the x- and y-components of $\underset{\sim}{\ell}_\alpha$. These considerations apply equally well to regular and momentum cells.

In the finite-difference approximation, velocities are fundamentally located at the vertices. Thus, as shown in Fig. 1,

$$\begin{aligned} u_{ij} &= u(x_{ij}, y_{ij}) \quad , \\ v_{ij} &= v(x_{ij}, y_{ij}) \quad , \\ w_{ij} &= w(x_{ij}, y_{ij}) \quad , \end{aligned} \tag{37}$$

where u and v are the x- and y-components of the fluid velocity u. Thermodynamic variables are located at cell centers,

$$Q_{ij} = Q(x^c_{ij}, y^c_{ij}) \quad , \tag{38}$$

where $Q = p, \rho, T, I$, or ρ_k. Quantities needed at points where they are not fundamentally located are obtained by averaging neighboring values.

C. State Relations

The quantities $I_k(T)$ are obtained from the JANAF tables[27] and are stored in tabular form at intervals of 100 K. A simple linear interpolation is used to determine the $I_k(T)$ at temperatures within the range of the tables. The quantities $c_{vk}(T)$ are simply approximated by differences between adjacent tabular values of $I_k(T)$, divided by 100 K. The temperature T determines the internal energy I via Eq. (15). Conversely, I determines T via the inverse of this relation. This inverse is performed by a simple linear search algorithm which takes advantage of the fact that $(\partial I/\partial T)_{\rho_k}$ is always positive. Let $T_n = 100\, n$ ($n = 0, 1, 2, \ldots$), and choose the initial value of n so that T_n is a reasonable estimate of the correct T. One then evaluates $I_n = I(T_n)$ from Eq. (15). If $I_n > I$, n is reduced, while if $I_n < I$, n is increased. The search proceeds in this way until I is bracketed by I_n and I_{n+1}; T is then evaluated by linear interpolation between T_n and T_{n+1}.

With the above background, we are now in a position to specify the CONCHAS difference equations. It is convenient to describe the three phases of a cycle separately.

D. Phase I. The Explicit Lagrangian Calculation

In phase I the dependent variables are updated just as they would be in an explicit Lagrangian ($\underset{\sim}{b} = \underset{\sim}{u}$) calculation. Define the partial cell masses by

$$(M_k)_{ij} = \int_{A_{ij}} R\rho_k \, dA = (\rho_k)_{ij} V_{ij} \quad , \tag{39}$$

where the second equality follows from the assumed uniformity of ρ_k within cell (i,j). Similarly, let the total cell mass be

$$M_{ij} = \int_{A_{ij}} R\rho dA = \rho_{ij} V_{ij} = \sum_k (M_k)_{ij} \quad . \tag{40}$$

The phase I calculation of the partial cell masses is performed as follows:

$$\frac{\left(M_k\right)^A_{ij} - \left(M_k\right)^n_{ij}}{\Delta t} = \sum_\alpha R^n_\alpha \rho^n_\alpha D^n_\alpha [\underset{\sim}{\nabla}(\rho^n_k/\rho^n)]_\alpha \cdot \underset{\sim}{n}^n_\alpha \Delta s^n_\alpha$$

$$+ \left(\dot{\rho}_k\right)^A_{ij} V^n_{ij} \quad , \tag{41}$$

where the sum is over the faces of cell (i,j), $\left[\nabla\left(\rho_k^n/\rho^n\right)\right]_\alpha$ is a shorthand notation for a straightfoward difference approximation[28] to $\nabla\left(\rho_k^n/\rho^n\right)$ at the center of the cell face α, and $\left(\dot{\rho}_k\right)_{ij}^A$ is evaluated by a procedure that will be described later. The total cell mass after phase I is given by

$$M_{ij}^A = \sum_k \left(M_k\right)_{ij}^A = M_{ij}^n \quad , \tag{42}$$

since chemistry and diffusion do not create or destroy mass. However, $\rho_{ij}^A \neq \rho_{ij}^n$ because $V_{ij}^A \neq V_{ij}^n$. The phase I values of the vertex positions are given by

$$\begin{aligned} x_{ij}^A &= x_{ij}^n + u_{ij}^n \Delta t \quad , \\ y_{ij}^A &= y_{ij}^n + v_{ij}^n \Delta t \quad , \end{aligned} \tag{43}$$

and V_{ij}^A is then given by Eqs. (31)-(34) with all x's and y's (including the x's implicit in the R's when $\delta = 1$) replaced by x^A's and y^A's. The phase I species densities and total density are then given by

$$\left(\rho_k\right)_{ij}^A = \left(M_k\right)_{ij}^A / V_{ij}^A \tag{44}$$

and

$$\rho_{ij}^A = M_{ij}^A / V_{ij}^A = M_{ij}^n / V_{ij}^A = \rho_{ij}^n \left(V_{ij}^n / V_{ij}^A\right) \quad . \tag{45}$$

Define the cell internal energy by

$$E_{ij} = \int_{A_{ij}} R\rho I dA = \rho_{ij} I_{ij} V_{ij} = M_{ij} I_{ij} \quad , \tag{46}$$

where the uniformity assumption has again been used. The phase I value of E_{ij} is determined by

$$\frac{E^A_{ij} - E^n_{ij}}{\Delta t} = - p^n_{ij} \sum_\alpha R^n_\alpha \underset{\sim}{u}^n_\alpha \cdot \underset{\sim}{n}^n_\alpha \Delta s^n_\alpha + [\underset{\approx}{g}^n : \underset{\sim\sim}{\nabla u}^n]_{ij} V^n_{ij} + \left[\underset{\sim}{\tau}^n \cdot \underset{\sim}{\nabla}(w^n/R^n)\right]_{ij} V^n_{ij}$$

$$+ V_{ij}\left[\sigma^n_o \underset{\sim}{u}^n/R^n\right]_{ij} \cdot \underset{\sim}{\nabla R} - \sum_\alpha R^n_\alpha \underset{\sim}{J}^n_\alpha \cdot \underset{\sim}{n}^n_\alpha \Delta s^n_\alpha$$

$$+ \dot{Q}^A_{ij} V^n_{ij} \quad . \tag{47}$$

The quantities in square brackets, and the heat flux vector $\underset{\sim}{J}^n_\alpha$, are given by straightforward difference expressions similar to those of the mass fluxes, and hence will not be written out here. The evaluation of $\dot{Q}^A_{ij}$ will be discussed below in conjunction with that of $\left(\dot{\rho}_k\right)^A_{ij}$. The phase I value of I_{ij} is simply given by

$$I^A_{ij} = E^A_{ij}/M^A_{ij} = E^A_{ij}/M^n_{ij} \quad , \tag{48}$$

and the phase I value of the pressure is given by

$$p^A_{ij} = R_g \, T^A_{ij} \sum_k \left(\rho_k\right)^A_{ij}/\mu_k \quad , \tag{49}$$

where T^A_{ij} is computed by inverting Eq. (15) with I replaced by I^A_{ij} and (ρ_k/ρ) replaced by $(\rho_k/\rho)^A_{ij}$.

The momentum equation, Eq. (27), is differenced by identifying the control area A with the area A^m_{ij} of momentum cell (i,j). The velocity is regarded as uniform within A^m_{ij}, but the density of course is not, since A^m_{ij} overlaps four regular cells, each of which has a different density. Therefore

$$\int_{A^m_{ij}} R\rho \underset{\sim}{u} dA = \underset{\sim}{u}_{ij} \int_{A^m_{ij}} R\rho dA = \mathcal{M}_{ij}\underset{\sim}{u}_{ij} \quad , \tag{50}$$

where the vertex mass $\mathcal{M}_{ij}$ is defined by

$$\mathcal{M}_{ij} = \int_{A^m_{ij}} R\rho dA = \frac{1}{2}\left(M_{ij} + M_{i-1,j} + M_{i,j-1} + M_{i-1,j-1}\right) \quad . \tag{51}$$

Since $M^A_{ij} = M^n_{ij}$, $\mathcal{M}^A_{ij} = \mathcal{M}^n_{ij}$. The phase I momentum calculation is then given by

$$\mathcal{M}^n_{ij} \frac{\underset{\sim}{u}^A_{ij} - \underset{\sim}{u}^n_{ij}}{\Delta t} = - R^n_{ij} \sum_\alpha p^n_\alpha \underset{\sim}{n}^n_\alpha \Delta s^n_\alpha + \sum_\alpha R^n_\alpha \underset{\approx}{\sigma}^n_\alpha \cdot \underset{\sim}{n}^n_\alpha \Delta s^n_\alpha$$

$$+ \left[(\rho w^2 - \sigma_o)/R\right]^n_{ij} \, \mathcal{V}^n_{ij} \underset{\sim}{\nabla R} + \underset{\sim}{G}\mathcal{M}^n_{ij} \tag{52}$$

where the sums are over the faces of momentum cell (i,j), $\mathcal{V}^n_{ij}$ is the volume of momentum cell (i,j) at time t^n, and $\left[(\rho w^2 - \sigma_o)/R\right]^n_{ij}$ denotes a straightforward difference approximation to $(\rho w^2 - \sigma_o)^n/R^n$ at the point $\left(x^n_{ij}, y^n_{ij}\right)$. $\mathcal{V}^n_{ij}$ is the sum of the volumes associated with the four triangles comprising momentum cell (i,j). Each such volume is the corresponding area times the algebraic mean of the three corner R values, just as in Eq. (33). Since $\underset{\sim}{G}$ and $\underset{\sim}{\nabla R}$ are independent of position and time, they do not require spatial or time indices. The pressure p^n_α is taken to be the pressure of the regular cell which has side α as a diagonal.

The swirl equation, Eq. (28), is also differenced using A^m_{ij} as the control area. By the same reasoning that led to Eq. (52), we obtain

$$M^n_{ij} \frac{R^A_{ij} w^A_{ij} - R^n_{ij} w^n_{ij}}{\Delta t} = \sum_\alpha R^n_\alpha \tau^n_{\sim\alpha} \cdot n^n_{\sim\alpha} \Delta s^n_\alpha \quad , \tag{53}$$

where again the sum is over the faces of momentum cell (i,j). Since Eq. (53) is used only when $\delta = 1$, $R^A_{ij} = x^A_{ij}$ and $R^n_{ij} = x^n_{ij}$.

Finally, we specify the procedure for evaluating the chemical source terms $\left(\dot{\rho}_k\right)^A_{ij}$ and $\dot{Q}^A$. These quantities are given by Eqs. (19) and (20) with $\dot{\omega}_r$ re- replaced by $\dot{\omega}^A_r$, which is computed as follows. Since there is no direct chemical coupling between different cells, we may focus attention on a representative cell (i,j) and suppress the subscripts ij.

It is convenient to implement a slight change in notation. Previously the index r was used to label all reactions, both kinetic and equilibrium. Henceforth we label the kinetic reactions by index r and the equilibrium reactions by index s.

The progress rates $\dot{\omega}_r$ for the kinetic reactions are computed under the assumption that, for each reaction r, every participating species is either inert ($a_{kr} = b_{kr}$) or appears on only one side of the reaction ($a_{kr} b_{kr} = 0$). We first calculate the quantities

$$\begin{aligned} \Omega_{fr} &= k^n_{fr} \prod_k \left(\tilde{\rho}_k/\mu_k\right)^{a'_{kr}} \quad , \\ \Omega_{br} &= k^n_{br} \prod_k \left(\tilde{\rho}_k/\mu_k\right)^{b'_{kr}} \quad , \end{aligned} \tag{54}$$

where k^n_{fr} and k^n_{br} are evaluated from Eq. (22) with T replaced by T^n, and $\tilde{\rho}_k$ denotes an intermediate value of ρ_k that has been updated due to kinetic reactions < r but not reactions ⩾ r. We next identify the species, call it species K, for which

$$\mu_k(b_{kr} - a_{kr})(\Omega_{fr} - \Omega_{br})/\tilde{\rho}_k$$

is a minimum. This species is called the <u>reference species</u> for reaction r; it is the species whose density is in greatest danger of being driven negative. Once K is identified, we define

$$\Lambda_T = \tilde{\rho}_K + \Delta t \mu_K[b_{Kr}\Omega_{fr} + a_{Kr}\Omega_{br}] \quad ,$$

$$\Lambda_B = \tilde{\rho}_K + \Delta t \mu_K[a_{Kr}\Omega_{fr} + b_{Kr}\Omega_{br}] \quad . \tag{55}$$

Then $\dot{\omega}_r^A$ is given by

$$\dot{\omega}_r^A = \frac{\tilde{\rho}_K}{\Delta t \mu_K(b_{Kr} - a_{Kr})}\left(\frac{\Lambda_T}{\Lambda_B} - 1\right) \quad . \tag{56}$$

This prescription makes the part of $\partial\rho_k/\partial t$ that is due to reaction r linearly implicit in ρ_K, which prevents ρ_K from being driven negative no matter how large Δt is.

The progress rates $\dot{\omega}_s$ for the equilibrium reactions are evaluated by an iterative procedure, in which all the equilibrium reactions are simultaneously relaxed until the equilibrium constraints (23) are satisfied to a specified tolerance. Let the iteration index be m and let $\Delta\omega_s^{(m)}$ denote the progress increment for reaction s on iteration m. Then $\dot{\omega}_s$ is given by

$$\dot{\omega}_s = \frac{1}{\Delta t}\sum_{m=1}^{\infty} \Delta\omega_s^{(m)} \quad . \tag{57}$$

The increments $\Delta\omega_s^{(m)}$ are calculated by

$$\Delta\omega_s^{(m)} = -\Omega[D_{s1} + (D_{s1}^2 - 4D_{s2}D_{s0})^{1/2}]/(2D_{s2}) \quad , \tag{58}$$

where

$$D_{s0} = K_c^s\tilde{R}_s - \tilde{P}_s \quad , \tag{59}$$

$$D_{s1} = K_c^s\tilde{R}_s\tilde{\alpha}_s - \tilde{P}_s\tilde{\beta}_s \ , \tag{60}$$

$$D_{s2} = -\ K_c^s\tilde{R}_s(1 + \tilde{\alpha}_s\Delta\omega_s^{max})/(\Delta\omega_s^{max})^2 + \tilde{P}_s(1 + \tilde{\beta}_s\Delta\omega_s^{min})/(\Delta\omega_s^{min})^2 \quad , \tag{61}$$

$$\tilde{R}_s = \prod_k (\tilde{\rho}_k/\mu_k)^{a_{ks}} \quad , \tag{62}$$

$$\tilde{P}_s = \prod_k (\tilde{\rho}_k/\mu_k)^{b_{ks}} \quad , \tag{63}$$

$$\tilde{\alpha}_s = \sum_k M_k(b_{ks} - a_{ks})a_{ks}/\tilde{\rho}_k \quad , \tag{64}$$

$$\tilde{\beta}_s = \sum_k M_k(b_{ks} - a_{ks})b_{ks}/\tilde{\rho}_k \quad , \tag{65}$$

and $K_c^s = K_c^s(T^n)$. The factor Ω is an adjustable relaxation coefficient, $\Omega \cong 1$. The quantities $\tilde{\rho}_k$ are intermediate values that have been updated due to all the equilibrium reactions on previous iterations, and to reactions $< s$ on the current iteration. The quantities $\Delta\omega_s^{max}$ and $\Delta\omega_s^{min}$ are maximum and minimum values of $\Delta\omega_s$, given respectively by

$$\Delta\omega_s^{max} = \min_{\{k \ni a_{ks} > b_{ks}\}} \left(\frac{\tilde{\rho}_k/\mu_k}{a_{ks} - b_{ks}}\right) \quad , \tag{66}$$

$$\Delta\omega_s^{min} = \max_{\{k \ni a_{ks} < b_{ks}\}} \left(\frac{\tilde{\rho}_k/\mu_k}{a_{ks} - b_{ks}} \right) . \tag{67}$$

Equation (58) for $\Delta\omega_s^{(m)}$ must be supplemented with restrictions to prevent any of the species involved in reaction s from being driven negative. If Eq. (58) yields a value of $\Delta\omega_s^{(m)}$ that exceeds 0.9 $\Delta\omega_s^{max}$ then $\Delta\omega_s^{(m)}$ is set equal to 0.9 $\Delta\omega_s^{(max)}$. Similarly, if Eq. (58) predicts that $\Delta\omega_s^{(m)} < 0.9\ \Delta\omega_s^{min}$, then $\Delta\omega_s^{(m)}$ is set equal to 0.9 $\Delta\omega_s^{min}$. In addition, if $\Delta\omega_s^{(m)}$ differs in sign from D_{s0}, $\Delta\omega_s^{(m)}$ is set equal to zero. This insures that reaction s is never driven away from equilibrium.

The equilibrium chemistry iteration procedure converges most rapidly when the different equilibrium reactions are as nearly independent as possible. Thus convergence can be accelerated greatly by a judicious choice of equilibrium reactions. Consider, for example the two reactions

$$2H_2O \rightleftharpoons 2H_2 + O_2,$$

$$2OH \rightleftharpoons H_2 + O_2.$$

At moderate temperatures and in the presence of reasonable amounts of O_2, the equilibrium of the second reaction lies far to the left; that is, the amount of H_2 present is much less than the amount of OH. This is therefore a poor choice of reactions, because any H_2 made by dissociation of H_2O in the first reaction will subsequently have to be converted into OH by the second reaction. A much better choice is to let H_2O dissociate directly into OH, so that the above two reactions are replaced by

$$2H_2O + O_2 \rightleftharpoons 4OH,$$

$$2OH \rightleftharpoons H_2 + O_2.$$

The rationale for the iterative procedure embodied in Eqs. (58) - (67) is not intended to be obvious on inspection. Space precludes a complete discussion here; a detailed description of the equilibrium chemistry algorithm will be given in a forthcoming publication[29].

E. Phase II. The Pressure Iteration

The pressure iteration is also Lagrangian in nature. First we give the simultaneous equations that the iteration solves, and then we discuss the iteration procedure itself.

The phase II vertex positions are determined by

$$x_{ij}^{B} = x_{ij}^{n} + u_{ij}^{B}\Delta t \quad ,$$
$$y_{ij}^{B} = y_{ij}^{n} + v_{ij}^{B}\Delta t \quad . \tag{68}$$

These positions then determine the phase II cell volumes V_{ij}^{B} via Eqs. (31)-(34). The partial cell masses and the total cell mass do not change during phase II. Therefore

$$\left(M_k\right)_{ij}^{B} = \left(M_k\right)_{ij}^{A} \quad ,$$
$$M_{ij}^{B} = M_{ij}^{A} = M_{ij}^{n} \quad , \tag{69}$$

and hence

$$\left(\rho_k\right)_{ij}^{B} = \left(M_k\right)_{ij}^{B}/V_{ij}^{B} = \left(M_k\right)_{ij}^{A}/V_{ij}^{B} = \left(\rho_k\right)_{ij}^{A}\left(V_{ij}^{A}/V_{ij}^{B}\right) \quad ,$$
$$\rho_{ij}^{B} = M_{ij}^{B}/V_{ij}^{B} = M_{ij}^{n}/V_{ij}^{B} = \rho_{ij}^{n}\left(V_{ij}^{n}/V_{ij}^{B}\right) \quad . \tag{70}$$

The specific internal energies I_{ij} also do not change during phase II:

$$I^B_{ij} = I^A_{ij} \quad . \tag{71}$$

The phase II pressure is determined by

$$p^B_{ij} = R_g \, T^A_{ij} \sum_k \left(\rho_k\right)^B_{ij} / \mu_k = p^A_{ij} V^A_{ij} / V^B_{ij} \quad . \tag{72}$$

Since $M^B_{ij} = M^n_{ij}$, $\mathcal{M}^B_{ij} = \mathcal{M}^n_{ij}$. The phase II velocities are then determined by

$$\mathcal{M}^n_{ij} \frac{\underset{\sim}{u}^B_{ij} - \underset{\sim}{u}^A_{ij}}{\Delta t} = - R^n_{ij} \sum_\alpha \left(p^B_\alpha - p^A_\alpha\right) \underset{\sim}{n}^n_\alpha \Delta s^n_\alpha \quad , \tag{73}$$

where the sum is over the faces of momentum cell (i,j) and p_α is again the pressure of the regular cell of which face α is the diagonal.

Equations (68)-(73) are an implicit system of equations for the basic unknown quantities x^B_{ij}, y^B_{ij}, u^B_{ij}, v^B_{ij}, and p^B_{ij}. These equations are solved by a pointwise iterative procedure similar to the method of successive over-relaxation.

Let the iteration index be ν, which will be displayed as a superscript in parentheses. The iteration scheme is specified by giving the prescription for advancing all quantities from iteration ν to iteration ν+1. The vertex positions are advanced first,

$$\begin{aligned} x^{(\nu+1)}_{ij} &= x^n_{ij} + u^{(\nu)}_{ij} \Delta t \quad , \\ y^{(\nu+1)}_{ij} &= y^n_{ij} + v^{(\nu)}_{ij} \Delta t \quad . \end{aligned} \tag{74}$$

The quantities $\left(x^{(\nu+1)}_{ij}, \; y^{(\nu+1)}_{ij}\right)$ then determine $V^{(\nu+1)}_{ij}$ in the usual way. The pressure change is computed by the relaxation formula

$$p_{ij}^{(\nu+1)} = p_{ij}^{(\nu)} - \beta_{ij}\left[p_{ij}^{(\nu)} - p_{eos}\left((\rho_k)_{ij}^{A} V_{ij}^{A} / V_{ij}^{(\nu+1)}, I_{ij}^{A}\right)\right] \tag{75}$$

in which $p_{eos}(\rho_k, I)$ is the equation of state function, and β_{ij} is a relaxation coefficient defined below. For an ideal gas mixture, this reduces to the computationally more efficient form

$$p_{ij}^{(\nu+1)} = p_{ij}^{(\nu)} - \beta_{ij}\left[p_{ij}^{(\nu)} - p_{ij}^{A} V_{ij}^{A} / V_{ij}^{(\nu+1)}\right] \quad . \tag{76}$$

Finally, the velocity is updated according to

$$M_{ij}^{n} \frac{\underset{\sim}{u}_{ij}^{(\nu+1)} - \underset{\sim}{u}_{ij}^{A}}{\Delta t} = - R_{ij}^{n} \sum_{\alpha} \left(p_{\alpha}^{(\nu+1)} - p_{\alpha}^{n}\right) \underset{\sim}{n}_{\alpha}^{n} \Delta s_{\alpha}^{n} \quad . \tag{77}$$

Since Eq. (76) determines the pressure change $\delta p_{ij}^{(\nu)} = p_{ij}^{(\nu+1)} - p_{ij}^{(\nu)}$, it is convenient to rewrite Eq. (77) in terms of $\delta \underset{\sim}{u}_{ij}^{(\nu)} = \underset{\sim}{u}_{ij}^{(\nu+1)} - \underset{\sim}{u}_{ij}^{(\nu)}$. We obtain

$$M_{ij}^{n} \delta \underset{\sim}{u}_{ij}^{(\nu)} = - \Delta t R_{ij}^{n} \sum_{\alpha} \delta p_{ij}^{(\nu)} \underset{\sim}{n}_{\alpha}^{n} \Delta s_{\alpha}^{n} \quad . \tag{78}$$

Equation (78) is more convenient for numerical purposes than Eq. (77), because it allows one to avoid saving the $\underset{\sim}{u}_{ij}^{A}$.

The iteration is initialized by setting

$$\underset{\sim}{u}_{ij}^{(0)} = \underset{\sim}{u}_{ij}^{A} \; , \quad p_{ij}^{(0)} = p_{ij}^{n} + \overline{\Delta p} \quad , \tag{79}$$

where $\overline{\Delta p}$ is an estimated change in overall pressure level (defined below), and the final converged values are given by

$$\left(x^B_{ij}, y^B_{ij}, p^B_{ij}, \underset{\sim}{u}^B_{ij}\right) = \lim_{\nu\to\infty} \left(x^{(\nu)}_{ij}, y^{(\nu)}_{ij}, p^{(\nu)}_{ij}, \underset{\sim}{u}^{(\nu)}_{ij}\right) \quad . \tag{80}$$

Of course, the limit $\nu \to \infty$ is achieved for all practical purposes at some finite value of ν; this value is determined by a convergence criterion and the iteration is terminated at that point. After the iteration has converged, V^B_{ij} is known and the densities $\left(\rho_k\right)^B_{ij}$ and ρ^B_{ij} are calculated by Eq. (70). The swirl velocity is then updated by

$$w^B_{ij} = w^A_{ij} R^A_{ij} / R^B_{ij} \quad , \tag{81}$$

which is equivalent to replacing $R^A_{ij} w^A_{ij}$ by $R^B_{ij} w^B_{ij}$ in Eq. (53).

The relaxation coefficient β_{ij} is given by

$$\beta_{ij} = \omega \left\{ \frac{\partial}{\partial p^A_{ij}} \left[p^A_{ij} - p_{eos}\left((\rho_k)^A_{ij},\ I^A_{ij} \right) \right] \right\}^{-1} \tag{82}$$

or

$$\beta_{ij} = \omega \left[1 + \frac{p^A_{ij}}{V^A_{ij}} \frac{\partial V_{ij}}{\partial p_{ij}} \right]^{-1} \quad , \tag{83}$$

where ω is the usual overrelaxation parameter. Eqs. (82) and (83) correspond to Eqs. (75) and (76), respectively. The derivatives in Eqs. (82) and (83) are evaluated numerically by inserting a small pressure perturbation into cell (i,j) and calculating the resulting volume change according to Eqs. (78), (74), and

(31)-(34). The value of ω may be varied in the range $0 < \omega < 2$ to accelerate convergence. Best results are usually obtained with $\omega > 1$.

Certain tricks are used to make the pressure iteration converge faster. The first trick is to incorporate the velocity boundary conditions directly into the iteration, which must be done both in subroutine PRESIT and subroutine DSDP. If this is not done, the boundary velocities are changed during the iteration. They are ultimately reset to the correct boundary values after each iteration, but in the meantime they create incorrect cell volumes and pressures in the cells adjacent to the boundary, and this retards iteration convergence. This procedure is admittedly somewhat inconvenient, but the savings in computer time makes it worthwhile.

The second trick is designed to alleviate the well known problem that long wavelength errors relax very slowly. In the present context, this means that the iteration is very inefficient in effecting a change in the overall pressure level. We therefore try to estimate the change in pressure level for the given time step and add it into the pressure field in advance, as indicated in Eq. (79). The pressure level change is estimated as

$$\overline{\Delta p} = \overline{p^A} - \overline{p^n} \quad , \tag{84}$$

where

$$\overline{p^n} = \sum_{ij} p^n_{ij} V^n_{ij} \Big/ \sum_{ij} V^n_{ij} \quad , \tag{85}$$

$$\overline{p^A} = \sum_{ij} p^A_{ij} V^A_{ij} \Big/ \sum_{ij} V^A_{ij} \quad . \tag{86}$$

The third and last trick[20] is to save the quantity

$$\Delta p^n_{ij} \equiv p^B_{ij} - p^{(0)}_{ij} \tag{87}$$

from the <u>previous</u> cycle, and to compute $p_{ij}^{(1)}$ on the current cycle by

$$p_{ij}^{(1)} = p_{ij}^{(0)} + \Delta p_{ij}^{n} \tag{88}$$

rather than by Eq. (76).

F. Phase III. The Rezone Phase

Phase III computes the transport of chemical species, momentum, and energy caused by the motion of fluid relative to the mesh. This transport is represented in Eqs. (25)-(29) by surface integrals of the form

$$S \equiv - \oint_{P} RQ(\underset{\sim}{u} - \underset{\sim}{b}) \cdot \underset{\sim}{n} d\ell \quad , \tag{89}$$

which represents the convective contribution to $(d/dt)\int RQdA$. Leaving the time variable continuous for the moment, we may approximate S as a sum over cell faces,

$$S = - \sum_{\alpha} Q_{\alpha}^{B} \int_{\alpha} R(\underset{\sim}{u} - \underset{\sim}{b}) \cdot \underset{\sim}{n} d\ell \quad , \tag{90}$$

where Q_{α}^{B} is the phase II value of Q at the center of cell face α. The integral

$$- \int_{\alpha} R(\underset{\sim}{u} - \underset{\sim}{b}) \cdot \underset{\sim}{n} d\ell \tag{91}$$

is now seen to be the rate at which cell volume changes due to the motion of cell face α relative to the fluid. To obtain the correct net volume change over the time interval Δt, the difference approximation to this rate is taken to be the associated volume change, call it δV_α, divided by Δt. Therefore

$$S = \frac{1}{\Delta t} \sum_\alpha Q_\alpha^B \, \delta V_\alpha \quad . \tag{92}$$

The volume δV_α, in turn, is simply the volume associated with the quadrilateral having as two opposing sides cell face α at level B and cell face α at level n+1. This volume is computed by a straightfoward modification of Eqs. (31)-(34), due account being taken of algebraic signs. These relationships are illustrated in Fig. 3.

With this background we can now complete the specification of the difference scheme. The final values of the partial cell masses are given by

$$\left(M_k\right)_{ij}^{n+1} = \left(M_k\right)_{ij}^{B} + \sum_\alpha \left(\rho_k\right)_\alpha^B \, \delta V_\alpha \quad , \tag{93}$$

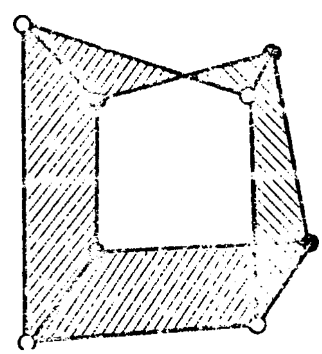

Fig. 3. Illustration of cell volume changes in Phase Three. The solid circles are the points (x_{ij}^B, y_{ij}^B); the open circles are the points $(x_{ij}^{n+1}, y_{ij}^{n+1})$. Positive volume changes are indicated by positive-sloped shadings, and vice versa. The volume changes cancel in double-shaded areas as they should.

and the total cell mass is given by

$$M_{ij}^{n+1} = M_{ij}^{B} + \sum_{\alpha} \rho_{\alpha}^{B} \, \delta V_{\alpha} = \sum_{\alpha} \left(M_k\right)_{ij}^{n+1} \quad . \tag{94}$$

The final vertex positions $\left(x_{ij}^{n+1}, y_{ij}^{n+1}\right)$ of course determine V_{ij}^{n+1} via Eqs. (31)-(34). The final values of the partial and total mass densities are then given by

$$\left(\rho_k\right)_{ij}^{n+1} = \left(M_k\right)_{ij}^{n+1} / V_{ij}^{n+1} \quad ,$$

$$\rho_{ij}^{n+1} = M_{ij}^{n+1} / V_{ij}^{n+1} = \sum_{k} \left(\rho_k\right)_{ij}^{n+1} \quad . \tag{95}$$

The final value of the cell energy is given by

$$E_{ij}^{n+1} = E_{ij}^{B} + \sum_{\alpha} \left(\rho I\right)_{\alpha}^{B} \delta V_{\alpha} \quad , \tag{96}$$

and the specific internal energy is

$$I_{ij}^{n+1} = E_{ij}^{n+1} / M_{ij}^{n+1} \quad . \tag{97}$$

Similarly, the final vertex velocities are determined by

$$\mathcal{M}_{ij}^{n+1} \underset{\sim}{u}_{ij}^{n+1} = \mathcal{M}_{ij}^{n} \underset{\sim}{u}_{ij}^{B} + \sum_{\alpha} \left(\rho \underset{\sim}{u}\right)_{\alpha}^{B} \delta \mathcal{V}_{\alpha} \quad , \tag{98}$$

$$\mathcal{M}_{ij}^{n+1} R_{ij}^{n+1} w_{ij}^{n+1} = \mathcal{M}_{ij}^{n} R_{ij}^{B} w_{ij}^{B} + \sum_{\alpha} \left(R\rho w\right)_{\alpha}^{B} \delta \mathcal{V}_{\alpha} \quad , \tag{99}$$

where $\delta \mathcal{V}_\alpha$ is the momentum-cell analog of δV_α for regular cells. In Eqs. (93)-(96) α indexes the sides of regular cell (i,j), while in Eqs. (98) and (99) it indexes the sides of momentum cell (i,j).

The cell-face quantities $\left(\rho_k\right)_\alpha^B$, $\left(\rho I\right)_\alpha^B$, $\left(\rho \underset{\sim}{u}\right)_\alpha^B$, and $(R\rho w)_\alpha^B$ are evaluated by the same partial donor-cell procedure used in YAQUI[11]. Since this procedure is described in the cited reference it will not be discussed here.

The final values of the pressure and temperature are determined by

$$\rho_{ij}^{n+1} I_{ij}^{n+1} = \sum_k (\rho_k)_{ij}^{n+1} I_k(T_{ij}^{n+1}) \quad , \tag{100}$$

$$p_{ij}^{n+1} = R_g \sum_k \left(\rho_k\right)_{ij}^{n+1} T_{ij}^{n+1}/\mu_k \quad . \tag{101}$$

This completes the description of a computational cycle.

G. Node Coupler

As in the YAQUI code, the CONCHAS difference scheme suffers from a lack of communication between adjacent vertices, which can allow slight oscillations to arise in the velocity field. This problem is alleviated by the use of a "node coupler" algorithm which introduces a small restoring acceleration at each vertex, based on the local velocity field. Each vertex is common to four regular cells, and the total restoring acceleration is the sum of contributions from each of these cells. Consider the typical cell (i,j) shown in Fig. 1, and define

$$\underset{\sim}{\Delta}_{ij} = A_{NC}(\underset{\sim}{u}_1 - \underset{\sim}{u}_2 + \underset{\sim}{u}_3 - \underset{\sim}{u}_4) \quad . \tag{102}$$

Here A_{NC} is a dimensionless coefficient, typically 0.05, and $\underset{\sim}{\Delta}_{ij}$ has the interpretation of an acceleration times Δt; that is, an impulse per unit mass. The total restoring acceleration acting on vertex (i,j) is then

$$\underset{\sim}{a}_{ij} = \frac{1}{\Delta t}\left(\underset{\sim}{\Delta}_{ij}^n - \underset{\sim}{\Delta}_{i-1,j}^n + \underset{\sim}{\Delta}_{i-1,j-1}^n - \underset{\sim}{\Delta}_{i,j-1}^n\right) \quad , \tag{103}$$

which is added to $\underset{\sim}{G}$ in Eq. (52).

H. Artificial Viscosity for Shock Waves

For problems involving shock waves, an artificial shock viscosity of the Von Neumann-Richtmyer type is included. Define

$$q_{ij} = \lambda_o \rho_{ij} A_{ij} D_{ij} \min(0, D_{ij}) \tag{104}$$

where λ_o is a dimensionless coefficient of order unity, and D_{ij} is a straightforward difference approximation to the divergence $\nabla \cdot \underset{\sim}{u}$ in cell (i,j). The quantity q_{ij} is an artificial viscous pressure; q^n_{ij} is added to p^n_{ij} in Eqs. (47) and (52).

I. Subgrid Scale Viscosity for Turbulence

The effects of turbulence on the fluid flow are modeled with a subgrid scale (SGS) eddy viscosity of the type suggested by Deardorff[30]. We postulate the turbulent coefficient of viscosity to be

$$\mu_T = \frac{\rho k_D^2 \Lambda^2}{\sqrt{2}} (\underset{\approx}{\sigma} : \underset{\approx}{\sigma} + \sigma_o^2)^{\frac{1}{2}} \quad , \tag{105}$$

where k_D is a dimensionless "universal" coefficient and Λ is taken to be the largest side of the cell in which μ_T is being computed. The viscosity μ used in the calculations is the sum of the molecular viscosity and μ_T.

There is an interesting analogy between the SGS eddy viscosity and the artificial viscosity used to treat shock waves. The artificial viscosity is used to expand the thickness of a shock wave from its physical value of a few mean free paths to a few computational cell widths. Similarly, it can be shown[31] that μ_T expands the Kolmogorov microscale to approximately Λ.

The viscosity used in CONCHAS actually consists of three components. First, there is a formula for the molecular viscosity for air that can be turned on or off with the AIRMU parameter in the program's data deck. Second, Eq. (105) is used to compute the SGS diffusivity. Deardorff[30] discusses the choice of k_D. Setting XKD to zero in the data deck turns off the SGS model. Finally, a constant diffusivity XMUO can be read from the data deck. The viscosity calculation is done in the first DO loop of subroutine VISC, and the user can easily change this algorithm if necessary.

J. Stability Restrictions

In a two-dimensional rectangular mesh, each explicit diffusive process imposes a stability restriction of the form

$$\nu \Delta t < \frac{1}{2} \frac{\Delta x^2 \Delta y^2}{\Delta x^2 + \Delta y^2} \quad , \tag{106}$$

where ν is the appropriate diffusivity, and Δx and Δy are the spatial increments. In a generalized mesh, it is reasonable to hypothesize that, at least to a first approximation, $\Delta x \Delta y$ is replaced by the cell area A and $\Delta x^2 + \Delta y^2$ is replaced by the square of the maximum cell diagonal ℓ^2. Equation (106) then becomes

$$\nu \Delta t < A^2 / 2\ell^2 \quad . \tag{107}$$

For the momentum equation the appropriate diffusivity is $4\mu/3\rho$, for the swirl equation it is μ/ρ, for the energy equation it is $K/\rho c_v$, and for the species continuity equations it is D. The overall diffusive stability restriction is therefore approximately

$$\Delta t < A^2 \left[2\ell^2 \max\left(\frac{4\mu}{3\rho} , \frac{K}{\rho c_v} , D \right) \right]^{-1} \quad . \tag{108}$$

There is also a convective stability restriction, which for a rectangular mesh becomes

$$\Delta t < \min\left(\frac{\Delta x}{|u - b_x|} , \frac{\Delta y}{|v - b_y|} \right) \quad , \tag{109}$$

where b_x and b_y are the components of the grid velocity $\underset{\sim}{b}$. Experience has shown that this restriction is approximately correct even in a generalized mesh, if Δx and Δy are evaluated by

$$\begin{aligned} \Delta x &= \max(|x_1 - x_3|, |x_2 - x_4|) \quad , \\ \Delta y &= \max(|y_1 - y_3|, |y_2 - y_4|) \quad , \end{aligned} \tag{110}$$

where the subscripts refer to the cell vertices, numbered as in Fig. 1.

Since the CONCHAS scheme is a variant of the ICE method, it has no sound-speed stability restriction.

K. Automatic Timestep Control

The timestep Δt is selected automatically based on the stability limits of the previous section and on the following considerations. At the start of a calculation, the user specifies a maximum timestep Δt_{max}. If, during the calculation, the number of pressure iterations required for convergence during phase II falls below a specified minimum, then Δt_{max} is increased by a factor of 1.02. On the other hand, if the number of iterations exceeds a specified maximum on a particular cycle, Δt_{max} is reduced by a factor of 0.75 and the cycle is rerun. The timestep to be used for the next cycle is computed by

$$\Delta t^{n+1} = \min(\Delta t_{max}, \chi\Delta t_{conv}, 0.8\ \Delta t_{diff}, 1.1\ \Delta t^n) \quad , \tag{111}$$

where Δt_{conv} is the right member of Eq. (109), Δt_{diff} is the right member of Eq. (108), and χ is a user-specified constant, $0 < \chi < 1$. The "min" operation in Eq. (111) includes a search over cells as well as arguments.

L. Boundary Conditions

The boundary conditions in CONCHAS are very simple, but the user can supply coding for any boundary condition desired. The test problem in the appendix uses adiabatic no-slip boundaries on three sides of the mesh and on the faces of the obstacle. The centerline is treated as an adiabatic free-slip boundary. Except as noted in Sect. III.E, all velocity boundary conditions are found in subroutine BC, and no other boundary conditions are needed for zero normal gradient conditions on other variables. Other boundary conditions, such as a specified temperature boundary, would require minor modifications to the program. For example, App. D shows how to set an inflow boundary condition for a gas jet. Unlike many hydrodynamics programs, CONCHAS uses no fictitious cells around the mesh.

IV. THE COMPUTER PROGRAM

This section provides sufficient information that the new CONCHAS user can set up and run the test problems given in the next section. It will also guide him in understanding the various parts of the program. A complete listing and data deck are provided in Appendix A. CONCHAS is an advanced experimental computer program, not a "black box" production code. Its use requires some knowledge of and experience with numerical fluid dynamics. It is advisable that the user become familiar with all parts of the program before attempting to modify it.

The program was written to be run on a CDC-7600 under the Livermore Time Sharing System (LTSS). However, the number of system-dependent features has been held to a minimum. They mostly occur in the graphics routines and time-accounting routines. These will be easy for the user to locate and replace or remove if necessary. The dimensions currently allow up to 12 species and 700 vertices, and these may be altered with the PARAMETER statement. Many of the arrays are stored in the 7600's large core memory (LCM), and this will have to be changed for other machines (i.e., delete the LEVEL 2 statements).

The subscripts ij are treated as a single index in the program, as this is appreciably more efficient than using doubly subscripted arrays. The single subscript IJ is computed as (j-1)*NXP+i, where NXP is the number of vertices in the x-direction. This is the same algorithm used by the compiler to compute addresses on a doubly-subscripted array whose first dimension is NXP. The variable IPJ is the single index for i+1,j and IMJ represents i-1,j. Other similar variables are used in the program, following the same pattern.

The CONCHAS program can run a problem in segments. The code compares the job time limit to the time used, and it writes a restart dump on the file TAPE7 when less than two minutes of central processor time remains. This dump may be used to continue the problem on a subsequent run, as explained in the subsection describing the data deck. Each time a dump is written, it is assigned a sequence number that must be matched by an input parameter. This procedure insures that the correct dump is used.

When doing engine geometries with squish, the cells can get very narrow, causing Δt to plummet. Subroutine CHOPPER is used to strip out or add a row of cells to the mesh so Δy can be controlled in the squish region. The variable NCHOP specifies the number of rows of cells to be left in the squish region between the top of the obstacle and the top of the mesh.

CDC computers have 64-bit words, which is about 13 decimal digits. Users of short-word machines should put CONCHAS into double precision before attempting to run any problems. Many problems simply cannot be run with 32-or 36-bit words because rounding errors are overwhelming.

A. Descriptions of Subroutines

The subroutines are found in alphabetical order in the program. The following list describes the function of each subroutine, and a flow chart is given in Fig. 4.

CONCHAS	Main program, it is the "driver" for most other subroutines.
AVISC	Computes artificial viscous pressure acceleration; adds node coupler.
BC	Sets boundary conditions.
CCFLUX	Does phase III fluxing of cell-centered variables, updates cell and vertex masses.
CHEM	General chemistry routine, calculates chemical changes to the ρ_k and I.
CHEMEQ	Equilibrium chemistry package.
CHOPPER	Adds or deletes a row of cells at the top of the mesh when δy gets below a specified minimum, called as part of the regrid routine.
CONTUR	Draws contour plots.
DSDP	Computes overrelaxation function β for the pressure iteration.
DVMAX	Finds the maximum velocity component in the mesh.
ENERGY	Adds pdV and artificial viscosity contributions to I.
EOS	Computes p from the equation of state using ρ_k, I, c_v.
FULOUT	Driver for output package.
GLOBAL	Computes and prints integrated quantities such as total mass.
MOMFLX	Fluxes momentum in phase III.
ODROP	If sense switch one is on, the run makes a restart dump and terminates.

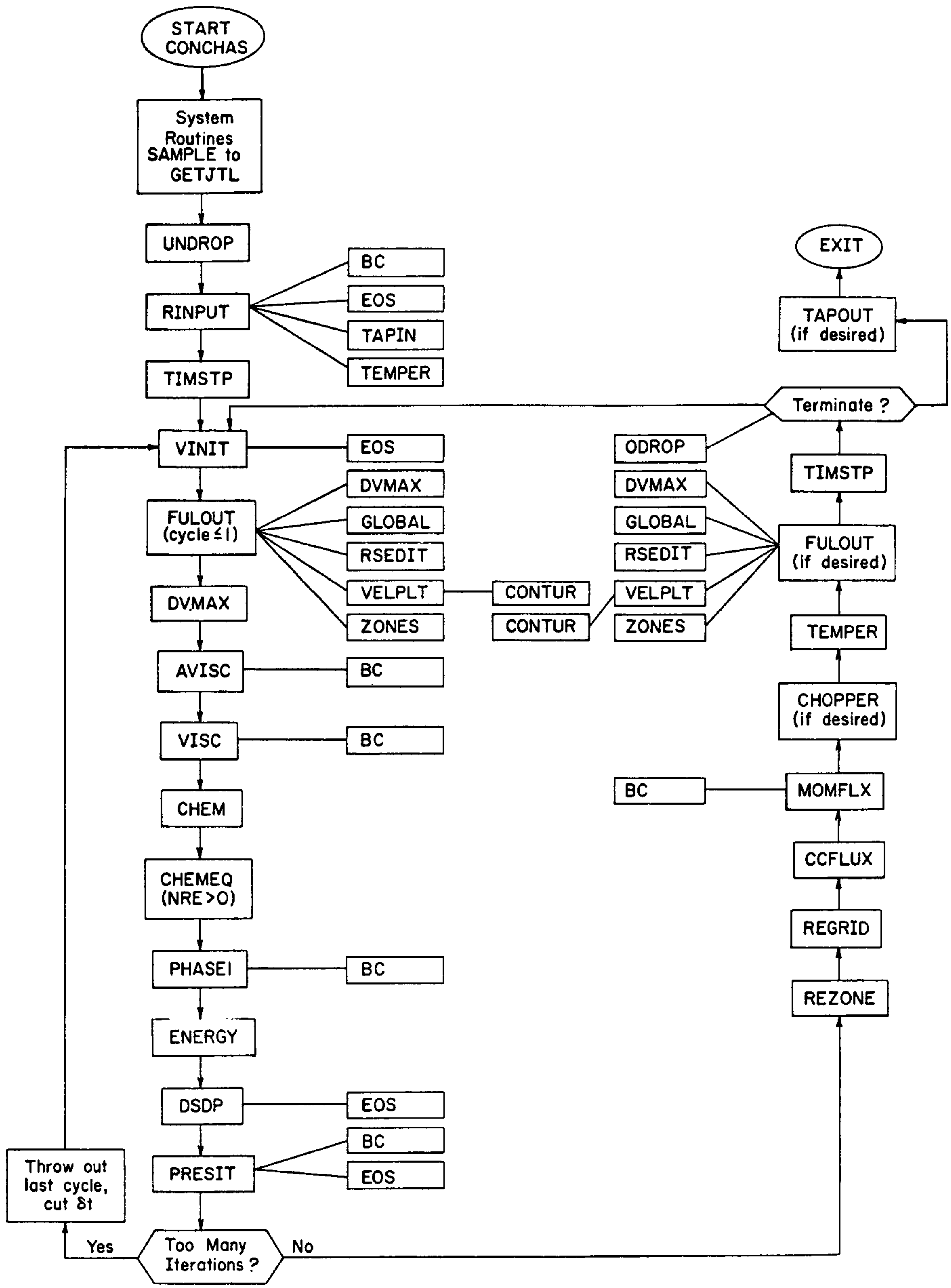

Fig. 4. CONCHAS flow chart.

PHASE1 Does explicit pressure gradients and body forces.

PRESIT Does the phase II pressure iteration; sets the final Lagrangian pressure, species densities, and velocities.

REGRID Computes new vertex positions and the relative velocity of the gas and the grid.

REZONE Computes the grid velocity for phase III.

RINPUT Reads data deck; initializes all variables using data cards and either a user-supplied routine to start a problem or a tape dump.

RSEDIT Prints the output on film and paper.

TAPIN Reads in restart tape, if one is used.

TAPOUT Writes the restart tape, if one is wanted.

TEMPER Computes c_v and T.

TIMSTP Computes Δt for the next cycle.

UNDROP System-dependent routine for initializing the film file.

VELPLT Draws the velocity plot; then calls CONTUR.

VINIT Swaps new time values into old time arrays prior to beginning a new cycle; calls EOS to update the pressure.

VISC Computes all viscous terms plus species, enthalpy, and temperature diffusion.

ZONES Draws the mesh on the film file.

B. Non-Universal System Routines

ADV(n) Advances film n frames.

$DRV(I_1,J_1,I_2,J_2)$ Draws a straight line between SC-4020 coordinates (I_1,J_1) and (I_2,J_2). The upper left hand corner of the frame is (0,0), and the lower right hand corner is (1023,1023).

GETJTL Returns job time limit in seconds.

LINCNT(n) Prints the next line on current film frame on line n (modulo 64).

PLT(i,j,k) Plots a character specified by the code number k at SC-4020 coordinates (i,j). Used in CONTUR to label the high and low contours with H and L respectively.

QEXP Quick exponential, gives 6 digits accuracy instead of 13, but much faster than EXP. Can replace with EXP.

QLOG Quick natural logarithm. Can replace with ALOG.

QSQRT Quick square root. Can replace with SQRT.

SAMPLE SAMPON SAMPTRM SETTERM	Routines to take timing statistics. May be deleted.
SSWTCH(1,J)	Tests sense switch one to see if it is on (J = 1) or off.

C. The Data Deck

The input data for CONCHAS is named CNDAT on LTSS, and is equivalenced to TAPE5 on the PROGRAM card. With the exception of some of the reaction data, there is only one variable on each card or card image. This arrangement has been found convenient on LTSS where a text editor is used to maintain the disk files. A brief definition of each input variable is given below.

NAME	An 8-word array containing a problem label.
NSP	Number of species for the first run of a problem; set to zero to force reading of a restart dump on subsequent runs.
NR	Number of reactions for the first run, thereafter the sequence number of the desired restart dump.
NFOUT	Number of cycles between output dumps on film.
NPOUT	Number of cycles between output dumps on paper.
LPR	0, suppresses all numerical output; 1, write numerical output only on film; 2, write on film and paper.
ITMAX	Maximum number of pressure iterations.
NX	Number of cells in the x-direction.
NY	Number of cells in the y-direction.
NRE	The number of equilibrium chemical reactions.
EPSCHM	Convergence criterion for the equilibrium chemistry iteration.
OMGCHM	Overrelaxation parameter for the equilibrium chemistry iteration.
XKD	The parameter k_D in the SGS eddy viscosity.
DX	Δx.
DY	Δy.
XIGNIT	Ignition parameter - see listing of subroutine CHEM for usage.
SIEI	Initial temperature.

OM	Overrelaxation parameter, ω.
PEPS	A parameter used by subroutine DSDP to compute $\partial V_{ij}/\partial p_{ij}$; typically equal to 10^{-4}.
EPS	The convergence parameter for the pressure iteration, ε.
AZFAC	The parameter χ, typically 0.1 - 0.2 (See Eq. (111)).
NCLAST	Number of cycles to be computed.
NOL	0, no obstacle; otherwise, the i of the column of vertices defining the left side of the obstacle.
NOR	0, no obstacle; otherwise, the i of the column of vertices defining the right side of the obstacle.
NOB	0, no obstacle; otherwise, the j of the row of vertices defining the bottom of the obstacle.
NOT	0, no obstacle; otherwise, the j of the row of vertices defining the top of the obstacle.
ITMIN	If the number of iterations is below ITMIN, Δt is increased.
AO	Fraction of convective momentum flux calculated with donor cell differencing; α_{OM} of Ref. 11.
BO	Fraction of all convective fluxes calculated with interpolated donor cell differencing; β_o of Ref. 11.
AOM	Fraction of convective flux of species densities and energy calculated with donor cell differencing; α_0 of Ref. 11.
IREZ	Rezone option: 0, Eulerian; 1, Lagrangian; 2, arbitrary user-supplied rezone algorithm in subroutine REZONE.
LAMZER	Artificial viscosity parameter, λ_o.
DTMAX	Maximum allowable time step.
DT	Initial Δt.
CYL	0, Cartesian coordinate; 1, cylindrical coordinates.
ANC	Node coupler coefficient, A_{NC}.
RGAS	Universal gas constant in the desired units; $R_g = 8.3143 \times 10^7$ in CGS units.
RPM	Engine revolutions per minute.
STROKE	Piston stroke.

ABDC	Piston is initially located ABDC degrees after bottom dead center.
GX	External acceleration in the x-direction.
GY	External acceleration in the y-direction.
XMUO	Kinematic viscosity.
RPR	A reciprocal Prandtl number, $K/c_v\mu$.
RSC	Reciprocal Schmidt number, $\rho D/\mu$.
DISS	On-off switch for viscous dissipation terms in the energy equation: 0, off; 1, on.
TCUT	If T is less than TCUT, the chemistry package is bypassed.
SWIRL	0, the swirl equation is bypassed; 1, the azimuthal velocity is calculated.
ANGVEL	Initial angular velocity of the fluid. Used only in RINPUT.
TBDDY	Boundary temperature if a fixed-temperature boundary is used.
ADIA	0, the fixed-temperature boundary capability in VISC is used; 1, the boundaries are adiabatic.
AIRMU	0, no molecular air viscosity is included in XMU; 1, air viscosity is included in XMU.

Next is a sequence of four cards for each species:

RHOI(K)	Initial value of the density of species k.
GAMMA(K)	Ratio of specific heats for species k, $\gamma_k = c_{pk}/c_{vk}$.
WT(K)	Molecular weight of species k, μ_k.
HTF(K)	Heat of formation at 0°K in kcal/mole.

Next we have the following sequence of cards for each reaction:

CF(L)	The forward rate coefficient, A_{fr}, for reaction L.
EF(L)	The forward activation temperature, E^+_{fr}.
ZETAF(L)	The forward temperature exponent, ζ_{fr}.
CB(L)	The backward rate coefficient, A_{br}.
EB(L)	The backward activation temperature, E^+_{br}.
ZETAB(L)	The backward temperature exponent, ζ_{br}.
AM(K,L)	The stoichiometric coefficient of species K on the left side of kinetic reaction L, a_{KL}.
BM(K,L)	The stoichiometric coefficient of species K on the right side of kinetic reaction L, b_{KL}.

AE(K,L)	The exponent of species K in the foward rate of reaction L, a'_{KL}.
BE(K,L)	The exponent of species K in the backward rate of reaction L, b'_{KL}.

Next we have a series of input cards for each equilibrium reaction.

AS(L), BS(L), CS(L), DS(L), ES(L)	Coefficients A_r, B_r, C_r, D_r, E_r, in functional form of equilibrium constant, see Eq. (24).
AN(K,L)	The stoichiometric coefficient of species K on the left side of equilibrium reaction L.
BN(K,L)	The stoichiometric coefficient of species K on the right side of equilibrium reaction L.

Finally, the last card contains NCHOP, the number of axial zones in the squish region when the piston reaches top dead center.

D. Other Important Variables

In addition to the variables listed in the data file, there are a number of others that should be defined. This list is not intended to be complete, but it is sufficient to enable the user to read and understand the program.

RWT(K)	Reciprocal molecular weight.
X(IJ)	X-values of vertex positions.
Y(IJ)	Y-values of vertex positions.
R(IJ)	1 if CYL = 0; X if CYL = 1.
P(IJ)	Pressure.
XMU(IJ)	Coefficient of viscosity, μ.
TCUTE	Cutoff temperature for the equilibrium chemistry package.
COND(IJ)	Thermal conductivity, K.
TEM(IJ)	Temperature, T.
EK(K)	Partial specific enthalpy (input) and energy (later) of species k.
RO(IJ)	Cell density, ρ.
SIE(IJ)	Specific internal energy, I.
U(IJ),UL(IJ)	Velocity component in the x-direction, u_{ij}.

V(IJ),VL(IJ)	Velocity component in the y-direction, v_{ij}.
W(IJ),WL(IJ)	Velocity component in the θ-direction, w_{ij}.
VOL(IJ)	Cell volume, V_{ij}.
MV(IJ)	Half the vertex mass, $\frac{1}{2}M_{ij}$.
MC(IJ)	Cell mass, M_{ij}.
NXP	NX + 1, the number of vertices in each row.
NYP	NY + 1, the number of vertices in each column.
SPD(IJ,K)	Species density, $(\rho_k)_{ij}$.
SPM(IJ,K)	Species mass, $(M_k)_{ij}$.
CV(K)	Species specific heat at constant volume, c_{vk}.
CVT(IJ)	Mixture specific heat at constant volume, c_v.
UREL(IJ),VREL(IJ)	Relative velocity between the gas and the grid, $(u-b_x, v-b_y)$.
PL(IJ)	Pressure at the end of phase II, p^B_{ij}.
ROL(IJ)	Density at the end of phase II, ρ^B_{ij}.
UG(IJ),VG(IJ)	Grid velocity in the laboratory frame, (b_x,b_y).

Please note that some variables change meaning during the cycle.

V. SAMPLE PROBLEMS

The first sample problem was run using the program in Appendix A and the data deck in Appendix B. Selected results are displayed in Appendix C exactly as they came out of the computer. This problem ran 200 cycles in 130 seconds, and it is suitable for checking out new copies of CONCHAS. The problem involves a piston just before top dead center compressing a homogeneous flammable mixture. The mixture is ignited at the upper left hand corner of the mesh, and the flame is followed until the fuel is exhausted. This problem is not intended to represent any real device and the zoning is very coarse, so no physical discussion of the results will be presented. It is intended strictly as a test case that uses most of the options in the program.

This problem involves 12 species among which occur three kinetic reactions and six equilibrium reactions. The kinetic reactions are

This problem involves 12 species among which occur three kinetic reactions and six equilibrium reactions. The kinetic reactions are

$$2C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O \quad ,$$

$$N + O_2 \rightleftarrows NO + O,$$

$$O + N_2 \rightleftarrows NO + N \quad .$$

The first reaction is a single-step octane oxidation reaction, and the last two reactions represent the simplified Zel'dovich mechanism for NO production. The equilibrium reactions are

$$H_2 \rightleftarrows 2H \quad ,$$

$$O_2 \rightleftarrows 2O \quad ,$$

$$N_2 \rightleftarrows 2N \quad ,$$

$$O_2 + H_2 \rightleftarrows 2OH \quad ,$$

$$2H_2O + O_2 \rightleftarrows 4OH \quad ,$$

$$O_2 + 2CO \rightleftarrows 2CO_2 \quad .$$

The rate coefficients for the former reactions and the equilibrium constants for the latter reactions may be reconstructed easily from the data deck. The coefficients in the equilibrium constant fits were obtained from the corresponding coefficients of Olikara and Borman.[32]

The second problem is a gas jet, which illustrates the use of an inflow boundary condition. The jet material is pure octane (species 1). Again, no particular device or experiment is being modeled, and no discussion of the physics will be presented. Appendix D contains the code modifications necessary to run this problem, the data deck, and selected graphical output from the calculation.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the contributions of various members of group T-3, especially Hans Ruppel. He wrote the basic first version of a simplified YAQUI program, called SALE,[33] which provided the foundation for CONCHAS. He and Tony Amsden contributed significantly to the development of CONCHAS as they continued the development of SALE.

REFERENCES

1. R. W. F. Gross and J. F. Bott, eds., Handbook of Chemical Lasers (Wiley-Interscience, New York, 1976).

2. J. D. Ramshaw, R. C. Mjolsness, and O. A. Farmer, J. Quant. Spectrosc. Radiat. Transfer 17, 149 (1977).

3. J. N. Mattavi and C. A. Amann, eds., Combustion Modeling in Reciprocating Engines (International Symposium at General Motors Research Laboratories, Warren, Michigan, 6-7 November, 1978, proceedings to be published).

4. Sixteenth Symposium (International) on Combustion (The Combustion Institute, 1976).

5. F. H. Harlow and A. A. Amsden, J. Comp. Phys. 3, 80 (1968).

6. F. H. Harlow and A. A. Amsden, J. Comp. Phys. 8, 197 (1971).

7. F. H. Harlow, A. A. Amsden, and C. W. Hirt, "Numerical Calculation of Fluid Flows at Arbitrary Mach Number," Proc. Intern. Conf. Numerical Methods in Fluid Dynamics, 2nd, University of California, Berkeley, September 15-19, 1970 (Springer-Verlag, 1971), p. 447.

8. J. G. Trulio, "Theory and Structure of the AFTON Codes," Air Force Weapons Laboratory report AFWL-TR-66-19 (June 1966).

9. C. W. Hirt, "An Arbitrary Lagrangian-Eulerian Computing Technique," Proc. Intern. Conf. Numerical Methods in Fluid Dynamics, 2nd, University of California, Berkeley, September 15-19, 1970 (Springer-Verlag, 1971), p. 350.

10. C. W. Hirt, A. A. Amsden, and J. L. Cook, J. Comp. Phys. 14, 227 (1974).

11. A. A. Amsden and C. W. Hirt, "YAQUI: An Arbitrary Lagrangian-Eulerian Computer Program for Fluid Flow at All Speeds," Los Alamos Scientific Laboratory report LA-5100 (March 1973).

12. W. E. Pracht, J. Comp. Phys. 17, 132 (1975).

13. W. E. Pracht and J. U. Brackbill, "BAAL: A Code for Calculating Three-Dimensional Fluid Flows at All Speeds with an Eulerian-Lagrangian Computing Mesh," Los Alamos Scientific Laboratory report LA-6342 (August 1976).

14. L. R. Stein, R. A. Gentry, and C. W. Hirt, Comp. Meth. Appl. Mech. Eng. 11, 57 (1977).

15. J. N. Tunstall, "On the Derivation of Conservative Finite-Difference Expressions for the Navier-Stokes Equations," Union Carbide Corporation, Nuclear Division report K/CSD-5, Oak Ridge, Tenn. (April 1977).

16. W. C. Rivard, T. D. Butler, and O. A. Farmer, "The Transient Dynamics of Chemically Reactive Gaseous Mixtures with Turbulence," Proc. Intern. Conf. Numerical Methods in Fluid Dynamics, 4th, University of Colorado, June 24-28, 1974 (Spinger-Verlag, 1975), p. 334.

17. W. C. Rivard, O. A. Farmer, and T. D. Butler, "RICE: A Computer Program for Multicomponent Chemically Reactive Flows at All Speeds," Los Alamos Scientific Laboratory report LA-5812 (March 1975).

18. W. C. Rivard, O. A. Farmer, T. D. Butler, and P. J. O'Rourke, "A Method for Increased Accuracy in Eulerian Fluid Dynamics Calculations," Los Alamos Scientific Laboratory report LA-5426-MS (October 1973).

19. T. D. Butler and P. J. O'Rourke, "A Numerical Method for Two-Dimensional Unsteady Reacting Flows," Proc. Intern. Symp. Combustion, 16th, Massachusetts Institute of Technology, August 15-20, 1976 (The Combustion Institute, 1977) p. 1503.

20. J. D. Ramshaw and J. K. Dukowicz, "APACHE: A Generalized-Mesh Eulerian Computer Code for Multicomponent Chemically Reactive Fluid Flow," Los Alamos Scientific Laboratory report LA-7427 (January 1979).

21. C. W. Hirt, B. D. Nichols, and N. C. Romero, "SOLA - A Numerical Solution Algorithm for Transient Fluid Flows," Los Alamos Scientific Laboratory report LA-5852 (April 1975).

22. L. D. Cloutman, C. W. Hirt, and N. C. Romero, "SOLA-ICE: A Numerical Solution Algorithm for Transient Compressible Fluid Flows," Los Alamos Scientific Laboratory report LA-6236 (July 1976).

23. R. Aris, Vectors, Tensors, and the Basic Equations of Fluid Mechanics (Prentice-Hall, 1962).

24. P. A. Thompson, Compressible-Fluid Dynamics (McGraw-Hill, New York, 1972).

25. R. D. Richtmyer and K. W. Morton, Difference Methods for Initial-Value Problems, 2nd ed. (Wiley/Interscience, 1967).

26. P. J. Roache, Computational Fluid Dynamics (Hermosa Publishers, Albuquerque, New Mexico, 1972).

27. D. R. Stull and H. Prophet, "JANAF Thermochemical Tables," 2nd ed. (U.S. Department of Commerce/National Bureau of Standards, NSRDS-NBS 37, June 1971); M. W. Chase et al., J. Phys. Chem. Ref. Data 3, 311 (1974).

28. J. U. Brackbill and L. G. Margolin, "An Algorithm for the Computation of Nonlinear Electron Thermal Conduction on an Arbitrarily Shaped Two-Dimensional Domain," Los Alamos Scientific Laboratory report LA-6964-MS (October 1977).

29. J. D. Ramshaw and L. D. Cloutman, "Numerical Method for Partial Equilibrium Flow," J. Comp. Phys. (submitted for publication).

30. J. W. Deardorff, J. Comp. Phys. 7, 120 (1971).

31. J. D. Ramshaw, "Alternate Interpretation of the Subgrid Scale Eddy Viscosity," Los Alamos Scientific Laboratory report LA-7955-MS (August 1979).

32. C. Olikara and G. L. Borman, "A Computer Program for Calculating Properties of Equilibrium Combustion Products with Some Applications to I. C. Engines," SAE Paper Number 750468 (1975).

33. A. A. Amsden, H. M. Ruppel, and C. W. Hirt, "SALE: A Simplified Computer Program for Fluid Flow at All Speeds," Los Alamos Scientific Laboratory report, in preparation.

LASL Identification No. LP-1028

APPENDIX A

CONCHAS CODE LISTING

```
 PROGRAM CONCHAS (CNDAT,TAPE5=CNDAT,TAPE6,TTY,TAPE59=TTY,TAPE7)    CONCH  2
 PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
 COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                              COMD   3
 COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,   COMD   4
1 EPSCHM                                                            COMD   5
 LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                              COMD   6
 COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP           COMD   7
 COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                        COMD   8
 LEVEL 2, PSD, DELP                                                 COMD   9
 COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                                COMD  10
 LEVEL 2, XMU, COND, TEM, HK                                        COMD  11
 COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)               COMD  12
 COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                             COMD  13
 COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)    COMD  14
 LEVEL 2, VOL, MV, MC                                               COMD  15
 COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                           COMD  16
 LEVEL 2, SPD, SPM                                                  COMD  17
 COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                           COMD  18
 COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),  COMD  19
1 RHOI(NSQ)                                                         COMD  20
 LEVEL 2, CVT                                                       COMD  21
 COMMON /KAH8/ CVT(NXQ)                                             COMD  22
 LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                      COMD  23
 COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),         COMD  24
1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                      COMD  25
 LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                            COMD  26
 COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                  COMD  27
 COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),       COMD  28
1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),  COMD  29
2 Q(NXQ)                                                            COMD  30
 COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX       COMD  32
 COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,   COMD  33
1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),    COMD  34
2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,   COMD  36
4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ            COMD  37
 COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)             COMD  38
 COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),   COMD  40
```

```
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      EXTERNAL SAMPTRM                                                  CONCH  4
      DATA NCYC, T /0,0./                                               CONCH  5
      DATA PI /3.14159265358 98/                                        CONCH  6
      DATA TQUIT, GRIND, ILIM /120.,0.,1H /                             CONCH  7
      DATA WORK /0./                                                    CONCH  8
      DATA TIME /0.0/                                                   CONCH  9
C +++                                                                   CONCH 10
C +++ INITIALIZATION                                                    CONCH 11
C +++                                                                   CONCH 12
      CALL GETJTL (TTL)                                                 CONCH 16
      CALL UNDROP                                                       CONCH 17
      WRITE (6,30)                                                      CONCH 18
      WRITE (12,30)                                                     CONCH 19
      CALL RINPUT                                                       CONCH 20
      CALL TIMSTP                                                       CONCH 21
      DTOLD=DT                                                          CONCH 22
      LOOPX=0                                                           CONCH 23
C +++                                                                   CONCH 24
C +++ BEGIN HYDRO LOOP                                                  CONCH 25
C +++                                                                   CONCH 26
   10 CALL VINIT                                                        CONCH 27
      LL=(NY-1)*NXP+NX                                                  CONCH 28
      IF (NCYC.LT.2) CALL FULOUT (0)                                    CONCH 29
      CALL DVMAX (0)                                                    CONCH 30
      IF (MOD(NCYC,NFOUT).EQ.0) WRITE (59,40) NCYC,DTOLD,T,NUMIT,GRIND  CONCH 31
     1 ,YPISTON,VPISTON,P(LL),ILIM                                      CONCH 32
      WRITE (6,40) NCYC,DTOLD,T,NUMIT,GRIND,YPISTON,VPISTON,P(LL),ILIM  CONCH 33
      WRITE (12,40) NCYC,DTOLD,T,NUMIT,GRIND,YPISTON,VPISTON,P(LL),ILIM CONCH 34
      DTOLD=DT                                                          CONCH 35
      NCYC=NCYC+1                                                       CONCH 36
      T=T+DT                                                            CONCH 37
      YPISTON=YPIST(NXP)+0.5*STROKE*(1.-COS(PI*RPM*T/30.+ABDC*PI/180.)) CONCH 38
```

```
      VPISTON=(STROKE*PI*RPM/60.)*SIN(PI*RPM*T/30.+ABDC*PI/180.)
      CALL AVISC
      CALL VISC
      CALL CHEM
      IF (NRE.GT.0) CALL CHEMEQ
      CALL PHASE1
      CALL ENERGY
      CALL DSDP
      CALL PRESIT
      IF (ILNGPI.EQ.0) GO TO 20
      T=T-DT
      DT=DT*0.75
      DTMAX=DTMAX*0.75
      DTSAV=DT
      DTOLD=DT
      WRITE (59,60) DT,NCYC
      WRITE (12,60) DT,NCYC
      WRITE (6,60) DT,NCYC
      LOOPX=LOOPX+1
      IF (LOOPX.EQ.20) CALL EXIT
      NCYC=NCYC-1
      GO TO 10
   20 CONTINUE
      WORK=WORK+DT*VPISTON*P(1)*PI*X(NXP)*X(NXP)
      CALL REZONE
      CALL REGRID
      CALL CCFLUX
      CALL MOMFLX
      IF (VPISTON.GT.0..AND.Y(NXP*NYP)-Y(NXP*NY).LE.DYCHOP) CALL CHOPPER
     1 (-1)
      IF (VPISTON.LT.0..AND.Y(NXP*NYP)-Y(NXP*NY).GT.FCHOP*DYCHOP) CALL
     1 CHOPPER (1)
      CALL TEMPER
      LOOPX=0
      IF (MOD(NCYC,NPOUT)*MOD(NCYC,NFOUT).EQ.0) CALL FULOUT (0)
      GRIND=TIME
      CALL SECOND (TIME)
      GRIND=(TIME-GRIND)*1000./FLOAT(NX*NY)
      TLEFT=TTL-TIME-TQUIT
      CALL DDROP (TLEFT)
```

```
      IF (TLEFT.LT.0.0) CALL TAPOUT
      CALL TIMSTP
      IF (NCYC.LT.NCLAST) GO TO 10
      WRITE (59,40) NCYC,DTOLD,T
      WRITE (6,40) NCYC,DTOLD,T
      WRITE (12,40) NCYC,DTOLD,T
      WRITE (59,50)
      CALL EXIT
C +++
C +++ FORMAT BLOCK
C +++
C
   30 FORMAT (15X,45HCONCHAS TWO DIMENSIONAL HYDRODYNAMICS PROGRAM//)
   40 FORMAT (1X,6HNCYC =,I5,1X,4HDT =,1PE14.6,1X,3HT =,E14.6,1X,7HNUMIT
     1 =,I4,1X,7HGRIND =,0PF6.2/5X,11HY(PISTON) =,1PE12.4,1X,11HV(PISTON
     2) =,E12.4,1X,10HPRESSURE =,E12.4,1X,A1)
   50 FORMAT (2X,18HNORMAL TERMINATION)
   60 FORMAT (2X,35HITERATION DID NOT CONVERGE DT NEW =,1PE12.4,1X,6HNCY
     1C =,I6)
      END


      SUBROUTINE AVISC
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,
     1 EPSCHM
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC
      LEVEL 2, PSD, DELP
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)
      LEVEL 2, XMU, COND, TEM, HK
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)
      LEVEL 2, VOL, MV, MC
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)
      LEVEL 2, SPD, SPM
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)
```

```
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEQ(NERQ)
      INTEGER AN, BN, CN
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
      DIMENSION RDSDP(1), RMV(1)
      EQUIVALENCE (UG,RDSDP), (RMV,E)
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP
C +++
C +++ QUADRATIC ARTIFICIAL VISCOUS PRESSURE
C +++
      IF (LAMZER.LE.0.) GO TO 60
      DO 20 J=1,NY
      IJ=(J-1)*NXP+1
      IJP=IJ+NXP
      DO 10 I=1,NX
      IPJ=IJ+1
      IPJP=IJP+1
```

```
      X1=X(IPJ)
      Y1=Y(IPJ)
      U1=UL(IPJ)
      V1=VL(IPJ)
      X2=X(IPJP)
      Y2=Y(IPJP)
      U2=UL(IPJP)
      V2=VL(IPJP)
      X3=X(IJP)
      Y3=Y(IJP)
      U3=UL(IJP)
      V3=VL(IJP)
      X4=X(IJ)
      Y4=Y(IJ)
      U4=UL(IJ)
      V4=VL(IJ)
      AREA=0.5*((X2-X4)*(Y3-Y1)-(X1-X3)*(Y4-Y2))
      RAREA=1./AREA
      DUDX=0.5*RAREA*((U2-U4)*(Y3-Y1)-(U1-U3)*(Y4-Y2))
      DVDY=0.5*RAREA*((V4-V2)*(X3-X1)-(V1-V3)*(X2-X4))
      UOR=(U1+U2+U3+U4)/(R(IPJ)+R(IPJP)+R(IJP)+R(IJ))
      A=DUDX+DVDY+UOR*CYL
      Q(IJ)=LAMZER*RO(IJ)*AREA*A*AMIN1(A,0.)
      IJP=IJP+1
   10 IJ=IJ+1
   20 CONTINUE
      DO 50 J=1,NY
      IJ=(J-1)*NXP+1
      IJP=IJ+NXP
      DO 40 I=1,NX
      IPJ=IJ+1
      IPJP=IJP+1
      XX=0.5*DT*Q(IJ)
      RM1=1.0/MV(IPJ)
      RM2=1.0/MV(IPJP)
      RM3=1.0/MV(IJP)
      RM4=1.0/MV(IJ)
      Y24=Y(IPJP)-Y(IJ)
      Y31=Y(IJP)-Y(IPJ)
      X24=X(IPJP)-X(IJ)
```

```
      X31=X(IJP)-X(IPJ)
      R1=R(IPJ)
      R2=R(IPJP)
      R3=R(IJP)
      R4=R(IJ)
      R24=0.5*(R2+R4)
      R31=0.5*(R3+R1)
      UL(IPJ)=UL(IPJ)+XX*RM1*R(IPJ)*(Y(IPJP)-Y(IJ))
      UL(IPJP)=UL(IPJP)+XX*RM2*R(IPJP)*(Y(IJP)-Y(IPJ))
      UL(IJP)=UL(IJP)+XX*RM3*R(IJP)*(Y(IJ)-Y(IPJP))
      UL(IJ)=UL(IJ)+XX*RM4*R(IJ)*(Y(IPJ)-Y(IJP))
      R24=R(IPJ)
      R31=R(IPJP)
      VL(IPJ)=VL(IPJ)-XX*RM1*X24*R24
      VL(IPJP)=VL(IPJP)-XX*RM2*X31*R31
      R24=R(IJP)
      R31=R(IJ)
      IF (I.NE.1) GO TO 30
      REXTR=R24+R24-R(IPJP)
      IF (REXTR.LT.0.) R24=0.5*(R(IPJP)+R24)
      REXTR=R31+R31-R(IPJ)
      IF (REXTR.LT.0.) R31=0.5*(R(IPJ)+R31)
   30 CONTINUE
      VL(IJP)=VL(IJP)+XX*RM3*X24*R24
      VL(IJ)=VL(IJ)+XX*RM4*X31*R31
      IJP=IJP+1
   40 IJ=IJ+1
   50 CONTINUE
      CALL BC (UL,VL,WL)
      GO TO 80
   60 CONTINUE
      IJP=NXP*NY
      DO 70 IJ=1,IJP
   70 Q(IJ)=0.
   80 CONTINUE
C +++
C +++ NODE COUPLER
C +++
      IF (ANC.LE.0.) RETURN
      DO 100 J=1,NY
```

```
      DO 90 I=1,NX                                                      AVISC 94
      IJP=J*NXP+I                                                       AVISC 95
      IJ=IJP-NXP                                                        AVISC 96
      IPJ=IJ+1                                                          AVISC 97
      IPJP=IJP+1                                                        AVISC 98
      AX=ANC*(U(IPJ)+U(IJP)-U(IJ)-U(IPJP))                              AVISC 99
      AY=ANC*(V(IPJ)+V(IJP)-V(IJ)-V(IPJP))                              AVISC100
      UL(IJ)=UL(IJ)+AX                                                  AVISC101
      VL(IJ)=VL(IJ)+AY                                                  AVISC102
      UL(IPJ)=UL(IPJ)-AX                                                AVISC103
      VL(IPJ)=VL(IPJ)-AY                                                AVISC104
      UL(IPJP)=UL(IPJP)+AX                                              AVISC105
      VL(IPJP)=VL(IPJP)+AY                                              AVISC106
      UL(IJP)=UL(IJP)-AX                                                AVISC107
      VL(IJP)=VL(IJP)-AY                                                AVISC108
   90 CONTINUE                                                          AVISC109
  100 CONTINUE                                                          AVISC110
      CALL BC (UL,VL,WL)                                                AVISC111
      RETURN                                                            AVISC112
      END                                                               AVISC113
```

```
      SUBROUTINE BC (UX,VX,WX)                                          BC     2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
```

```
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      DIMENSION UX(1), VX(1), WX(1)                                     BC     4
C +++                                                                   BC     5
C +++ SET VELOCITY BOUNDARY CONDITIONS.                                 BC     6
C +++ TOP, RIGHT, AND BOTTOM BOUNDARIES ARE NO-SLIP.                    BC     7
C +++ LEFT BOUNDARY IS FREE-SLIP (AXIS OF SYMMETRY).                    BC     8
C +++ SEE SUBROUTINES DSDP AND PRESIT FOR MORE BOUNDARY CONDITIONS.     BC     9
C +++ IT WAS NECESSARY TO PUT SOME CODING IN-LINE FOR EFFICIENCY        BC    10
C +++ IN THE PRESSURE ITERATION.                                        BC    11
```

```
C +++                                                              BC      12
      DO 10 J=1,NYP                                                BC      13
      IJ=(J-1)*NXP+1                                               BC      14
      UX(IJ)=0.                                                    BC      15
      UX(IJ+NX)=0.                                                 BC      16
      VX(IJ+NX)=0.                                                 BC      17
      WX(IJ)=0.                                                    BC      18
      WX(IJ+NX)=0.                                                 BC      19
   10 IJ=IJ+1                                                      BC      20
      DO 20 I=1,NXP                                                BC      21
      IJ1=I                                                        BC      22
      IJ2=NY*NXP+I                                                 BC      23
      VX(IJ1)=VPISTON                                              BC      24
      UX(IJ1)=0.                                                   BC      25
      WX(IJ1)=0.                                                   BC      26
      VX(IJ2)=0.                                                   BC      27
      UX(IJ2)=0.                                                   BC      28
      WX(IJ2)=0.                                                   BC      29
   20 CONTINUE                                                     BC      30
      IF (NOL.LE.0) GO TO 40                                       BC      31
      DO 30 J=NOB,NOT                                              BC      32
      IJ=(J-1)*NXP+NOL-1                                           BC      33
      DO 30 I=NOL,NOR                                              BC      34
      IJ=IJ+1                                                      BC      35
      UX(IJ)=0.                                                    BC      36
      VX(IJ)=VPISTON                                               BC      37
      WX(IJ)=0.                                                    BC      38
   30 CONTINUE                                                     BC      39
   40 CONTINUE                                                     BC      40
      RETURN                                                       BC      41
      END                                                          BC      42


      SUBROUTINE CCFLUX                                            CCFLUX 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                   COMD    2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                        COMD    3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD    4
```

```
1 EPSCHM                                                              COMD
 LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                                COMD
 COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP             COMD
 COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                          COMD
 LEVEL 2, PSD, DELP                                                   COMD
 COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                                  COMD
 LEVEL 2, XMU, COND, TEM, HK                                          COMD
 COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)                 COMD
 COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                               COMD
 COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)      COMD
 LEVEL 2, VOL, MV, MC                                                 COMD
 COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                             COMD
 LEVEL 2, SPD, SPM                                                    COMD
 COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                             COMD
 COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),    COMD
1 RHOI(NSQ)                                                           COMD
 LEVEL 2, CVT                                                         COMD
 COMMON /KAH8/ CVT(NXQ)                                               COMD
 LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                        COMD
 COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),           COMD
1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                        COMD
 LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                              COMD
 COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                    COMD
 COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),         COMD
1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),    COMD
2 Q(NXQ)                                                              COMD
 COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD
1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX         COMD
 COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,     COMD
1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),      COMD
2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD
3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,     COMD
4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ              COMD
 COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)               COMD
 COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD
1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),     COMD
2 QEQ(NERQ)                                                           COMD
 INTEGER AN, BN, CN                                                   COMD
 COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),     COMD
1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD
```

```
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)       COMD  45
      DIMENSION RDSDP(1), RMV(1)                                         COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                    COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                        COMD  48
      DIMENSION AT(100), FT(100)                                         CCFLUX 4
C +++                                                                   CCFLUX 5
C +++ PHASE III.  FLUXING OF CELL CENTERED QUANTITIES                    CCFLUX 6
C +++                                                                   CCFLUX 7
      DO 30 J=1,NY                                                       CCFLUX 8
      IJ=(J-1)*NXP+1                                                     CCFLUX 9
      IJP=IJ+NXP                                                         CCFLUX10
      IJM=IJ-NXP                                                         CCFLUX11
      DO 20 I=1,NX                                                       CCFLUX12
      IMJ=IJ-1                                                           CCFLUX13
      IPJ=IJ+1                                                           CCFLUX14
      IPJP=IJP+1                                                         CCFLUX15
      X1=X(IPJ)                                                          CCFLUX16
      Y1=Y(IPJ)                                                          CCFLUX17
      R1=R(IPJ)                                                          CCFLUX18
      X2=X(IPJP)                                                         CCFLUX19
      Y2=Y(IPJP)                                                         CCFLUX20
      R2=R(IPJP)                                                         CCFLUX21
      X3=X(IJP)                                                          CCFLUX22
      Y3=Y(IJP)                                                          CCFLUX23
      R3=R(IJP)                                                          CCFLUX24
      X4=X(IJ)                                                           CCFLUX25
      Y4=Y(IJ)                                                           CCFLUX26
      R4=R(IJ)                                                           CCFLUX27
      XP1=X1-UREL(IPJ)*DT                                                CCFLUX28
      XP2=X2-UREL(IPJP)*DT                                               CCFLUX29
      XP3=X3-UREL(IJP)*DT                                                CCFLUX30
      XP4=X4-UREL(IJ)*DT                                                 CCFLUX31
      YP1=Y1-VREL(IPJ)*DT                                                CCFLUX32
      YP2=Y2-VREL(IPJP)*DT                                               CCFLUX33
      YP3=Y3-VREL(IJP)*DT                                                CCFLUX34
      YP4=Y4-VREL(IJ)*DT                                                 CCFLUX35
      RP1=XP1*CYL+OMCYL                                                  CCFLUX36
      RP2=XP2*CYL+OMCYL                                                  CCFLUX37
      RP3=XP3*CYL+OMCYL                                                  CCFLUX38
      RP4=XP4*CYL+OMCYL                                                  CCFLUX39
```

```
      VOLR=VOL(IJ)                                                      CCFLUX40
      VOLT=VOL(IJ)                                                      CCFLUX41
      VOLC=VOL(IJ)                                                      CCFLUX42
      IF (I.NE.NX) VOLR=VOL(IPJ)                                        CCFLUX43
      IF (J.NE.NY) VOLT=VOL(IJP)                                        CCFLUX44
      FLL=-FR                                                           CCFLUX45
      AL=-AR                                                            CCFLUX46
      IF (I.EQ.1) FLL=AL=0.                                             CCFLUX47
      FB=-FT(I)                                                         CCFLUX48
      AB=-AT(I)                                                         CCFLUX49
      IF (J.EQ.1) FB=AB=0.                                              CCFLUX50
      FR=((XP1*(Y1-YP2)+X1*(YP2-YP1)+XP2*(YP1-Y1))*(RP1+R1+RP2)+(X1*(Y2 CCFLUX51
     1 -YP2)+X2*(YP2-Y1)+XP2*(Y1-Y2))*(R1+R2+RP2))*TWLFTH               CCFLUX52
      AR=AOM*SIGN(1.,FR)+BO*4.*FR/(VOLR+VOLC)                           CCFLUX53
      FT(I)=((XP3*(YP2-Y3)+XP2*(Y3-YP3)+X3*(YP3-YP2))*(RP3+RP2+R3)+(XP2*CCFLUX54
     1 (Y2-Y3)+X2*(Y3-YP2)+X3*(YP2-Y2))*(RP2+R2+R3))*TWLFTH             CCFLUX55
      AT(I)=AOM*SIGN(1.,FT(I))+BO*4.*FT(I)/(VOLT+VOLC)                  CCFLUX56
      S1=FR*(1.-AR)                                                     CCFLUX57
      S2=FR*(1.+AR)                                                     CCFLUX58
      S3=FT(I)*(1.-AT(I))                                               CCFLUX59
      S4=FT(I)*(1.+AT(I))                                               CCFLUX60
      S5=FLL*(1.-AL)                                                    CCFLUX61
      S6=FLL*(1.+AL)                                                    CCFLUX62
      S7=FB*(1.-AB)                                                     CCFLUX63
      S8=FB*(1.+AB)                                                     CCFLUX64
      S9=S1+S3+S5+S7                                                    CCFLUX65
      MP(IJ)=0.                                                         CCFLUX66
      MJP=IJP                                                           CCFLUX67
      MPJ=IPJ                                                           CCFLUX68
      MJM=IJM                                                           CCFLUX69
      MMJ=IMJ                                                           CCFLUX70
      IF (I.EQ.1) MMJ=IJ                                                CCFLUX71
      IF (I.EQ.NX) MPJ=IJ                                               CCFLUX72
      IF (J.EQ.1) MJM=IJ                                                CCFLUX73
      IF (J.EQ.NY) MJP=IJ                                               CCFLUX74
      DO 10 K=1,NSP                                                     CCFLUX75
      SPM(IJ,K)=MIP(IJ)*SPD(IJ,K)+S9*SPD(IJ,K)+S2*SPD(MPJ,K)+S4*SPD(MJP CCFLUX76
     1 ,K)+S6*SPD(MMJ,K)+S8*SPD(MJM,K)                                  CCFLUX77
      MP(IJ)=MP(IJ)+SPM(IJ,K)                                           CCFLUX78
   10 CONTINUE                                                          CCFLUX79
```

```
      SIE(IJ)=(MC(IJ)*E(IJ)+S9*ROL(IJ)*E(IJ)+S2*ROL(MPJ)*E(MPJ)+S4*ROL  CCFLUX80
     1 (MJP)*E(MJP)+S6*ROL(MMJ)*E(MMJ)+S8*ROL(MJM)*E(MJM))/MP(IJ)        CCFLUX81
      ATR=(X2*(Y3-Y1)-X1*(Y3-Y2)-X3*(Y2-Y1))*(R1+R2+R3)                  CCFLUX82
      ABL=-(X1*(Y4-Y3)+X3*(Y1-Y4)+X4*(Y3-Y1))*(R3+R4+R1)                 CCFLUX83
      VOL(IJ)=SIXTH*(ATR+ABL)                                            CCFLUX84
      IJ=IPJ                                                             CCFLUX85
      IJP=IPJP                                                           CCFLUX86
   20 IJM=IJM+1                                                          CCFLUX87
   30 CONTINUE                                                           CCFLUX88
      DO 60 J=1,NY                                                       CCFLUX89
      IJ=(J-1)*NXP+1                                                     CCFLUX90
      IJP=IJ+NXP                                                         CCFLUX91
      DO 50 I=1,NX                                                       CCFLUX92
      IPJ=IJ+1                                                           CCFLUX93
      IPJP=IJP+1                                                         CCFLUX94
      MC(IJ)=MP(IJ)                                                      CCFLUX95
      RO(IJ)=MC(IJ)/VOL(IJ)                                              CCFLUX96
      DO 40 K=1,NSP                                                      CCFLUX97
      SPD(IJ,K)=SPM(IJ,K)/VOL(IJ)                                        CCFLUX98
   40 CONTINUE                                                           CCFLUX99
      MVT(IJ)=MVT(IJ)+0.25*MC(IJ)                                        CCFLU100
      MVT(IPJ)=MVT(IPJ)+0.25*MC(IJ)                                      CCFLU101
      MVT(IPJP)=MVT(IPJP)+0.25*MC(IJ)                                    CCFLU102
      MVT(IJP)=MVT(IJP)+0.25*MC(IJ)                                      CCFLU103
      IJ=IJ+1                                                            CCFLU104
   50 IJP=IJP+1                                                          CCFLU105
   60 CONTINUE                                                           CCFLU106
      RETURN                                                             CCFLU107
      END                                                                CCFLU108
```

```
      SUBROUTINE CHEM                                                    CHEM   2
C                                                                        CHEM   3
C     THIS SUBROUTINE CALCULATES THE CHANGE IN SPECIES DENSITIES AND     CHEM   4
C     INTERNAL ENERGY DUE TO CHEMICAL REACTIONS                          CHEM   5
C                                                                        CHEM   6
      INTEGER AM, BM, CM                                                 CHEM   7
```

```
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,
     1 EPSCHM
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC
      LEVEL 2, PSD, DELP
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)
      LEVEL 2, XMU, COND, TEM, HK
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)
      LEVEL 2, VOL, MV, MC
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)
      LEVEL 2, SPD, SPM
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEO(NERQ)
```

```
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      REAL KF, KB                                                       CHEM   9
      IF (NR.LE.0) RETURN                                               CHEM  10
      JC=-NXP                                                           CHEM  11
      DO 80 J=1,NY                                                      CHEM  12
      JC=JC+NXP                                                         CHEM  13
      DO 80 I=1,NX                                                      CHEM  14
      IF (I.GE.NOL.AND.I.LT.NOR.AND.J.GE.NOB.AND.J.LT.NOT) GO TO 80     CHEM  15
      IJ=I+JC                                                           CHEM  16
      TIJ=TEM(IJ)                                                       CHEM  17
      IF (TIJ.LT.TCUT) GO TO 80                                         CHEM  18
      RTIJ=1./TIJ                                                       CHEM  19
      DO 70 L=1,NR                                                      CHEM  20
      DOMEGA(L)=0.                                                      CHEM  21
      RP=1.                                                             CHEM  22
      PP=1.                                                             CHEM  23
      NS=NELEM(L)                                                       CHEM  24
      DO 20 KK=1,NS                                                     CHEM  25
      K=CM(KK,L)                                                        CHEM  26
      ROM=SPD(IJ,K)*RWT(K)                                              CHEM  27
      IF (AM(K,L).EQ.0) GO TO 10                                        CHEM  28
      IF (ROM.LE.0.) RP=0.                                              CHEM  29
      IF (ROM.GT.0.) RP=RP*ROM**AE(K,L)                                 CHEM  30
   10 CONTINUE                                                          CHEM  31
      IF (BM(K,L).EQ.0) GO TO 20                                        CHEM  32
      IF (ROM.LE.0.) PP=0.                                              CHEM  33
      IF (ROM.GT.0.) PP=PP*ROM**BE(K,L)                                 CHEM  34
   20 CONTINUE                                                          CHEM  35
      KB=0.                                                             CHEM  36
      KF=0.                                                             CHEM  37
      TEB=1.                                                            CHEM  38
      TEF=1.                                                            CHEM  39
      EKB=1.                                                            CHEM  40
      EKF=1.                                                            CHEM  41
```

```
      IF (CB(L).LE.0.) GO TO 30
C     BACKWARD REACTION COEFFICIENT
      IF (EB(L).NE.0.) EKB=QEXP(-EB(L)*RTIJ)
      IF (ZETAB(L).NE.0.) TEB=TIJ**ZETAB(L)
      KB=CB(L)*TEB*EKB
   30 CONTINUE
      IF (CF(L).LE.0.) GO TO 40
C     FORWARD REACTION COEFFICIENT
      IF (EF(L).NE.0.) EKF=QEXP(-EF(L)*RTIJ)
      IF (ZETAF(L).NE.0.) TEF=TIJ**ZETAF(L)
      KF=CF(L)*TEF*EKF
   40 CONTINUE
C
C     IF ANY RATE COEFFICIENTS CANNOT BE PUT IN STANDARD FORM
C     CODE THEM BY HAND AND PUT THEM HERE
C
C     FIND THE REFERENCE SPECIES
C
      OMEG=KF*RP-KB*PP
      RMIN=0.
      DOMEGA(L)=0.
      IF (OMEG.EQ.0.) GO TO 70
      DO 50 KK=1,NS
      K=CM(KK,L)
      IF (SPD(IJ,K).LE.0.) GO TO 50
      ROM=OMEG*(BM(K,L)-AM(K,L))*WT(K)/SPD(IJ,K)
      IF (ROM.GE.0.) GO TO 50
      IF (ROM.LT.RMIN) KREF=K
      IF (ROM.LT.RMIN) RMIN=ROM
   50 CONTINUE
      ROM=SPD(IJ,KREF)*RWT(KREF)
      CTOP=AM(KREF,L)*KB*PP+BM(KREF,L)*KF*RP
      CBOT=AM(KREF,L)*KF*RP+BM(KREF,L)*KB*PP
      ROMREF=ROM*(ROM+DT*CTOP)/(ROM+DT*CBOT)
      DOMEGA(L)=(ROMREF-ROM)/(BM(KREF,L)-AM(KREF,L))
      DO 60 K=1,NSP
      BMA=(BM(K,L)-AM(K,L))*DOMEGA(L)
      SPD(IJ,K)=SPD(IJ,K)+WT(K)*BMA
   60 CONTINUE
      DRE=QR(L)*DOMEGA(L)
```

```
      E(IJ)=E(IJ)+DRE/RO(IJ)
   70 CONTINUE
   80 CONTINUE
C +++
C +++ IGNITION PROCEDURE
C +++
      IJ=(NY-1)*NXP+1
      IF (TEM(IJ).LT.1600.) E(IJ)=E(IJ)*(1.+XIGNIT)
      RETURN
      END
```

```
      SUBROUTINE CHEMEQ
C +++
C +++ THIS SUBROUTINE CALCULATES THE CHANGE IN SPECIES DENSITIES AND
C +++ INTERNAL ENERGY DUE TO EQUILIBRIUM CHEMICAL REACTIONS
C +++
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)
      COMMON X(NXQ), R(NXQ), Y(NXQ), F(NXQ)
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,
     1 EPSCHM
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC
      LEVEL 2, PSD, DELP
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)
      LEVEL 2, XMU, COND, TEM, HK
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)
      LEVEL 2, VOL, MV, MC
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)
      LEVEL 2, SPD, SPM
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
```

```
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      REAL KCS                                                          CHEMEQ 8
      DIMENSION EQC(NERQ)                                               CHEMEQ 9
      DATA TCUTE /1200./                                                CHEMEQ10
      DATA NCHEM, NERR /100,0/                                          CHEMEQ11
      IF (NRE.LE.0) RETURN                                              CHEMEQ12
      JC=-NXP                                                           CHEMEQ13
      DO 90 J=1,NY                                                      CHEMEQ14
      JC=JC+NXP                                                         CHEMEQ15
      DO 90 I=1,NX                                                      CHEMEQ16
      IF (I.GE.NOL.AND.I.LT.NOR.AND.J.GE.NOB.AND.J.LT.NOT) GO TO 90     CHEMEQ17
      IJ=I+JC                                                           CHEMEQ18
      TIJ=TEM(IJ)                                                       CHEMEQ19
      IF (TIJ.LT.TCUTE) GO TO 90                                        CHEMEQ20
      TA=.001*TIJ                                                       CHEMEQ21
```

```
      TALOG=QLOG(TA)                                                    CHEMEQ22
      DO 10 L=1,NRE                                                     CHEMEQ23
      EQC(L)=QEXP(AS(L)*TALOG+BS(L)/TA+CS(L)+TA*(DS(L)+ES(L)*TA))       CHEMEQ24
   10 CONTINUE                                                          CHEMEQ25
      RROCV=1./(RO(IJ)*CVT(IJ))                                         CHEMEQ26
      N=0                                                               CHEMEQ27
C +++ BEGIN NCHEM LOOP                                                   CHEMEQ28
   20 CONTINUE                                                          CHEMEQ29
      N=N+1                                                             CHEMEQ30
      ICONV=0                                                           CHEMEQ31
      DO 80 L=1,NRE                                                     CHEMEQ32
      PRMAX=1.E+200                                                     CHEMEQ33
      PRMIN=-1.E+200                                                    CHEMEQ34
      RP=1.                                                             CHEMEQ35
      PP=1.                                                             CHEMEQ36
      NS=NLM(L)                                                         CHEMEQ37
      P1=0.                                                             CHEMEQ38
      R1=0.                                                             CHEMEQ39
      DO 40 KK=1,NS                                                     CHEMEQ40
      K=CN(KK,L)                                                        CHEMEQ41
      ROM=AMAX1(SPD(IJ,K),1.E-80)*RWT(K)                                CHEMEQ42
      IAB=AN(K,L)-BN(K,L)                                               CHEMEQ43
      CONK=-IAB/ROM                                                     CHEMEQ44
      IF (IAB.GT.0) PRMAX=AMIN1(PRMAX,ROM/IAB)                          CHEMEQ45
      IF (IAB.LT.0) PRMIN=AMAX1(PRMIN,ROM/IAB)                          CHEMEQ46
      IF (AN(K,L).EQ.0) GO TO 30                                        CHEMEQ47
      R1=R1+AN(K,L)*CONK                                                CHEMEQ48
      RP=RP*ROM**AN(K,L)                                                CHEMEQ49
   30 CONTINUE                                                          CHEMEQ50
      IF (BN(K,L).EQ.0) GO TO 40                                        CHEMEQ51
      P1=P1+BN(K,L)*CONK                                                CHEMEQ52
      PP=PP*ROM**BN(K,L)                                                CHEMEQ53
   40 CONTINUE                                                          CHEMEQ54
      R2=-(1.+R1*PRMAX)/(PRMAX*PRMAX)                                   CHEMEQ55
      P2=-(1.+P1*PRMIN)/(PRMIN*PRMIN)                                   CHEMEQ56
      KCS=EQC(L)                                                        CHEMEQ57
      DSS=KCS*RP-PP                                                     CHEMEQ58
      IF (ABS(DSS).GT.EPSCHM*PP) ICONV=1                                CHEMEQ59
      D1=KCS*RP*R1-PP*P1                                                CHEMEQ60
      D2=KCS*RP*R2-PP*P2                                                CHEMEQ61
```

```
      ARG=D1*D1-4.*D2*DSS                                                CHEMEQ62
      IF (D2.NE.0..AND.ARG.GE.0.) GO TO 50                               CHEMEQ63
      PROG(L)=-DSS/D1                                                    CHEMEQ64
      GO TO 60                                                           CHEMEQ65
   50 CONTINUE                                                           CHEMEQ66
      ROOT=SQRT(ARG)                                                     CHEMEQ67
      PROG(L)=(-D1-ROOT)/(2.*D2)                                         CHEMEQ68
      IF (PROG(L)*DSS.LT.0.) PROG(L)=0.                                  CHEMEQ69
   60 CONTINUE                                                           CHEMEQ70
      PROG(L)=OMGCHM*PROG(L)                                             CHEMEQ71
      PROG(L)=AMIN1(PROG(L),0.9*PRMAX)                                   CHEMEQ72
      PROG(L)=AMAX1(PROG(L),0.9*PRMIN)                                   CHEMEQ73
      DO 70 K=1,NSP                                                      CHEMEQ74
      BMA=(BN(K,L)-AN(K,L))*PROG(L)                                      CHEMEQ75
      SPD(IJ,K)=SPD(IJ,K)+WT(K)*BMA                                      CHEMEQ76
   70 CONTINUE                                                           CHEMEQ77
      DRE=QEQ(L)*PROG(L)                                                 CHEMEQ78
      E(IJ)=E(IJ)+DRE/RO(IJ)                                             CHEMEQ79
   80 CONTINUE                                                           CHEMEQ80
      IF (ICONV.EQ.1.AND.N.LT.NCHEM) GO TO 20                            CHEMEQ81
   90 CONTINUE                                                           CHEMEQ82
      RETURN                                                             CHEMEQ83
      END                                                                CHEMEQ84
```

```
      SUBROUTINE CHOPPER (NDIF)                                          CHOP   2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                         COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                              COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,   COMD   4
     1 EPSCHM                                                            COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                              COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP           COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                        COMD   8
      LEVEL 2, PSD, DELP                                                 COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                                COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                        COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)               COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                             COMD  13
```

```
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
C +++                                                                   CHOP   4
C +++ THIS ROUTINE ADDS OR DELETES ONE ROW OF CELLS AT THE TOP OF THE   CHOP   5
C +++ MESH.  YL = TEMPORARY STORAGE OF NEW Y, FL IS TEMPORARY STORAGE   CHOP   6
C +++ OF NEW DEPENDENT VARIABLES.                                       CHOP   7
C +++                                                                   CHOP   8
```

```
      IF (NY.EQ.NYMAX.AND.NDIF.EQ.1) RETURN
      LX=1
      IF (NDIF.LT.0) LX=-1
      LY=NY+LX
      LYP=NYP+LX
      WRITE (59,180) NCYC
      DYNEW=(Y(NXP*NYP)-Y(NXP*NOT))/FLOAT(LYP-NOT)
      YL(NOT)=Y(NXP*NOT)
      DO 10 J=NOT,LY
   10 YL(J+1)=YL(J)+DYNEW
C +++
C +++ REZONE SPD, RO, SIE.
C +++
      NSPP=NSP+1
      DO 80 I=1,NX
      DO 50 JL=NOT,LY
      DO 20 K=1,NSPP
      FL(JL,K)=0.
   20 CONTINUE
      DO 40 J=NOT,NY
      IJ=NXP*(J-1)+I
      IJP=IJ+NXP
      IF (Y(IJP).LE.YL(JL).OR.Y(IJ).GE.YL(JL+1)) GO TO 40
      FRAC=(AMIN1(Y(IJP),YL(JL+1))-AMAX1(Y(IJ),YL(JL)))/(Y(IJP)-Y(IJ))
      DO 30 K=1,NSP
   30 FL(JL,K)=FL(JL,K)+FRAC*SPD(IJ,K)*VOL(IJ)
      FL(JL,NSP+1)=FL(JL,NSP+1)+FRAC*SIE(IJ)*MC(IJ)
   40 CONTINUE
   50 CONTINUE
      DO 70 JL=NOT,LY
      IJ=(JL-1)*NXP+I
      SIE(IJ)=FL(JL,NSP+1)
      RO(IJ)=0.
      DO 60 K=1,NSP
      SPD(IJ,K)=FL(JL,K)
   60 RO(IJ)=RO(IJ)+SPD(IJ,K)
   70 CONTINUE
   80 CONTINUE
C +++
C +++ VELOCITY INTERPOLATION
```

```
C +++                                                                   CHOP  49
      NOTP=NOT+1                                                        CHOP  50
      DO 130 I=1,NXP                                                    CHOP  51
      IJ=(NOT-1)*NXP+I                                                  CHOP  52
      FL(NOT,1)=U(IJ)                                                   CHOP  53
      FL(NOT,2)=V(IJ)                                                   CHOP  54
      FL(NOT,3)=W(IJ)                                                   SPRUCE 1
      IJ=NY*NXP+I                                                       CHOP  55
      FL(LYP,1)=U(IJ)                                                   CHOP  56
      FL(LYP,2)=V(IJ)                                                   CHOP  57
      FL(LYP,3)=W(IJ)                                                   SPRUCE 2
      DO 110 JL=NOTP,LY                                                 CHOP  58
      DO 90 J=NOTP,NYP                                                  CHOP  59
      IJ=(J-1)*NXP+I                                                    CHOP  60
      IF (Y(IJ).GE.YL(JL)) GO TO 100                                    CHOP  61
   90 CONTINUE                                                          CHOP  62
  100 CONTINUE                                                          CHOP  63
      FRAC=(YL(JL)-Y(IJ-NXP))/(Y(IJ)-Y(IJ-NXP))                         CHOP  64
      FL(JL,1)=U(IJ)*FRAC+U(IJ-NXP)*(1.-FRAC)                           CHOP  65
      FL(JL,2)=V(IJ)*FRAC+V(IJ-NXP)*(1.-FRAC)                           CHOP  66
      FL(JL,3)=W(IJ)*FRAC+W(IJ-NXP)*(1.-FRAC)                           CHOP  67
  110 CONTINUE                                                          CHOP  68
      DO 120 J=NOTP,LYP                                                 CHOP  69
      IJ=(J-1)*NXP+I                                                    CHOP  70
      U(IJ)=FL(J,1)                                                     CHOP  71
      V(IJ)=FL(J,2)                                                     CHOP  72
      W(IJ)=FL(J,3)                                                     CHOP  73
  120 CONTINUE                                                          CHOP  74
  130 CONTINUE                                                          CHOP  75
C +++                                                                   CHOP  76
C +++ UPDATE Y, VOL, MC, MV.                                            CHOP  77
C +++                                                                   CHOP  78
      DO 140 I=1,NXP                                                    CHOP  79
      DO 140 J=NOT,LYP                                                  CHOP  80
      IJ=(J-1)*NXP+I                                                    CHOP  81
      VOL(IJ)=0.                                                        CHOP  82
      MC(IJ)=0.                                                         CHOP  83
      MV(IJ)=0.                                                         CHOP  84
      Y(IJ)=YL(J)                                                       CHOP  85
  140 CONTINUE                                                          CHOP  86
```

```
      DO 160 I=1,NX
      DO 160 J=NOT,LY
      IJP=J*NXP+I
      IJ=IJP-NXP
      IPJP=IJP+1
      IPJ=IJ+1
      ATR=(X(IPJP)*(Y(IJP)-Y(IPJ))-X(IPJ)*(Y(IJP)-Y(IPJP))-X(IJP)*
     1 (Y(IPJP)-Y(IPJ)))*(R(IPJ)+R(IPJP)+R(IJP))
      ABL=(X(IPJ)*(Y(IJ)-Y(IJP))+X(IJP)*(Y(IPJ)-Y(IJ))+X(IJ)*(Y(IJP)-
     1 Y(IPJ)))*(R(IJP)+R(IJ)+R(IPJ))
      VOL(IJ)=SIXTH*(ATR-ABL)
      MC(IJ)=RO(IJ)
      RO(IJ)=MC(IJ)/VOL(IJ)
      SIE(IJ)=SIE(IJ)/MC(IJ)
      DO 150 K=1,NSP
  150 SPD(IJ,K)=SPD(IJ,K)/VOL(IJ)
      MV(IJ)=0.25*MC(IJ)+MV(IJ)
      MV(IPJ)=0.25*MC(IJ)+MV(IPJ)
      MV(IJP)=0.25*MC(IJ)+MV(IJP)
      MV(IPJP)=0.25*MC(IJ)+MV(IPJP)
  160 CONTINUE
      NY=LY
      NYP=LYP
      IF (LX.EQ.-1) RETURN
      DO 170 I=1,NX
      IJ=(NY-1)*NXP+I
      TEM(IJ)=TEM(IJ-NXP)
      CVT(IJ)=SIE(IJ)/TEM(IJ)
  170 CONTINUE
      RETURN
C +++
C
  180 FORMAT (1X,24HCHOPPER CALLED ON CYCLE ,I6)
      END
```

```
      SUBROUTINE CONTUR (L,KSP,IP1,JP1,CQ,X,Y,T,NCYC)
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT
      DIMENSION CQ(1), X(1), Y(1)
      DIMENSION IX1(2), IY1(2), XCO(4), YCO(4), CON(40)
      DIMENSION MESS(10)
      DIMENSION LABC(20)
      DATA (MESS(I),I=1,7) /10HISOBARS   ,10HISOPYCNICS,10HSIE       ,
     1 10HVA ISOTACH,10H          ,10HISOTHERMS ,10HVISCOSITY /
      DATA NCON /11/
      DATA (LABC(K),K=1,12) /4HFUEL,2HO2,2HN2,3HCO2,3HH2O,1HH,2HH2,1HO,
     1 1HN,2HOH,2HCO,2HNO/
C
C     CONTOUR PLOTS OF ARRAY CQ
C
      IP2=IP1+1
      JP2=JP1+1
      JBAR=JP1-1
      IBAR=IP1-1
C +++
C +++ SET SCALING FACTORS
C +++
      XL=1.E+70
      YB=XL
      XR=-XL
      YT=XR
      DO 20 J=1,JP2
      DO 10 I=1,IP2
      IJ=(J-1)*IP2+I
      XL=AMIN1(XL,X(IJ))
      XR=AMAX1(XR,X(IJ))
      YB=AMIN1(YB,Y(IJ))
      YT=AMAX1(YT,Y(IJ))
   10 CONTINUE
   20 CONTINUE
      FIYB=916.
      XD=(XR-XL)/(YT-YB)
      YY=0.
      IF (XD.LT.1.13556) YY=1.
      FIXL=AMAX1(0.,(511.-450.*XD)*YY)
      FIXR=(511.+450.*XD)*YY+1022.*(1.-YY)
```

```
      FIYT=16.*YY+(916.-1022./XD)*(1.-YY)                               CONTUR42
      XCONV=(FIXR-FIXL)/(XR-XL)                                         CONTUR43
      YCONV=(FIYT-FIYB)/(YT-YB)                                         CONTUR44
C +++                                                                   CONTUR45
C +++ SET CONTOUR VALUES                                                CONTUR46
C +++                                                                   CONTUR47
      QMN=1.E+200                                                       CONTUR48
      QMX=-QMN                                                          CONTUR49
      DO 50 J=1,JP1                                                     CONTUR50
      IJ=(J-1)*IP2+1                                                    CONTUR51
      DO 40 I=1,IP1                                                     CONTUR52
      IF (I.GE.NOL.AND.I.LT.NOR.AND.J.GE.NOB.AND.J.LT.NOT) GO TO 30     CONTUR53
      QMN=AMIN1(CQ(IJ),QMN)                                             CONTUR54
      QMX=AMAX1(CQ(IJ),QMX)                                             CONTUR55
   30 CONTINUE                                                          CONTUR56
   40 IJ=IJ+1                                                           CONTUR57
   50 CONTINUE                                                          CONTUR58
      XX=QMX-QMN                                                        CONTUR59
      IF (XX.LE.0.001*AMAX1(ABS(QMX),ABS(QMN))) RETURN                  CONTUR60
      DQ=0.1*(XX+1.E-200)                                               CONTUR61
      DO 60 K=1,NCON                                                    CONTUR62
   60 CON(K)=QMN+(FLOAT(K-1))*DQ                                        CONTUR63
C +++                                                                   CONTUR64
C +++ PRINT THE LABELS ON THE PLOT                                      CONTUR65
C +++                                                                   CONTUR66
      K=NCON                                                            CONTUR67
      CALL ADV (1)                                                      CONTUR68
      CALL LINCNT (60)                                                  CONTUR69
      IF (L.NE.5) WRITE (12,230) MESS(L),T,NCYC                         CONTUR70
      IF (L.EQ.5) WRITE (12,220) KSP,T,NCYC,LABC(KSP)                   CONTUR71
      WRITE (12,240) QMN,QMX,CON(2),CON(K-1),DQ                         CONTUR72
C +++                                                                   CONTUR73
C +++ DRAW THE CONTOURS                                                 CONTUR74
C +++                                                                   CONTUR75
      DO 170 J=2,JP1                                                    CONTUR76
      IJ=(J-1)*IP2+1                                                    CONTUR77
      IJM=IJ-IP2                                                        CONTUR78
      IJP=IJ+IP2                                                        CONTUR79
      DO 160 I=1,IBAR                                                   CONTUR80
      IPJ=IJ+1                                                          CONTUR81
```

```
      IPJM=IJM+1                                                        CONTUR82
      IF (I.GE.NOL-1.AND.I.LT.NOR.AND.J.GE.NOB.AND.J.LE.NOT) GO TO 150  CONTUR83
      N=0                                                               CONTUR84
      DO 140 KK=2,K                                                     CONTUR85
      K1=0                                                              CONTUR86
      K2=0                                                              CONTUR87
      K3=0                                                              CONTUR88
      K4=0                                                              CONTUR89
      IF (CQ(IJM).LE.CON(KK)) K1=1                                      CONTUR90
      IF (CQ(IPJM).LE.CON(KK)) K2=1                                     CONTUR91
      IF (CQ(IJ).LE.CON(KK)) K3=1                                       CONTUR92
      IF (CQ(IPJ).LE.CON(KK)) K4=1                                      CONTUR93
      KSUM=K1+K2+K3+K4                                                  CONTUR94
      IF (KSUM.EQ.4) GO TO 150                                          CONTUR95
      IF (K1*K2*K3*K4.NE.0.OR.KSUM.EQ.0) GO TO 140                      CONTUR96
      IF (N.GT.0) GO TO 90                                              CONTUR97
      IJB=IJM                                                           CONTUR98
      IJA=IJ                                                            CONTUR99
      DO 80 JJ=1,2                                                      CONTU100
      DO 70 II=1,2                                                      CONTU101
      IPJB=IJB+1                                                        CONTU102
      IPJA=IJA+1                                                        CONTU103
      N=N+1                                                             CONTU104
      XCO(N)=.25*(X(IPJB)+X(IPJA)+X(IJA)+X(IJB))                        CONTU105
      YCO(N)=.25*(Y(IPJB)+Y(IPJA)+Y(IJA)+Y(IJB))                        CONTU106
      IJA=IPJA                                                          CONTU107
   70 IJB=IPJB                                                          CONTU108
      IJB=IJ                                                            CONTU109
   80 IJA=IJP                                                           CONTU110
   90 LL=0                                                              CONTU111
      IF (K1+K3.NE.1) GO TO 100                                         CONTU112
      IC1=1                                                             CONTU113
      IC2=3                                                             CONTU114
      IJ1=IJM                                                           CONTU115
      IJ2=IJ                                                            CONTU116
      KR1=1                                                             CONTU117
      GO TO 130                                                         CONTU118
  100 IF (K1+K2.NE.1) GO TO 110                                         CONTU119
      IC1=1                                                             CONTU120
      IC2=2                                                             CONTU121
```

```
      IJ1=IJM
      IJ2=IPJM
      KR1=2
      GO TO 130
  110 IF (K2+K4.NE.1) GO TO 120
      IC1=2
      IC2=4
      IJ1=IPJM
      IJ2=IPJ
      KR1=3
      GO TO 130
  120 IF (K3+K4.NE.1) GO TO 140
      IC1=3
      IC2=4
      IJ1=IJ
      IJ2=IPJ
      KR1=4
  130 LL=LL+1
      XX=(CON(KK)-CQ(IJ1))/(CQ(IJ2)-CQ(IJ1))
      IX1(LL)=FIXL+(XCO(IC1)+XX*(XCO(IC2)-XCO(IC1))-XL)*XCONV
      IY1(LL)=FIYB+(YCO(IC1)+XX*(YCO(IC2)-YCO(IC1))-YB)*YCONV
      IF (LL.LT.2) GO TO (100,110,120,140), KR1
      CALL DRV (IX1(1),IY1(1),IX1(2),IY1(2))
      IF (KK.EQ.2) CALL PLT (IX1(1),IY1(1),35)
      IF (KK.EQ.K-1) CALL PLT (IX1(1),IY1(1),24)
      LL=0
      IF (IJ2.EQ.IPJM) GO TO 110
  140 CONTINUE
  150 CONTINUE
      IJM=IPJM
      IJ=IPJ
  160 IJP=IJP+1
  170 CONTINUE
C +++
C +++ DRAW THE FRAME
C +++
      DO 190 J=1,JP1
      IJ=(J-1)*IP2+1
      IJP=IJ+IP2
      DO 180 I=1,IP1
```

```
      IPJ=IJ+1
      IPJP=IJP+1
      IIX1=FIXL+(X(IPJ)-XL)*XCONV
      IIY1=FIYB+(Y(IPJ)-YB)*YCONV
      IIX2=FIXL+(X(IPJP)-XL)*XCONV
      IIY2=FIYB+(Y(IPJP)-YB)*YCONV
      IX3=FIXL+(X(IJP)-XL)*XCONV
      IY3=FIYB+(Y(IJP)-YB)*YCONV
      IX4=FIXL+(X(IJ)-XL)*XCONV
      IY4=FIYB+(Y(IJ)-YB)*YCONV
      IF (I.EQ.1) CALL DRV (IX3,IY3,IX4,IY4)
      IF (J.EQ.1) CALL DRV (IX4,IY4,IIX1,IIY1)
      IF (I.EQ.IP1) CALL DRV (IIX1,IIY1,IIX2,IIY2)
      IF (J.EQ.JP1) CALL DRV (IIX2,IIY2,IX3,IY3)
      IJ=IPJ
  180 IJP=IPJP
  190 CONTINUE
C +++
C +++ DRAW THE OBSTACLE
C +++
      IF (NOL.LE.0) RETURN
      NOR1=NOR-1
      NOT1=NOT-1
      DO 200 J=NOB,NOT1
      IJP=J*IP2+NOL
      IJ=IJP-IP2
      IX3=FIXL+(X(IJ)-XL)*XCONV
      IY3=FIYB+(Y(IJ)-YB)*YCONV
      IX4=FIXL+(X(IJP)-XL)*XCONV
      IY4=FIYB+(Y(IJP)-YB)*YCONV
      CALL DRV (IX3,IY3,IX4,IY4)
      IJP=J*IP2+NOR
      IJ=IJP-IP2
      IX3=FIXL+(X(IJ)-XL)*XCONV
      IY3=FIYB+(Y(IJ)-YB)*YCONV
      IX4=FIXL+(X(IJP)-XL)*XCONV
      IY4=FIYB+(Y(IJP)-YB)*YCONV
      CALL DRV (IX3,IY3,IX4,IY4)
  200 CONTINUE
      DO 210 I=NOL,NOR1
```

```
      IJ=(NOB-1)*IP2+I                                                  CONTU202
      IPJ=IJ+1                                                          CONTU203
      IX3=FIXL+(X(IJ)-XL)*XCONV                                         CONTU204
      IY3=FIYB+(Y(IJ)-YB)*YCONV                                         CONTU205
      IX4=FIXL+(X(IPJ)-XL)*XCONV                                        CONTU206
      IY4=FIYB+(Y(IPJ)-YB)*YCONV                                        CONTU207
      CALL DRV (IX3,IY3,IX4,IY4)                                        CONTU208
      IJ=NOT1*IP2+I                                                     CONTU209
      IPJ=IJ+1                                                          CONTU210
      IX3=FIXL+(X(IJ)-XL)*XCONV                                         CONTU211
      IY3=FIYB+(Y(IJ)-YB)*YCONV                                         CONTU212
      IX4=FIXL+(X(IPJ)-XL)*XCONV                                        CONTU213
      IY4=FIYB+(Y(IPJ)-YB)*YCONV                                        CONTU214
      CALL DRV (IX3,IY3,IX4,IY4)                                        CONTU215
  210 CONTINUE                                                          CONTU216
      RETURN                                                            CONTU217
C                                                                       CONTU218
C     FORMAT BLOCK                                                      CONTU219
C                                                                       CONTU220
  220 FORMAT (8H SPECIES,I3,14H MASS FRACTION,4X,3HT =,1PE14.6,2X,7HCYCLCONTU221
     1E =,I6,4X,A10)                                                    CONTU222
  230 FORMAT (1X,A10,2X,3HT =,1PE14.6,2X,7HCYCLE =,I6)                  CONTU223
  240 FORMAT (1X,4HMIN=,1PE13.5,5H MAX=,E13.5,3H L=,E13.5,3H H=,E13.5,4HCONTU224
     1 DQ=,E13.5)                                                       CONTU225
      END                                                               CONTU226
```

```
      SUBROUTINE DSDP                                                   DSDP   2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
```

```
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NxQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
C +++                                                                   DSDP   4
C +++ COMPUTE THE OVERRELAXATION FACTOR FOR THE PRESSURE ITERATION      DSDP   5
```

```
C +++
      DATA PTEMP, PSTAR /0.,0./
      DO 40 J=1,NY
      IJ=(J-1)*NXP+1
      IJP=IJ+NXP
      DO 30 I=1,NX
      IPJ=IJ+1
      IPJP=IJP+1
      X1=X(IPJ)
      X2=X(IPJP)
      X3=X(IJP)
      X4=X(IJ)
      R1=R(IPJ)
      R2=R(IPJP)
      R3=R(IJP)
      R4=R(IJ)
      Y1=Y(IPJ)
      Y2=Y(IPJP)
      Y3=Y(IJP)
      Y4=Y(IJ)
      U1=UL(IPJ)
      U2=UL(IPJP)
      U3=UL(IJP)
      U4=UL(IJ)
      V1=VL(IPJ)
      V2=VL(IPJP)
      V3=VL(IJP)
      V4=VL(IJ)
      X1P=X1+U1*DT
      Y1P=Y1+V1*DT
      X2P=X2+U2*DT
      Y2P=Y2+V2*DT
      X3P=X3+U3*DT
      Y3P=Y3+V3*DT
      X4P=X4+U4*DT
      Y4P=Y4+V4*DT
      R1P=X1P*CYL+OMCYL
      R2P=X2P*CYL+OMCYL
      R3P=X3P*CYL+OMCYL
      R4P=X4P*CYL+OMCYL
```

```
      ATR=(X2P*(Y3P-Y1P)-X1P*(Y3P-Y2P)-X3P*(Y2P-Y1P))*(R1P+R2P+R3P)      DSDP  46
      ABL=-(X1P*(Y4P-Y3P)+X3P*(Y1P-Y4P)+X4P*(Y3P-Y1P))*(R3P+R4P+R1P)     DSDP  47
      VOLLZ=SIXTH*(ATR+ABL)                                               DSDP  48
      XITEMP=SIE(IJ)+P(IJ)*(1.0-VOLLZ/VOL(IJ))/RO(IJ)                     DSDP  49
      ROTEMP=0.                                                           DSDP  50
      DO 10 K=1,NSP                                                       DSDP  51
      TSPD(K)=SPD(IJ,K)*VOL(IJ)/VOLLZ                                     DSDP  52
   10 ROTEMP=ROTEMP+TSPD(K)                                               DSDP  53
      CALL EOS (PTEMP,XITEMP,IJ)                                          DSDP  54
      DP=PEPS*PTEMP                                                       DSDP  55
      DTP=0.5*DT*DP                                                       DSDP  56
      RM1=1.0/MV(IPJ)                                                     DSDP  57
      RM2=1.0/MV(IPJP)                                                    DSDP  58
      RM3=1.0/MV(IJP)                                                     DSDP  59
      RM4=1.0/MV(IJ)                                                      DSDP  60
C +++ IF TESTS FROM HERE TO DSDP.77 SET VELOCITY BOUNDARY CONDITIONS      DSDP  61
      IF (I.EQ.1.OR.J.EQ.1) RM4=0.                                        DSDP  62
      IF (J.EQ.1.OR.I.EQ.NX) RM1=0.                                       DSDP  63
      IF (I.EQ.NX.OR.J.EQ.NY) RM2=0.                                      DSDP  64
      IF (I.EQ.1.OR.J.EQ.NY) RM3=0.                                       DSDP  65
      Y24=Y(IPJP)-Y(IJ)                                                   DSDP  66
      Y31=Y(IJP)-Y(IPJ)                                                   DSDP  67
      X24=X(IPJP)-X(IJ)                                                   DSDP  68
      X31=X(IJP)-X(IPJ)                                                   DSDP  69
      R24=0.5*(R2+R4)                                                     DSDP  70
      R31=0.5*(R3+R1)                                                     DSDP  71
      U1P=U1+DTP*RM1*Y24*R1                                               DSDP  72
      U3P=U3-DTP*RM3*Y24*R3                                               DSDP  73
      U2P=U2+DTP*RM2*Y31*R2                                               DSDP  74
      U4P=U4-DTP*RM4*Y31*R4                                               DSDP  75
      IF (I.EQ.1.AND.J.GT.1) RM4=1./MV(IJ)                                DSDP  76
      IF (I.EQ.1.AND.J.LT.NY) RM3=1./MV(IJP)                              DSDP  77
      V1P=V1-DTP*RM1*X24*R24                                              DSDP  78
      V3P=V3+DTP*RM3*X24*R24                                              DSDP  79
      V2P=V2-DTP*RM2*X31*R31                                              DSDP  80
      V4P=V4+DTP*RM4*X31*R31                                              DSDP  81
      X1P=X1+U1P*DT                                                       DSDP  82
      Y1P=Y1+V1P*DT                                                       DSDP  83
      X2P=X2+U2P*DT                                                       DSDP  84
      Y2P=Y2+V2P*DT                                                       DSDP  85
      X3P=X3+U3P*DT                                                       DSDP  86
```

```
      Y3P=Y3+V3P*DT                                                     DSDP  87
      X4P=X4+U4P*DT                                                     DSDP  88
      Y4P=Y4+V4P*DT                                                     DSDP  89
      R1P=X1P*CYL+OMCYL                                                 DSDP  90
      R2P=X2P*CYL+OMCYL                                                 DSDP  91
      R3P=X3P*CYL+OMCYL                                                 DSDP  92
      R4P=X4P*CYL+OMCYL                                                 DSDP  93
      ATR=(X2P*(Y3P-Y1P)-X1P*(Y3P-Y2P)-X3P*(Y2P-Y1P))*(R1P+R2P+R3P)     DSDP  94
      ABL=-(X1P*(Y4P-Y3P)+X3P*(Y1P-Y4P)+X4P*(Y3P-Y1P))*(R3P+R4P+R1P)    DSDP  95
      VOLL=SIXTH*(ATR+ABL)                                              DSDP  96
      XISTAR=XITEMP+PTEMP*(1.0-VOLL/VOLLZ)/ROTEMP                       DSDP  97
      DO 20 K=1,NSP                                                     DSDP  98
   20 TSPD(K)=SPD(IJ,K)*VOL(IJ)/VOLL                                    DSDP  99
      CALL EOS (PSTAR,XISTAR,IJ)                                        DSDP 100
      RDSDP(IJ)=DP/(PTEMP+DP-PSTAR)*OM                                  DSDP 101
      IJ=IJ+1                                                           DSDP 102
      IJP=IJP+1                                                         DSDP 103
   30 CONTINUE                                                          DSDP 104
   40 CONTINUE                                                          DSDP 105
      RETURN                                                            DSDP 106
      END                                                               DSDP 107
```

```
      SUBROUTINE DVMAX (IK)                                             DVMAX  2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
```

```
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      VMAX=-1.E+20                                                      DVMAX  4
      IF (IK.EQ.1) GO TO 30                                             DVMAX  5
      DO 20 J=1,NYP                                                     DVMAX  6
      IJ=(J-1)*NXP+1                                                    DVMAX  7
      DO 10 I=1,NXP                                                     DVMAX  8
      VMAX=AMAX1(VMAX,ABS(U(IJ)),ABS(V(IJ)))                            DVMAX  9
   10 IJ=IJ+1                                                           DVMAX 10
```

```
20 CONTINUE
   GO TO 60
30 DO 50 J=1,NYP
   IJ=(J-1)*NXP+1
   DO 40 I=1,NXP
   VMAX=AMAX1(VMAX,ABS(UL(IJ)),ABS(VL(IJ)))
40 IJ=IJ+1
50 CONTINUE
60 RETURN
   END
```

```
      SUBROUTINE ENERGY
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,
     1 EPSCHM
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC
      LEVEL 2, PSD, DELP
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)
      LEVEL 2, XMU, COND, TEM, HK
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)
      LEVEL 2, VOL, MV, MC
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)
      LEVEL 2, SPD, SPM
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
```

```
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX       COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      DO 20 J=1,NY                                                      ENERGY 4
      IJ=(J-1)*NXP+1                                                    ENERGY 5
      IJP=IJ+NXP                                                        ENERGY 6
      DO 10 I=1,NX                                                      ENERGY 7
      IPJ=IJ+1                                                          ENERGY 8
      IPJP=IJP+1                                                        ENERGY 9
      X1=X(IPJ)                                                         ENERGY10
      Y1=Y(IPJ)                                                         ENERGY11
      R1=R(IPJ)                                                         ENERGY12
      X2=X(IPJP)                                                        ENERGY13
      Y2=Y(IPJP)                                                        ENERGY14
      R2=R(IPJP)                                                        ENERGY15
      X3=X(IJP)                                                         ENERGY16
      Y3=Y(IJP)                                                         ENERGY17
      R3=R(IJP)                                                         ENERGY18
      X4=X(IJ)                                                          ENERGY19
      Y4=Y(IJ)                                                          ENERGY20
```

```
      R4=R(IJ)                                                          ENERGY21
      Y24=Y2-Y4                                                         ENERGY22
      Y31=Y3-Y1                                                         ENERGY23
      X24=X2-X4                                                         ENERGY24
      X31=X3-X1                                                         ENERGY25
      HR24=0.5*(R2+R4)                                                  ENERGY26
      HR13=0.5*(R1+R3)                                                  ENERGY27
      U1=U(IPJ)                                                         ENERGY28
      V1=V(IPJ)                                                         ENERGY29
      U2=U(IPJP)                                                        ENERGY30
      V2=V(IPJP)                                                        ENERGY31
      U3=U(IJP)                                                         ENERGY32
      V3=V(IJP)                                                         ENERGY33
      U4=U(IJ)                                                          ENERGY34
      V4=V(IJ)                                                          ENERGY35
      AREA=0.5*((X2-X4)*(Y3-Y1)-(X1-X3)*(Y4-Y2))                        ENERGY36
      RAREA=1./AREA                                                     ENERGY37
      DUDX=0.5*RAREA*((U2-U4)*(Y3-Y1)-(U1-U3)*(Y4-Y2))                  ENERGY38
      DVDY=0.5*RAREA*((V4-V2)*(X3-X1)-(V1-V3)*(X2-X4))                  ENERGY39
      UOR=(U1+U2+U3+U4)/(R1+R2+R3+R4)                                   ENERGY40
      DELV=DUDX+DVDY+CYL*UOR                                            ENERGY41
      E(IJ)=E(IJ)-DT*(P(IJ)+Q(IJ))*DELV/RO(IJ)                          ENERGY42
      IJP=IJP+1                                                         ENERGY43
   10 IJ=IJ+1                                                           ENERGY44
   20 CONTINUE                                                          ENERGY45
      RETURN                                                            ENERGY46
      END                                                               ENERGY47
```

```
      SUBROUTINE EOS (PTEMP,SIETMP,IJ)                                  EOS     2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD    2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD    3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD    4
     1 EPSCHM                                                           COMD    5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD    6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD    7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD    8
```

```
      LEVEL 2, PSD, DELP                                                COMD
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD
      LEVEL 2, XMU, COND, TEM, HK                                       COMD
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD
      LEVEL 2, VOL, MV, MC                                              COMD
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD
      LEVEL 2, SPD, SPM                                                 COMD
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD
     1 RHOI(NSQ)                                                        COMD
      LEVEL 2, CVT                                                      COMD
      COMMON /KAH8/ CVT(NXQ)                                            COMD
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                           COMD
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                 COMD
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD
     2 Q(NXQ)                                                           COMD
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD
     2 QEQ(NERQ)                                                        COMD
      INTEGER AN, BN, CN                                                COMD
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD
      DIMENSION RDSDP(1), RMV(1)                                        COMD
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD
```

```
      XXX=0.                                                            EOS     4
      DO 10 K=1,NSP                                                     EOS     5
   10 XXX=XXX+TSPD(K)*RWT(K)                                            EOS     6
      TTEMP=TEM(IJ)+(SIETMP-SIE(IJ))/CVT(IJ)                            EOS     7
      PTEMP=XXX*TTEMP*RGAS                                              EOS     8
      RETURN                                                            EOS     9
      END                                                               EOS    10
```

```
      SUBROUTINE FULOUT (IK)                                            FULOUT 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD    2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD    3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD    4
     1 EPSCHM                                                           COMD    5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD    6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD    7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD    8
      LEVEL 2, PSD, DELP                                                COMD    9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD   10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD   11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD   12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD   13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD   14
      LEVEL 2, VOL, MV, MC                                              COMD   15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD   16
      LEVEL 2, SPD, SPM                                                 COMD   17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD   18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD   19
     1 RHOI(NSQ)                                                        COMD   20
      LEVEL 2, CVT                                                      COMD   21
      COMMON /KAH8/ CVT(NXQ)                                            COMD   22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD   23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD   24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD   25
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU                           COMD   26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU                 COMD   27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD   28
```

```
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                            COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      CALL GLOBAL                                                       FULOUT 4
      IF (MOD(NCYC,NFOUT).NE.0.AND.NCYC.GT.1) GO TO 30                  FULOUT 5
      YMIN=1.E+250                                                      FULOUT 6
      YMAX=-YMIN                                                        FULOUT 7
      DO 10 I=1,NXP                                                     FULOUT 8
      YMAX=AMAX1(YMAX,Y(NY*NXP+I))                                      FULOUT 9
   10 YMIN=AMIN1(YMIN,Y(I))                                             FULOUT10
      XMIN=1.E+250                                                      FULOUT11
      XMAX=-XMIN                                                        FULOUT12
      DO 20 J=1,NYP                                                     FULOUT13
      XMAX=AMAX1(XMAX,X(J*NXP))                                         FULOUT14
      IJ=(J-1)*NXP+1                                                    FULOUT15
   20 XMIN=AMIN1(XMIN,X(IJ))                                            FULOUT16
      XCONV=950./(1.05*AMAX1(YMAX-YMIN,XMAX-XMIN))                      FULOUT17
      YCONV=XCONV                                                       FULOUT18
      CALL ADV (1)                                                      FULOUT19
      CALL DVMAX (IK)                                                   FULOUT20
      CALL ZONES                                                        FULOUT21
      CALL VELPLT (IK)                                                  FULOUT22
      LUN=12                                                            FULOUT23
```

```
      CALL RSEDIT (IK,LUN)                                              FULOUT24
   30 CONTINUE                                                          FULOUT25
      IF (MOD(NCYC,NPOUT).NE.0.AND.NCYC.GT.1) GO TO 40                  FULOUT26
      LUN=6                                                             FULOUT27
      CALL RSEDIT (IK,LUN)                                              FULOUT28
   40 CONTINUE                                                          FULOUT29
      RETURN                                                            FULOUT30
      END                                                               FULOUT31
```

```
      SUBROUTINE GLOBAL                                                 GLOBAL 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
```

```
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                          COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),     COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                          COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)           COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                       COMD  41
      INTEGER AN, BN, CN                                               COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                       COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                  COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                      COMD  48
C +++                                                                  GLOBAL 4
C +++ COMPUTE TOTAL MASS, MOMENTUM, AND ENERGY                         GLOBAL 5
C +++                                                                  GLOBAL 6
      TOTM=0.                                                          GLOBAL 7
      TOTI=0.                                                          GLOBAL 8
      TOTQ=0.                                                          GLOBAL 9
      TOTNO=0.                                                         OUTPQ  1
      DO 20 J=1,NY                                                     GLOBAL10
      DO 10 I=1,NX                                                     GLOBAL11
      IF (I.GE.NOL.AND.I.LT.NOR.AND.J.GE.NOB.AND.J.LT.NOT) GO TO 10    GLOBAL12
      IJ=(J-1)*NXP+I                                                   GLOBAL13
      TOTM=TOTM+MC(IJ)                                                 GLOBAL14
      TOTI=TOTI+MC(IJ)*SIE(IJ)                                         GLOBAL15
      TOTNO=TOTNO+SPM(IJ,NSP)                                          OUTPQ  2
C +++ THE CALCULATION IN THE NEXT LINE IS PROBLEM-DEPENDENT            GLOBAL16
      TOTQ=TOTQ+SPD(IJ,1)*4.025E+11*VOL(IJ)                            GLOBAL17
   10 CONTINUE                                                         GLOBAL18
```

```
 20 CONTINUE                                                           GLOBAL19
    TOTU=0.                                                            GLOBAL20
    TOTV=0.                                                            GLOBAL21
    TOTK=0.                                                            GLOBAL22
    TOTW=0.                                                            GLOBAL23
    DO 40 J=1,NYP                                                      GLOBAL24
    IJ=(J-1)*NXP                                                       GLOBAL25
    DO 30 I=1,NXP                                                      GLOBAL26
    IJ=IJ+1                                                            GLOBAL27
    IF (I.GT.NOL.AND.I.LT.NOR.AND.J.GT.NOB.AND.J.LT.NOT) GO TO 30      GLOBAL28
    TOTU=TOTU+MV(IJ)*U(IJ)                                             GLOBAL29
    TOTV=TOTV+MV(IJ)*V(IJ)                                             GLOBAL30
    TOTW=TOTW+MV(IJ)*W(IJ)                                             GLOBAL31
    TOTK=TOTK+MV(IJ)*(U(IJ)*U(IJ)+V(IJ)*V(IJ)+W(IJ)*W(IJ))             GLOBAL32
 30 CONTINUE                                                           GLOBAL33
 40 CONTINUE                                                           GLOBAL34
    TOTM=TOTM*2.*PI                                                    GLOBAL35
    TOTNO=TOTNO*2.*PI                                                  OUTPQ  3
    TOTI=TOTI*2.*PI                                                    GLOBAL36
    TOTK=TOTK*PI                                                       GLOBAL37
    TOTQ=TOTQ*2.*PI                                                    GLOBAL38
    TOTE=TOTK+TOTI+TOTQ                                                GLOBAL39
    TOTU=TOTU*2.*PI                                                    GLOBAL40
    TOTV=TOTV*2.*PI                                                    GLOBAL41
    TOTW=TOTW*2.*PI                                                    GLOBAL42
    IF (LPR.GT.1) WRITE (6,50) TOTM,TOTU,TOTV,TOTI,TOTE,TOTQ,WORK,TOTWGLOBAL43
   1 ,TOTNO                                                            OUTPQ  4
    IF (LPR.GT.0) WRITE (12,50) TOTM,TOTU,TOTV,TOTI,TOTE,TOTQ,WORK     GLOBAL44
   1 ,TOTW,TOTNO                                                       OUTPQ  5
    RETURN                                                             GLOBAL46
C                                                                      GLOBAL47
 50 FORMAT (1X,5HMASS=,1PE15.8,7H U MOM=,E15.8,7H V MOM=,E15.8,5H SIE=GLOBAL48
   1 ,E14.7,7H TOT E=,E14.7,8HCHEM E=,E14.7/3X,6HWORK =,E14.7,         OUTPQ  6
   2 3X,14HANG MOMENTUM =,E14.7,2X,8HGMS NO =,E14.7)                   OUTPQ  7
    END                                                                GLOBAL51
```

```
      SUBROUTINE MOMFLX                                                 MOMFLX 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
```

```
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      DO 20 J=1,NYP                                                     MOMFLX 4
      IJ=(J-1)*NXP+1                                                    MOMFLX 5
      DO 10 I=1,NXP                                                     MOMFLX 6
      RMV(IJ)=1./MVT(IJ)                                                MOMFLX 7
      UP(IJ)=UL(IJ)*MV(IJ)*RMV(IJ)                                      MOMFLX 8
      VP(IJ)=VL(IJ)*MV(IJ)*RMV(IJ)                                      MOMFLX 9
      WP(IJ)=WL(IJ)*MV(IJ)*RMV(IJ)*(R(IJ)-DT*UG(IJ))                    MOMFLX10
   10 IJ=IJ+1                                                           MOMFLX11
   20 CONTINUE                                                          MOMFLX12
      DO 40 J=1,NY                                                      MOMFLX13
      IJ=(J-1)*NXP+1                                                    MOMFLX14
      IJP=IJ+NXP                                                        MOMFLX15
      DO 30 I=1,NX                                                      MOMFLX16
      IPJ=IJ+1                                                          MOMFLX17
      IPJP=IJP+1                                                        MOMFLX18
      X1=X(IPJ)                                                         MOMFLX19
      Y1=Y(IPJ)                                                         MOMFLX20
      R1=R(IPJ)                                                         MOMFLX21
      UL1=UL(IPJ)                                                       MOMFLX22
      UG1=UG(IPJ)                                                       MOMFLX23
      VL1=VL(IPJ)                                                       MOMFLX24
      VG1=VG(IPJ)                                                       MOMFLX25
      X2=X(IPJP)                                                        MOMFLX26
      Y2=Y(IPJP)                                                        MOMFLX27
      R2=R(IPJP)                                                        MOMFLX28
      UL2=UL(IPJP)                                                      MOMFLX29
      UG2=UG(IPJP)                                                      MOMFLX30
      VL2=VL(IPJP)                                                      MOMFLX31
      VG2=VG(IPJP)                                                      MOMFLX32
      X3=X(IJP)                                                         MOMFLX33
      Y3=Y(IJP)                                                         MOMFLX34
      R3=R(IJP)                                                         MOMFLX35
```

```
      UL3=UL(IJP)                                                       MOMFLX36
      UG3=UG(IJP)                                                       MOMFLX37
      VL3=VL(IJP)                                                       MOMFLX38
      VG3=VG(IJP)                                                       MOMFLX39
      X4=X(IJ)                                                          MOMFLX40
      Y4=Y(IJ)                                                          MOMFLX41
      R4=R(IJ)                                                          MOMFLX42
      UL4=UL(IJ)                                                        MOMFLX43
      UG4=UG(IJ)                                                        MOMFLX44
      VL4=VL(IJ)                                                        MOMFLX45
      VG4=VG(IJ)                                                        MOMFLX46
      WL1=WL(IPJ)*R1                                                    MOMFLX47
      WL2=WL(IPJP)*R2                                                   MOMFLX48
      WL3=WL(IJP)*R3                                                    MOMFLX49
      WL4=WL(IJ)*R4                                                     MOMFLX50
      XX=0.0625*DT*ROL(IJ)                                              MOMFLX51
      UL13=UL1+UL3                                                      MOMFLX52
      VL13=VL1+VL3                                                      MOMFLX53
      UL24=UL2+UL4                                                      MOMFLX54
      VL24=VL2+VL4                                                      MOMFLX55
      F13=XX*(R1+R3)*((UG1+UG3-UL13)*(Y3-Y1)+(VG1+VG3-VL13)*(X1-X3))    MOMFLX56
      F24=XX*(R2+R4)*((UG2+UG4-UL24)*(Y2-Y4)+(VG2+VG4-VL24)*(X4-X2))    MOMFLX57
      FM1=F24*RMV(IPJ)                                                  MOMFLX58
      FM2=F13*RMV(IPJP)                                                 MOMFLX59
      FM3=F24*RMV(IJP)                                                  MOMFLX60
      FM4=F13*RMV(IJ)                                                   MOMFLX61
      XX=B0*4./(VOL(IJ)*ROL(IJ))                                        MOMFLX62
      AL13=A0*SIGN(1.,F13)+XX*F13                                       MOMFLX63
      AL24=A0*SIGN(1.,F24)+XX*F24                                       MOMFLX64
      OPAL13=1.+AL13                                                    MOMFLX65
      OPAL24=1.+AL24                                                    MOMFLX66
      OMAL13=1.-AL13                                                    MOMFLX67
      OMAL24=1.-AL24                                                    MOMFLX68
      XX=UL3*OMAL24+UL1*OPAL24                                          MOMFLX69
      UP(IPJ)=UP(IPJ)-FM1*XX                                            MOMFLX70
      UP(IJP)=UP(IJP)+FM3*XX                                            MOMFLX71
      XX=UL4*OMAL13+UL2*OPAL13                                          MOMFLX72
      UP(IPJP)=UP(IPJP)-FM2*XX                                          MOMFLX73
      UP(IJ)=UP(IJ)+FM4*XX                                              MOMFLX74
      XX=VL3*OMAL24+VL1*OPAL24                                          MOMFLX75
```

```
      VP(IPJ)=VP(IPJ)-FM1*XX
      VP(IJP)=VP(IJP)+FM3*XX
      XX=VL4*OMAL13+VL2*OPAL13
      VP(IPJP)=VP(IPJP)-FM2*XX
      VP(IJ)=VP(IJ)+FM4*XX
      XX=WL3*OMAL24+WL1*OPAL24
      WP(IPJ)=WP(IPJ)-FM1*XX
      WP(IJP)=WP(IJP)+FM3*XX
      XX=WL4*OMAL13+WL2*OPAL13
      WP(IPJP)=WP(IPJP)-FM2*XX
      WP(IJ)=WP(IJ)+FM4*XX
      IJ=IPJ
   30 IJP=IPJP
   40 CONTINUE
      DO 60 J=1,NYP
      IJ=(J-1)*NXP+1
      DO 50 I=1,NXP
      U(IJ)=UP(IJ)
      V(IJ)=VP(IJ)
      W(IJ)=WP(IJ)/AMAX1(1.E-99,R(IJ))
      MV(IJ)=MVT(IJ)
   50 IJ=IJ+1
   60 CONTINUE
      CALL BC (U,V,W)
      RETURN
      END
```

```
      SUBROUTINE ODROP (TL)
      CALL SSWTCH (1,J)
      IF (J.NE.1) RETURN
      TL=-1.
      WRITE (59,10)
      RETURN
C
   10 FORMAT (//1X,44HSENSE SWITCH 1 IS ON, WILL TERMINATE SHORTLY//)
      END
```

```
      SUBROUTINE PHASE1                                                 PHASE1 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
```

```
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
C +++                                                                   PHASE1 4
C +++ PHASE 1 PRESSURE GRADIENTS                                        PHASE1 5
C +++                                                                   PHASE1 6
      DO 40 J=1,NY                                                      PHASE1 7
      IJ=(J-1)*NXP+1                                                    PHASE1 8
      IJP=IJ+NXP                                                        PHASE1 9
      DO 30 I=1,NX                                                      PHASE110
      IPJ=IJ+1                                                          PHASE111
      IPJP=IJP+1                                                        PHASE112
      DTP=0.5*DT*P(IJ)                                                  PHASE113
      RM1=1.0/MV(IPJ)                                                   PHASE114
      RM2=1.0/MV(IPJP)                                                  PHASE115
      RM3=1.0/MV(IJP)                                                   PHASE116
      RM4=1.0/MV(IJ)                                                    PHASE117
      R1=R(IPJ)                                                         PHASE118
      R2=R(IPJP)                                                        PHASE119
      R3=R(IJP)                                                         PHASE120
      R4=R(IJ)                                                          PHASE121
      R24=0.5*(R2+R4)                                                   PHASE122
      R31=0.5*(R3+R1)                                                   PHASE123
      Y24=Y(IPJP)-Y(IJ)                                                 PHASE124
      Y31=Y(IJP)-Y(IPJ)                                                 PHASE125
      X24=X(IPJP)-X(IJ)                                                 PHASE126
      X31=X(IJP)-X(IPJ)                                                 PHASE127
      UL(IPJ)=UL(IPJ)+DTP*RM1*R(IPJ)*(Y(IPJP)-Y(IJ))                    PHASE128
      UL(IPJP)=UL(IPJP)+DTP*RM2*R(IPJP)*(Y(IJP)-Y(IPJ))                 PHASE129
      UL(IJP)=UL(IJP)+DTP*RM3*R(IJP)*(Y(IJ)-Y(IPJP))                    PHASE130
      UL(IJ)=UL(IJ)+DTP*RM4*R(IJ)*(Y(IPJ)-Y(IJP))                       PHASE131
      VL(IPJ)=VL(IPJ)-DTP*RM1*X24*R(IPJ)                                PHASE132
      R222=R(IJP)                                                       PHASE133
      IF (I.NE.1) GO TO 10                                              PHASE134
      REXTR=R222+R222-R(IPJP)                                           PHASE135
```

```
      IF (REXTR.LT.O.) R222=0.5*(R(IPJP)+R222)
   10 CONTINUE
      VL(IJP)=VL(IJP)+DTP*RM3*X24*R222
      VL(IPJP)=VL(IPJP)-DTP*RM2*X31*R(IPJP)
      R222=R(IJ)
      IF (I.NE.1) GO TO 20
      REXTR=R222+R222-R(IPJ)
      IF (REXTR.LT.O.) R222=0.5*(R(IPJ)+R222)
   20 CONTINUE
      VL(IJ)=VL(IJ)+DTP*RM4*X31*R222
      IJ=IJ+1
   30 IJP=IJP+1
   40 CONTINUE
C +++
C +++ BODY AND CENTRIPETAL FORCES
C +++
      DTGX=DT*GX
      DTGY=DT*GY
      DO 60 J=1,NYP
      IJ=NXP*(J-1)
      DO 50 I=1,NXP
      IJ=IJ+1
      RRL=R(IJ)*R(IJ)/AMAX1(1.E-80,R(IJ)+U(IJ)*DT)**3
      VL(IJ)=VL(IJ)+DTGY
      UL(IJ)=UL(IJ)+DTGX+SWIRL*WL(IJ)*WL(IJ)*DT*RRL
   50 CONTINUE
   60 CONTINUE
      CALL BC (UL,VL,WL)
      RETURN
      END
```

```
      SUBROUTINE PRESIT
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKO, OMGCHM,
     1 EPSCHM
```

```
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                              COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP           COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                        COMD   8
      LEVEL 2, PSD, DELP                                                 COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                                COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                        COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)               COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                             COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)    COMD  14
      LEVEL 2, VOL, MV, MC                                               COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                           COMD  16
      LEVEL 2, SPD, SPM                                                  COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                           COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),  COMD  19
     1 RHOI(NSQ)                                                         COMD  20
      LEVEL 2, CVT                                                       COMD  21
      COMMON /KAH8/ CVT(NXQ)                                             COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                      COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),         COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                      COMD  25
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU                            COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU                  COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),       COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),  COMD  29
     2 Q(NXQ)                                                            COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX       COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,   COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),    COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,   COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ            COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)             COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),   COMD  40
     2 QEQ(NERQ)                                                         COMD  41
      INTEGER AN, BN, CN                                                 COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),   COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)       COMD  45
```

```
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      LOGICAL FIRST, JOBS                                               PRESIT 4
      DATA PSTAR, NUMIT /0.,0/                                          PRESIT 5
C +++                                                                   PRESIT 6
C +++ PRESSURE ITERATION FOR PHASE II                                   PRESIT 7
C +++                                                                   PRESIT 8
      VSUM=0.                                                           PRESIT 9
      PSUM=0.                                                           PRESIT10
      PNSUM=0.                                                          PRESIT11
      DO 20 J=1,NY                                                      PRESIT12
      IJ=(J-1)*NXP                                                      PRESIT13
      DO 20 I=1,NX                                                      PRESIT14
      IJ=IJ+1                                                           PRESIT15
      IF (I.GE.NOL.AND.I.LT.NOR.AND.J.GE.NOB.AND.J.LT.NOT) GO TO 20     PRESIT16
      DO 10 K=1,NSP                                                     PRESIT17
   10 TSPD(K)=SPD(IJ,K)                                                 PRESIT18
      CALL EOS (PSTAR,E(IJ),IJ)                                         PRESIT19
      PSD(IJ)=PSTAR                                                     PRESIT20
      VSUM=VSUM+VOL(IJ)                                                 PRESIT21
      PSUM=PSUM+PSTAR*VOL(IJ)                                           PRESIT22
      PNSUM=PNSUM+PL(IJ)*VOL(IJ)                                        PRESIT23
   20 CONTINUE                                                          PRESIT24
      PBAR=PSUM/VSUM                                                    PRESIT25
      PBAR=PBAR*VSUM/(VSUM-DT*VPISTON*0.5*X(NXP)*X(NXP))                PRESIT26
      PNBAR=PNSUM/VSUM                                                  PRESIT27
      DO 30 J=1,NY                                                      PRESIT28
      IJ=(J-1)*NXP                                                      PRESIT29
      DO 30 I=1,NX                                                      PRESIT30
      IJ=IJ+1                                                           PRESIT31
      PL(IJ)=PL(IJ)+PBAR-PNBAR                                          PRESIT32
   30 CONTINUE                                                          PRESIT33
      NUMIT=0                                                           PRESIT34
      ILNGPI=0                                                          PRESIT35
   40 NUMIT=NUMIT+1                                                     PRESIT36
      MUSTIT=0                                                          PRESIT37
      FIRST=NUMIT.EQ.1.AND.NCYC.GT.1                                    PRESIT38
      DO 90 J=1,NY                                                      PRESIT39
      IJ=(J-1)*NXP+1                                                    PRESIT40
```

```
      IJP=IJ+NXP
      JOBS=J.GE.NOB.AND.J.LT.NOT
      DO 80 I=1,NX
      IPJ=IJ+1
      IPJP=IJP+1
      IF (JOBS.AND.I.GE.NOL.AND.I.LT.NOR) GO TO 70
      X1=X(IPJ)
      R1=R(IPJ)
      Y1=Y(IPJ)
      U1=UL(IPJ)
      V1=VL(IPJ)
      X2=X(IPJP)
      R2=R(IPJP)
      Y2=Y(IPJP)
      U2=UL(IPJP)
      V2=VL(IPJP)
      X3=X(IJP)
      R3=R(IJP)
      Y3=Y(IJP)
      U3=UL(IJP)
      V3=VL(IJP)
      X4=X(IJ)
      R4=R(IJ)
      Y4=Y(IJ)
      U4=UL(IJ)
      V4=VL(IJ)
      X1P=X1+UL(IPJ)*DT
      X2P=X2+UL(IPJP)*DT
      X3P=X3+UL(IJP)*DT
      X4P=X4+UL(IJ)*DT
      Y1P=Y1+VL(IPJ)*DT
      Y2P=Y2+VL(IPJP)*DT
      Y3P=Y3+VL(IJP)*DT
      Y4P=Y4+VL(IJ)*DT
      R1P=X1P*CYL+OMCYL
      R2P=X2P*CYL+OMCYL
      R3P=X3P*CYL+OMCYL
      R4P=X4P*CYL+OMCYL
      ATR=(X2P*(Y3P-Y1P)-X1P*(Y3P-Y2P)-X3P*(Y2P-Y1P))*(R1P+R2P+R3P)
      ABL=-(X1P*(Y4P-Y3P)+X3P*(Y1P-Y4P)+X4P*(Y3P-Y1P))*(R3P+R4P+R1P)
```

```
      VW=SIXTH*(ATR+ABL)                                                PRESIT81
      MIP(IJ)=VW                                                        PRESIT82
      VRAT=VOL(IJ)/VW                                                   PRESIT83
      PSTAR=PSD(IJ)*VRAT                                                PRESIT84
C +++                                                                   PRESIT85
C +++ IF THE DENSITY CANNOT BE FACTORED OUT OF THE EQUATION OF STATE    PRESIT86
C +++ (FOR EXAMPLE, P=(GAMMA-1)*RHO*SIE+A*TEM**4/3), A COMPLETELY       PRESIT87
C +++ GENERAL, BUT LESS EFFICIENT, REPLACEMENT FOR THE LINE DEFINING    PRESIT88
C +++ PSTAR IS THE FOLLOWING 7 LINES.                                   PRESIT89
C     XISTAR=E(IJ)                                                      PRESIT90
C     ROL(IJ)=0.                                                        PRESIT91
C     DO 500 K=1,NSP                                                    PRESIT92
C     TSPD(K)=SPD(IJ,K)*VRAT                                            PRESIT93
C     ROL(IJ)=ROL(IJ)+TSPD(K)                                           PRESIT94
C 500 CONTINUE                                                          PRESIT95
C     CALL EOS (PSTAR,XISTAR,IJ)                                        PRESIT96
C +++                                                                   PRESIT97
      S=PL(IJ)-PSTAR                                                    PRESIT98
      DP=-S*RDSDP(IJ)                                                   PRESIT99
      IF (FIRST) DP=DELP(IJ)*DT/DTSAV                                   PRESI100
      PL(IJ)=PL(IJ)+DP                                                  PRESI101
      Y24=Y2-Y4                                                         PRESI102
      Y31=Y3-Y1                                                         PRESI103
      X31=X3-X1                                                         PRESI104
      X24=X2-X4                                                         PRESI105
      R24=0.5*(R2+R4)                                                   PRESI106
      R31=0.5*(R3+R1)                                                   PRESI107
      XX=0.5*DT*DP                                                      PRESI108
      RM1=1.0/MV(IPJ)                                                   PRESI109
      RM2=1.0/MV(IPJP)                                                  PRESI110
      RM3=1.0/MV(IJP)                                                   PRESI111
      RM4=1.0/MV(IJ)                                                    PRESI112
C +++ IF TESTS AT PRESIT.114-117 AND 128-129 SET BOUNDARY CONDITIONS    PRESI113
      IF (I.EQ.1.OR.J.EQ.1) RM4=0.                                      PRESI114
      IF (J.EQ.1.OR.I.EQ.NX) RM1=0.                                     PRESI115
      IF (I.EQ.NX.OR.J.EQ.NY) RM2=0.                                    PRESI116
      IF (I.EQ.1.OR.J.EQ.NY) RM3=0.                                     PRESI117
      UL(IPJ)=UL(IPJ)+XX*RM1*R(IPJ)*(Y(IPJP)-Y(IJ))                     PRESI118
      UL(IPJP)=UL(IPJP)+XX*RM2*R(IPJP)*(Y(IJP)-Y(IPJ))                  PRESI119
      UL(IJP)=UL(IJP)+XX*RM3*R(IJP)*(Y(IJ)-Y(IPJP))                     PRESI120
```

```
      UL(IJ)=UL(IJ)+XX*RM4*R(IJ)*(Y(IPJ)-Y(IJP))
      R24=R(IPJ)
      R31=R(IJ)
      IF (I.NE.1) GO TO 50
      REXTR=2.0*R31-R(IPJ)
      IF (REXTR.LT.0.) R31=0.5*(R(IPJ)+R31)
   50 CONTINUE
      IF (I.EQ.1.AND.J.GT.1) RM4=1./MV(IJ)
      IF (I.EQ.1.AND.J.LT.NY) RM3=1./MV(IJP)
      VL(IPJ)=V1-XX*RM1*X24*R24
      VL(IJ)=V4+XX*RM4*X31*R31
      R31=R(IPJP)
      R24=R(IJP)
      IF (I.NE.1) GO TO 60
      REXTR=2.0*R24-R(IPJP)
      IF (REXTR.LT.0.) R24=0.5*(R(IPJP)+R24)
   60 CONTINUE
      VL(IPJP)=V2-XX*RM2*X31*R31
      VL(IJP)=V3+XX*RM3*X24*R24
      IF (ABS(S).GT.EPS*ABS(PSTAR)) MUSTIT=1
   70 CONTINUE
      IJ=IJ+1
   80 IJP=IJP+1
   90 CONTINUE
      CALL BC (UL,VL,WL)
      IF (NUMIT.GT.ITMAX) ILNGPI=1
      IF (ILNGPI.EQ.1) RETURN
      IF (MUSTIT.EQ.1.OR.NUMIT.EQ.1) GO TO 40
      DO 110 J=1,NY
      IJ=(J-1)*NXP+1
      DO 100 I=1,NX
      DELP(IJ)=PL(IJ)-P(IJ)+PNBAR-PBAR
      DTSAV=DT
      P(IJ)=PL(IJ)
  100 IJ=IJ+1
  110 CONTINUE
      DO 140 J=1,NY
      IJ=(J-1)*NXP
      DO 130 I=1,NX
      IJ=IJ+1
```

```
      ROL(IJ)=0.                                                        PRESI161
      VRAT=VOL(IJ)/MIP(IJ)                                              PRESI162
      DO 120 K=1,NSP                                                    PRESI163
      SPD(IJ,K)=SPD(IJ,K)*VRAT                                          PRESI164
      ROL(IJ)=ROL(IJ)+SPD(IJ,K)                                         PRESI165
  120 CONTINUE                                                          PRESI166
  130 CONTINUE                                                          PRESI167
  140 CONTINUE                                                          PRESI168
      DO 150 J=1,NYP                                                    PRESI169
      IJ=(J-1)*NXP                                                      PRESI170
      DO 150 I=1,NXP                                                    PRESI171
      IJ=IJ+1                                                           PRESI172
      WL(IJ)=WL(IJ)*R(IJ)/AMAX1(1.E-100,R(IJ)+DT*UL(IJ))                PRESI173
  150 CONTINUE                                                          PRESI174
      RETURN                                                            PRESI175
      END                                                               PRESI176
```

```
      SUBROUTINE REGRID                                                 REGRID 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
```

```
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
C +++                                                                   REGRID 4
C +++ MOVE VERTICES AND COMPUTE RELATIVE VELOCITY BETWEEN GAS AND GRID  REGRID 5
C +++                                                                   REGRID 6
      DO 20 J=1,NYP                                                     REGRID 7
      IJ=(J-1)*NXP+1                                                    REGRID 8
      IJP=IJ+NXP                                                        REGRID 9
      DO 10 I=1,NXP                                                     REGRID10
      X(IJ)=X(IJ)+DT*UG(IJ)                                             REGRID11
      Y(IJ)=Y(IJ)+DT*VG(IJ)                                             REGRID12
      R(IJ)=X(IJ)*CYL+OMCYL                                             REGRID13
      IJ=IJ+1                                                           REGRID14
      IJP=IJP+1                                                         REGRID15
```

```
   10 CONTINUE                                                          REGRID16
   20 CONTINUE                                                          REGRID17
      DO 30 I=1,NXP                                                     REGRID18
      Y(I)=YPIST(I)+YPISTON-YPIST(NXP)                                  REGRID19
   30 CONTINUE                                                          REGRID20
      DO 50 J=1,NYP                                                     REGRID21
      IJ=(J-1)*NXP+1                                                    REGRID22
      DO 40 I=1,NXP                                                     REGRID23
      UREL(IJ)=UG(IJ)-UL(IJ)                                            REGRID24
      VREL(IJ)=VG(IJ)-VL(IJ)                                            REGRID25
      MVT(IJ)=0.                                                        REGRID26
   40 IJ=IJ+1                                                           REGRID27
   50 CONTINUE                                                          REGRID28
      RETURN                                                            REGRID29
      END                                                               REGRID30
```

```
      SUBROUTINE REZONE                                                 REZONE 2
      LEVEL 2, YT, VT                                                   REZONE 3
      COMMON /AT/ YT(100), VT(100)                                      REZONE 4
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
```

```
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEQ(NERQ)
      INTEGER AN, BN, CN
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
      DIMENSION RDSDP(1), RMV(1)
      EQUIVALENCE (UG,RDSDP), (RMV,E)
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP
C +++
C +++ COMPUTE GRID VELOCITY FOR THE REZONER
C +++
      JREZ=IREZ+1
      GO TO (10,40,70), JREZ
C +++ EULERIAN
   10 CONTINUE
      DO 30 J=1,NYP
      IJ=(J-1)*NXP+1
      DO 20 I=1,NXP
```

```
      UG(IJ)=0.                                                         REZONE16
      VG(IJ)=0.                                                         REZONE17
   20 IJ=IJ+1                                                           REZONE18
   30 CONTINUE                                                          REZONE19
      RETURN                                                            REZONE20
C +++ LAGRANGIAN                                                        REZONE21
   40 DO 60 J=1,NYP                                                     REZONE22
      IJ=(J-1)*NXP+1                                                    REZONE23
      DO 50 I=1,NXP                                                     REZONE24
      UG(IJ)=UL(IJ)                                                     REZONE25
      VG(IJ)=VL(IJ)                                                     REZONE26
   50 IJ=IJ+1                                                           REZONE27
   60 CONTINUE                                                          REZONE28
      RETURN                                                            REZONE29
C +++ GENERAL REZONE                                                    REZONE30
   70 CONTINUE                                                          REZONE31
      DO 80 I=1,NXP                                                     REZONE32
      IJTOP=NY*NXP+I                                                    REZONE33
      DO 80 J=1,NYP                                                     REZONE34
      IJ=(J-1)*NXP+I                                                    REZONE35
      UG(IJ)=0.                                                         REZONE36
      VG(IJ)=VPISTON                                                    REZONE37
      NO=MAX0(0,NOT-1)*NXP+I                                            REZONE38
      IF (J.GT.NOT) VG(IJ)=VPISTON*(Y(IJTOP)-Y(IJ))/(Y(IJTOP)-Y(NO))    REZONE39
   80 CONTINUE                                                          REZONE40
      IF (NOT.LE.0) RETURN                                              REZONE41
C +++                                                                   REZONE42
C +++ REZONE THE CUP IF NECESSARY                                       REZONE43
C +++                                                                   REZONE44
      IJP=NOT*NXP+1                                                     REZONE45
      IJ=IJP-NXP                                                        REZONE46
      IJM=IJ-NXP                                                        REZONE47
      DX00=Y(IJP)-Y(IJ)                                                 REZONE48
      IF (DX00.GT.0.99*(Y(IJ)-Y(IJM)).AND.VPISTON.GT.0.) RETURN         REZONE49
      IF (VPISTON.LT.0..AND.DX00.GE.0.226) RETURN                       REZONE50
      NOTM=NOT-1                                                        REZONE51
      DX01=DX00                                                         REZONE52
      FF=2.                                                             REZONE53
      QQ=(Y(IJ)-Y(1))/DX00                                              REZONE54
      DO 90 I=1,200                                                     REZONE55
```

```
      DF=AMAX1(1.E-200,FLOAT(NOT)*(FF**NOTM)-1.-QQ)                    REZONE56
      DF=(FF**NOT-FF*(1.+QQ)+QQ)/DF                                    REZONE57
      FS=FF                                                            REZONE58
      FF=FF-DF                                                         REZONE59
      IF (I.GT.190) WRITE (59,140) NCYC,I,FF,DF                        REZONE60
      IF (ABS(FF-FS).LT.1.E-10*FF) GO TO 100                           REZONE61
   90 CONTINUE                                                         REZONE62
      CALL EXIT                                                        REZONE63
  100 CONTINUE                                                         REZONE64
      YT(NOT)=Y(IJ)                                                    REZONE65
      YT(1)=Y(1)                                                       REZONE66
      VTM=0.                                                           REZONE67
      DO 110 JJ=2,NOTM                                                 REZONE68
      DX01=DX01*FF                                                     REZONE69
      J=NOT+1-JJ                                                       REZONE70
      YT(J)=YT(J+1)-DX01                                               REZONE71
      VT(J)=(YT(J)-Y((J-1)*NXP+1))/DT                                  REZONE72
      VTM=AMAX1(VTM,ABS(VT(J)))                                        REZONE73
  110 CONTINUE                                                         REZONE74
      DTTO=AZFAC*DX00/AMAX1(1.E-200,VTM)                               REZONE75
      RATIO=AMIN1(1.,DTTO/DT)                                          REZONE76
      DO 130 J=2,NOTM                                                  REZONE77
      VT(J)=RATIO*VT(J)                                                REZONE78
      DO 120 I=1,NXP                                                   REZONE79
      IJ=(J-1)*NXP+I                                                   REZONE80
      VG(IJ)=VT(J)                                                     REZONE81
  120 CONTINUE                                                         REZONE82
  130 CONTINUE                                                         REZONE83
      RETURN                                                           REZONE84
C                                                                      REZONE85
  140 FORMAT (1X,18HREZONE FAIL, NCYC=,I5,3H I=,I4,8H FF, DF=,1P2E20.12)REZONE86
      END                                                              REZONE87
```

```
      SUBROUTINE RINPUT                                                RINPUT 2
      INTEGER AM, BM, CM                                               RINPUT 3
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                       COMD   2
```

```
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ IV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
```

```
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)     COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      DIMENSION HOUT(31)                                                RINPUT 5
      DATA XRAT, DXRAT /0.48,3./                                        RINPUT 6
C +++                                                                   RINPUT 7
C +++ INPUT THE ENTHALPIES OF THE SPECIES FROM THE JANNAF TABLES        RINPUT 8
C +++ UNITS ARE KCAL/MOLE. 1=OCTANE, 2=O2, 3=N2, 4=CO2, 5=H2O,          RINPUT 9
C +++ 6=H, 7=H2, 8=O, 9=N, 10=OH, 11=CO, 12=NO                          RINPUT10
C +++                                                                   RINPUT11
      DATA (EK(N,1),N=1,51) /0.,2.8968,5.7936,8.6904,13.827,20.130,27.41RINPUT12
     1 9,35.58,44.51,54.079,64.177,74.768,85.796,97.157,108.84,120.75,13RINPUT13
     2 2.65,144.56,156.47,168.38,180.29,192.2,204.11,216.02,227.93,239.8RINPUT14
     3 4,251.74,263.65,275.56,287.47,299.38,311.29,323.2,335.11,347.02,3RINPUT15
     4 58.93,370.83,382.74,394.65,406.56,418.47,430.38,442.29,454.20,466RINPUT16
     5 .11,478.02,489.92,501.83,513.74,525.65,537.56/                   RINPUT17
      DATA (EK(N,2),N=1,51) /-2.075,-1.381,-.685,.013,.724,1.455,2.21,2.RINPUT18
     1 988,3.786,4.6,5.427,6.266,7.114,7.971,8.835,9.706,10.583,11.465,1RINPUT19
     2 2.354,13.249,14.149,15.054,15.966,16.882,17.804,18.732,19.664,20.RINPUT20
     3 602,21.545,22.493,23.446,24.403,25.365,26.331,27.302,28.276,29.25RINPUT21
     4 4,30.236,31.221,32.209,33.201,34.196,35.193,36.193,37.196,38.201,RINPUT22
     5 39.208,40.218,41.229,42.242,43.257/                              RINPUT23
      DATA (EK(N,3),N=1,51) /-2.072,-1.379,-.683,.013,.71,1.413,2.125,2.RINPUT24
     1 853,3.596,4.355,5.129,5.917,6.718,7.529,8.35,9.179,10.015,10.858,RINPUT25
     2 11.707,12.56,13.418,14.28,15.146,16.015,16.886,17.761,18.638,19.5RINPUT26
     3 17,20.398,21.28,22.165,23.051,23.939,24.829,25.719,26.611,27.505,RINPUT27
     4 28.399,29.295,30.191,31.089,31.988,32.888,33.788,34.690,35.593,36RINPUT28
     5 .496,37.4,38.306,39.212,40.119/                                  RINPUT29
      DATA (EK(N,4),N=1,51) /-2.238,-1.543,-.816,.016,.958,1.987,3.087,4RINPUT30
     1 .245,5.453,6.702,7.984,9.296,10.632,11.988,13.362,14.75,16.152,17RINPUT31
     2 .565,18.987,20.418,21.857,23.303,24.755,26.212,27.674,29.141,30.6RINPUT32
     3 13,32.088,33.567,35.049,36.535,38.024,39.515,41.01,42.507,44.006,RINPUT33
     4 45.508,47.012,48.518,50.027,51.538,53.051,54.566,56.082,57.601,59RINPUT34
     5 .122,60.644,62.169,63.695,65.223,66.753/                         RINPUT35
      DATA (EK(N,5),N=1,51) /-2.367,-1.581,-.784,.015,.825,1.654,2.509,3RINPUT36
     1 .39,4.3,5.24,6.209,7.21,8.24,9.298,10.384,11.495,12.63,13.787,14.RINPUT37
     2 964,16.16,17.373,18.602,19.846,21.103,22.372,23.653,24.945,26.246RINPUT38
```

```
3 ,27.556,28.875,30.201,31.535,32.876,34.223,35.577,36.936,38.3,39.RINPUT39
4 669,41.043,42.422,43.805,45.192,46.583,47.977,49.375,50.777,52.18RINPUT40
5 1,53.589,55.,56.413,57.829/                                       RINPUT41
 DATA (EK(N,6),N=1,51) /-1.481,-.984,-.488,.009,.506,1.003,1.5,1.99RINPUT42
1 6,2.493,2.99,3.487,3.984,4.481,4.977,5.474,5.971,6.468,6.965,7.46RINPUT43
2 1,7.958,8.455,8.952,9.449,9.945,10.442,10.939,11.436,11.933,12.43RINPUT44
3 ,12.926,13.423,13.92,14.417,14.914,15.41,15.907,16.404,16.901,17.RINPUT45
4 398,17.895,18.391,18.888,19.385,19.882,20.379,20.875,21.372,21.86RINPUT46
5 9,22.366,22.863,23.359/                                           RINPUT47
 DATA (EK(N,7),N=1,51) /-2.024,-1.265,-.662,.013,.707,1.406,2.106,2RINPUT48
1 .808,3.514,4.226,4.944,5.67,6.404,7.148,7.902,8.668,9.446,10.233,RINPUT49
2 11.03,11.836,12.651,13.475,14.307,15.146,15.993,16.848,17.708,18.RINPUT50
3 575,19.448,20.326,21.21,22.098,22.992,23.891,24.794,25.703,26.616RINPUT51
4 ,27.535,28.457,29.385,30.317,31.253,32.194,33.139,34.088,35.042,3RINPUT52
5 5.999,36.961,37.926,38.895,39.868/                                RINPUT53
 DATA (EK(N,8),N=1,51) /-1.608,-1.08,-.523,.01,.528,1.038,1.544,2.0RINPUT54
1 48,2.55,3.052,3.552,4.051,4.551,5.049,5.548,6.046,6.544,7.042,7.5RINPUT55
2 40,8.038,8.536,9.034,9.532,10.029,10.527,11.026,11.524,12.023,12.RINPUT56
3 522,13.022,13.522,14.023,14.524,15.026,15.529,16.033,16.537,17.04RINPUT57
4 3,17.549,18.057,18.565,19.075,19.586,20.098,20.611,21.126,21.641,RINPUT58
5 22.158,22.676,23.195,23.715/                                      RINPUT59
 DATA (EK(N,9),N=1,51) /-1.481,-.984,-.488,.009,.506,1.003,1.5,1.99RINPUT60
1 6,2.493,2.99,3.487,3.984,4.481,4.977,5.474,5.971,6.468,6.965,7.46RINPUT61
2 1,7.958,8.455,8.952,9.449,9.946,10.444,10.941,11.439,11.938,12.43RINPUT62
3 7,12.936,13.437,13.939,14.441,14.946,15.451,15.959,16.469,16.98,1RINPUT63
4 7.495,18.012,18.531,19.054,19.58,20.11,20.643,21.18,21.721,22.266RINPUT64
5 ,22.816,23.37,23.928/                                             RINPUT65
 DATA (EK(N,10),N=1,51) /-2.192,-1.467,-.711,.013,.725,1.432,2.137,RINPUT66
1 2.845,3.556,4.275,5.003,5.742,6.491,7.252,8.023,8.805,9.596,10.39RINPUT67
2 7,11.207,12.024,12.849,13.681,14.52,15.364,16.214,17.069,17.929,1RINPUT68
3 8.794,19.662,20.535,21.411,22.291,23.174,24.06,24.949,25.841,26.7RINPUT69
4 35,27.632,28.532,29.434,30.338,31.245,32.153,33.064,33.976,34.89,RINPUT70
5 35.807,36.725,37.644,38.566,39.489/                               RINPUT71
 DATA (EK(N,11),N=1,51) /-2.072,-1.379,-.683,.013,.711,1.417,2.137,RINPUT72
1 2.873,3.627,4.397,5.163,5.983,6.794,7.616,8.446,9.285,10.13,10.98RINPUT73
2 ,11.836,12.697,13.561,14.43,15.301,16.175,17.052,17.931,18.813,19RINPUT74
3 .696,20.582,21.469,22.357,23.248,24.139,25.032,25.927,26.822,27.7RINPUT75
```

```
     4 19,28.617,29.516,30.416,31.316,32.218,33.121,34.025,34.93,35.835,RINPUT76
     5 36.741,37.649,38.557,39.465,40.375/                              RINPUT77
      DATA (EK(N,12),N=1,51) /-2.197,-1.451,-.705,.013,.727,1.448,2.186,RINPUT78
     1 2.942,3.716,4.507,5.313,6.131,6.96,7.798,8.644,9.496,10.354,11.21RINPUT79
     2 7,12.084,12.955,13.829,14.706,15.587,16.469,17.534,18.241,19.129,RINPUT80
     3 20.02,20.911,21.805,22.7,23.596,24.493,25.392,26.291,27.192,28.09RINPUT81
     4 4,28.997,29.9,30.805,31.71,32.616,33.523,34.431,35.34,36.249,37.1RINPUT82
     5 59,38.07,38.982,39.894,40.807/                                   RINPUT83
C +++                                                                   RINPUT84
C +++ READ DATA DECK                                                    RINPUT85
C +++                                                                   RINPUT86
      READ (5,320) NAME                                                 RINPUT87
      READ (5,370) NSP,NR,NFOUT,NPOUT,LPR,ITMAX,NX,NY,NRE               RINPUT88
      READ (5,440) EPSCHM,OMGCHM,XKD                                    RINPUT89
      READ (5,350) HOUT(5),DX,HOUT(6),DY                                RINPUT90
      READ (5,350) HOUT(10),XIGNIT,HOUT(11),SIEI                        RINPUT91
      READ (5,350) HOUT(12),OM,HOUT(13),PEPS,HOUT(14),EPS               RINPUT92
      READ (5,340) HOUT(16),AZFAC                                       RINPUT93
      READ (5,370) NCLAST,NOL,NOR,NOB,NOT,ITMIN                         RINPUT94
      READ (5,340) HOUT(20),A0,HOUT(21),B0                              RINPUT95
      READ (5,340) HOUT(22),AOM                                         RINPUT96
      READ (5,330) HOUT(24),IREZ                                        RINPUT97
      READ (5,440) LAMZER,DTMAX,DT,CYL                                  RINPUT98
      READ (5,340) HOUT(31),ANC                                         RINPUT99
      READ (5,350) HOUT(2),RGAS                                         RINPU100
      READ (5,440) RPM,STROKE,ABDC,GX,GY                                RINPU101
      READ (5,440) XMUO,RPR,RSC,DISS,TCUT                               RINPU102
      READ (5,440) SWIRL,ANGVEL,TBDDY,ADIA,AIRMU                        RINPU103
      IF (NSP.LE.0) CALL TAPIN                                          RINPU104
C +++ SPECIES AND REACTION DATA INPUT                                   RINPU105
      DO 10 K=1,NSP                                                     RINPU106
      READ (5,390) RHOI(K),GAMMA(K),WT(K),HTFORM(K)                     RINPU107
C +++ CHANGE UNITS FROM KCAL/MOLE TO CGS UNITS                          RINPU108
      HTFORM(K)=HTFORM(K)*4.184E+10                                     RINPU109
      GAM1(K)=GAMMA(K)-1.                                               RINPU110
      CV(K)=RGAS/(GAM1(K)*WT(K))                                        RINPU111
      RWT(K)=1./WT(K)                                                   RINPU112
   10 CONTINUE                                                          RINPU113
C +++                                                                   RINPU114
C +++ CONVERT EK ARRAY FROM ENTHALPY TO SIE (ERGS PER GRAM)             RINPU115
```

```
C +++                                                                   RINPU116
      DO 20 K=1,NSP                                                     RINPU117
      HKZERO=EK(1,K)                                                    RINPU118
      DO 20 N=1,51                                                      RINPU119
      TEMP=100.*FLOAT(N-1)                                              RINPU120
      EK(N,K)=4.184E+10*RWT(K)*(EK(N,K)-HKZERO-1.987E-03*TEMP)          RINPU121
   20 CONTINUE                                                          RINPU122
      IF (NR.LE.0) GO TO 60                                             RINPU123
      DO 30 K=1,NR                                                      RINPU124
      READ (5,390) CF(K),EF(K),ZETAF(K)                                 RINPU125
      READ (5,390) CB(K),EB(K),ZETAB(K)                                 RINPU126
      READ (5,500) (AM(KKK,K),KKK=1,NSP)                                RINPU127
      READ (5,500) (BM(KKK,K),KKK=1,NSP)                                RINPU128
      READ (5,510) (AE(KKK,K),KKK=1,NSP)                                RINPU129
      READ (5,510) (BE(KKK,K),KKK=1,NSP)                                RINPU130
   30 CONTINUE                                                          RINPU131
C                                                                       RINPU132
C     SETS REACTION-SPECIES INDEX ARRAYS                                RINPU133
C                                                                       RINPU134
      DO 50 L=1,NR                                                      RINPU135
      NELEM(L)=0                                                        RINPU136
      NK=0                                                              RINPU137
      QR(L)=0.                                                          RINPU138
      DO 40 K=1,NSP                                                     RINPU139
      CM(K,L)=0                                                         RINPU140
      IF (AM(K,L).EQ.0.AND.BM(K,L).EQ.0) GO TO 40                       RINPU141
      NK=NK+1                                                           RINPU142
      CM(NK,L)=K                                                        RINPU143
      QR(L)=QR(L)+(AM(K,L)-BM(K,L))*HTFORM(K)                           RINPU144
   40 CONTINUE                                                          RINPU145
   50 NELEM(L)=NK                                                       RINPU146
   60 CONTINUE                                                          RINPU147
      IF (NRE.LE.0) GO TO 100                                           RINPU148
      DO 70 L=1,NRE                                                     RINPU149
      READ (5,390) AS(L),BS(L),CS(L),DS(L),ES(L)                        RINPU150
      READ (5,500) (AN(K,L),K=1,NSP)                                    RINPU151
      READ (5,500) (BN(K,L),K=1,NSP)                                    RINPU152
   70 CONTINUE                                                          RINPU153
      DO 90 L=1,NRE                                                     RINPU154
      NLM(L)=0                                                          RINPU155
```

```
      NK=0
      QEQ(L)=0.
      DO 80 K=1,NSP
      CN(K,L)=0
      IF (AN(K,L).EQ.0.AND.BN(K,L).EQ.0) GO TO 80
      NK=NK+1
      CN(NK,L)=K
      QEQ(L)=QEQ(L)+(AN(K,L)-BN(K,L))*HTFORM(K)
   80 CONTINUE
   90 NLM(L)=NK
  100 CONTINUE
      IF (LPR.EQ.0) GO TO 210
      WRITE (12,320) NAME
      WRITE (12,380) NSP,NR,NFOUT,NPOUT,LPR,ITMAX,NX,NY
      WRITE (12,550) NRE,EPSCHM,XKD,OMGCHM
      WRITE (12,350) HOUT(5),DX,HOUT(6),DY
      WRITE (12,360) HOUT(10),XIGNIT,HOUT(11),SIEI
      WRITE (12,360) HOUT(12),OM,HOUT(13),PEPS,HOUT(14),EPS
      WRITE (12,340) HOUT(16),AZFAC
      WRITE (12,480) NCLAST,NOL,NOR,NOB,NOT,ITMIN
      WRITE (12,340) HOUT(20),AO,HOUT(21),BO
      WRITE (12,340) HOUT(22),AOM
      WRITE (12,330) HOUT(24),IREZ
      WRITE (12,460) LAMZER,DTMAX,DT,CYL
      WRITE (12,340) HOUT(31),ANC
      WRITE (12,360) HOUT(2),RGAS
      WRITE (12,450) RPM,STROKE,ABDC,GX,GY
      WRITE (12,470) XMUO,RPR,RSC,DISS,TCUT
      WRITE (12,580) SWIRL,ANGVEL,TBODY,ADIA,AIRMU
      WRITE (12,410)
      DO 110 K=1,NSP
      WRITE (12,400) K,RHOI(K),CV(K),GAMMA(K),WT(K),HTFORM(K)
  110 CONTINUE
      IF (NR.LE.0) GO TO 130
      WRITE (12,420)
      DO 120 K=1,NR
      WRITE (12,400) K,QR(K)
      WRITE (12,520) CF(K),EF(K),ZETAF(K),CB(K),EB(K),ZETAB(K)
      I=3HLHS
      WRITE (12,530) I,(AM(KKK,K),KKK=1,NSP)
```

```
      I=3HRHS
      WRITE (12,530) I,(BM(KKK,K),KKK=1,NSP)
      I=4H FOR
      WRITE (12,540) I,(AE(KKK,K),KKK=1,NSP)
      I=4HBACK
      WRITE (12,540) I,(BE(KKK,K),KKK=1,NSP)
  120 CONTINUE
  130 CONTINUE
      IF (NRE.LE.0) GO TO 150
      DO 140 L=1,NRE
      WRITE (12,560) L,AS(L),BS(L),CS(L),DS(L),ES(L),QEQ(L),NLM(L)
      IMES=2HAN
      WRITE (12,570) IMES,(AN(K,L),K=1,NSP)
      IMES=2HBN
      WRITE (12,570) IMES,(BN(K,L),K=1,NSP)
      IMES=2HCN
      WRITE (12,570) IMES,(CN(K,L),K=1,NSP)
  140 CONTINUE
  150 CONTINUE
      WRITE (12,430)
      IF (LPR.EQ.1) GO TO 210
      WRITE (6,320) NAME
      WRITE (6,380) NSP,NR,NFOUT,NPOUT,LPR,ITMAX,NX,NY
      WRITE (6,550) NRE,EPSCHM,XKD,OMGCHM
      WRITE (6,350) HOUT(5),DX,HOUT(6),DY
      WRITE (6,360) HOUT(10),XIGNIT,HOUT(11),SIEI
      WRITE (6,360) HOUT(12),OM,HOUT(13),PEPS,HOUT(14),EPS
      WRITE (6,340) HOUT(16),AZFAC
      WRITE (6,480) NCLAST,NOL,NOR,NOB,NOT,ITMIN
      WRITE (6,340) HOUT(20),AO,HOUT(21),BO
      WRITE (6,340) HOUT(22),AOM
      WRITE (6,330) HOUT(24),IREZ
      WRITE (6,460) LAMZER,DTMAX,DT,CYL
      WRITE (6,340) HOUT(31),ANC
      WRITE (6,360) HOUT(2),RGAS
      WRITE (6,450) RPM,STROKE,ABDC,GX,GY
      WRITE (6,470) XMUO,RPR,RSC,DISS,TCUT
      WRITE (6,580) SWIRL,ANGVEL,TBODY,ADIA,AIRMU
      WRITE (6,410)
      DO 160 K=1,NSP
```

```
      WRITE (6,400) K,RHOI(K),CV(K),GAMMA(K),WT(K),HTFORM(K)
  160 CONTINUE
      IF (NR.LE.0) GO TO 180
      WRITE (6,420)
      DO 170 K=1,NR
      WRITE (6,400) K,QR(K)
      WRITE (6,520) CF(K),EF(K),ZETAF(K),CB(K),EB(K),ZETAB(K)
      I=3HLHS
      WRITE (6,530) I,(AM(KKK,K),KKK=1,NSP)
      I=3HRHS
      WRITE (6,530) I,(BM(KKK,K),KKK=1,NSP)
      I=4H FOR
      WRITE (6,540) I,(AE(KKK,K),KKK=1,NSP)
      I=4HBACK
      WRITE (6,540) I,(BE(KKK,K),KKK=1,NSP)
  170 CONTINUE
  180 CONTINUE
      IF (NRE.LE.0) GO TO 200
      DO 190 L=1,NRE
      WRITE (6,560) L,AS(L),BS(L),CS(L),DS(L),ES(L),QEQ(L),NLM(L)
      IMES=2HAN
      WRITE (6,570) IMES,(AN(K,L),K=1,NSP)
      IMES=2HBN
      WRITE (6,570) IMES,(BN(K,L),K=1,NSP)
      IMES=2HCN
      WRITE (6,570) IMES,(CN(K,L),K=1,NSP)
  190 CONTINUE
  200 CONTINUE
      WRITE (6,430)
C +++
C +++ INITIALIZE X, Y, R, AND VERTEX QUANTITIES
C +++
  210 CONTINUE
      IF (T.GT.0.0) GO TO 310
      NYMAX=NY
      OMCYL=1.-CYL
      DTSAV=DT
      SIXTH=1./6.
      TWLFTH=0.5*SIXTH
      NYP=NY+1
```

```
      NXP=NX+1
      DO 240 J=1,NYP
      DO 230 I=1,NXP
      IJ=(J-1)*NXP+I
      X(IJ)=FLOAT(I-1)*DX
      Y(I)=7.1625
      IF (J.GT.1) Y(IJ)=Y(IJ-NXP)+DY
      YPIST(I)=0.
      R(IJ)=X(IJ)*CYL+OMCYL
      U(IJ)=0.
      V(IJ)=0.
      UREL(IJ)=0.
      VREL(IJ)=0.
      W(IJ)=SWIRL*ANGVEL*R(IJ)
      MV(IJ)=0.
      TEM(IJ)=0.
      P(IJ)=0.
      RO(IJ)=0.
      VOL(IJ)=0.
      DO 220 K=1,NSP
      SPD(IJ,K)=0.
      SPM(IJ,K)=0.
  220 CONTINUE
  230 CONTINUE
  240 CONTINUE
      YPISTON=Y(1)
      VPISTON=0.
      CALL BC (U,V,W)
C +++
C +++ INITIALIZE THE CELL CENTERED QUANTITIES
C +++
      DO 280 J=1,NY
      IJ=(J-1)*NXP+1
      IJP=IJ+NXP
      DO 270 I=1,NX
      IPJ=IJ+1
      IPJP=IJP+1
      RO(IJ)=0.
      TOI=0.
      DO 250 K=1,NSP
```

```
      SPD(IJ,K)=RHOI(K)                                                 RINPU316
      TSPD(K)=SPD(IJ,K)                                                 RINPU317
      RO(IJ)=RO(IJ)+SPD(IJ,K)                                           RINPU318
      TOI=TOI+SPD(IJ,K)*CV(K)                                           RINPU319
  250 CONTINUE                                                          RINPU320
      CVT(IJ)=TOI/RO(IJ)                                                RINPU321
      ATR=(X(IPJP)*(Y(IJP)-Y(IPJ))-X(IPJ)*(Y(IJP)-Y(IPJP))-X(IJP)*(     RINPU322
     1 Y(IPJP)-Y(IPJ)))*(R(IPJ)+R(IPJP)+R(IJP))                         RINPU323
      ABL=-(X(IPJ)*(Y(IJ)-Y(IJP))+X(IJP)*(Y(IPJ)-Y(IJ))+X(IJ)*(Y(IJP)-  RINPU324
     1 Y(IPJ)))*(R(IJP)+R(IJ)+R(IPJ))                                   RINPU325
      VOL(IJ)=SIXTH*(ATR+ABL)                                           RINPU326
      MC(IJ)=VOL(IJ)*RO(IJ)                                             RINPU327
      RDSDP(IJ)=0.                                                      RINPU328
      XMU(IJ)=0.                                                        RINPU329
      COND(IJ)=0.                                                       RINPU330
      TEM(IJ)=SIEI                                                      RINPU331
      TB=0.01*TEM(IJ)                                                   RINPU332
      IT=TB                                                             RINPU333
      FR=TB-FLOAT(IT)                                                   RINPU334
      SIE(IJ)=0.                                                        RINPU335
      TOI=0.                                                            RINPU336
      DO 260 K=1,NSP                                                    RINPU337
      SIE(IJ)=SIE(IJ)+((1.-FR)*EK(IT+1,K)+FR*EK(IT+2,K))*SPD(IJ,K)      RINPU338
  260 TOI=TOI+CV(K)*SPD(IJ,K)                                           RINPU339
      SIE(IJ)=SIE(IJ)/RO(IJ)                                            RINPU340
      CALL EOS (P(IJ),SIE(IJ),IJ)                                       RINPU341
      IJ=IPJ                                                            RINPU342
      IJP=IPJP                                                          RINPU343
  270 CONTINUE                                                          RINPU344
  280 CONTINUE                                                          RINPU345
      DO 300 J=1,NY                                                     RINPU346
      IJ=(J-1)*NXP+1                                                    RINPU347
      IJP=IJ+NXP                                                        RINPU348
      DO 290 I=1,NX                                                     RINPU349
      IPJ=IJ+1                                                          RINPU350
      IPJP=IJP+1                                                        RINPU351
      MV(IJ)=MV(IJ)+0.25*MC(IJ)                                         RINPU352
      MV(IPJ)=MV(IPJ)+0.25*MC(IJ)                                       RINPU353
      MV(IPJP)=MV(IPJP)+0.25*MC(IJ)                                     RINPU354
      MV(IJP)=MV(IJP)+0.25*MC(IJ)                                       RINPU355
```

```
      IJP=IJP+1
  290 IJ=IJ+1
  300 CONTINUE
      CALL TEMPER
  310 CONTINUE
      READ (5,370) NCHOP
      FCHOP=FLOAT(NCHOP+1)/FLOAT(NCHOP)
      IK=MAX0(1,NOT)*NXP
      DYCHOP=0.999*(Y(NXP*NYP)-Y(IK)-STROKE-YPIST(NXP)+Y(NXP))/
     1 FLOAT(NCHOP)
      WRITE (6,490) NCHOP,DYCHOP
      WRITE (12,490) NCHOP,DYCHOP
      RETURN
C +++
C +++ FORMAT BLOCK
C +++
C
  320 FORMAT (8A10)
  330 FORMAT (A10,I5)
  340 FORMAT (A10,F10.5)
  350 FORMAT (A10,E20.8)
  360 FORMAT (1X,A10,1PE20.8)
  370 FORMAT (10X,I5)
  380 FORMAT (5X,5HNSP =,I5,16X,4HNR =,I5/3X,7HNFOUT =,I5,13X,7HNPOUT =
     1 ,I5/5X,5HLPR =,I5,13X,7HITMAX =,I5/6X,4HNX =,I5,16X,4HNY =,I5)
  390 FORMAT (10X,E20.8)
  400 FORMAT (1X,I5,1P5E20.6)
  410 FORMAT (///40X,12HSPECIES DATA//5X,1HK,11X,4HRHOI,18X,2HCV,15X,
     1 5HGAMMA,18X,2HWT,16X,6HHTFORM)
  420 FORMAT (//40X,13HREACTION DATA//5X,1HK,11X,2HQR)
  430 FORMAT (///)
  440 FORMAT (10X,E20.8)
  450 FORMAT (5X,5HRPM =,1PE20.8/2X,8HSTROKE =,E20.8/4X,6HABDC =,E20.8/6
     1 X,4HGX =,E20.8/6X,4HGY =,E20.8)
  460 FORMAT (2X,8HLAMZER =,1PE20.8/3X,7HDTMAX =,E20.8/6X,4HDT =,E20.8/5
     1 X,5HCYL =,E20.8)
  470 FORMAT (4X,6HXMUO =,1PE20.8/5X,5HRPR =,E20.8/5X,5HRSC =,E20.8/4X,6
     1 HDISS =,E20.8/4X,6HTCUT =,E20.8)
  480 FORMAT (2X,8HNCLAST =,I5/5X,5HNOL =,I5/5X,5HNOR =,I5/5X,5HNOB =,I5
     1 /5X,5HNOT =,I5/3X,7HITMIN =,I5)
```

```
490 FORMAT (//1X,28HCHOPPER PARAMETERS - NCHOP =,I4/3X,13HHALF PERIOD RINPU396
   1=,1PE13.5,2X,8HDYCHOP =,E13.5)                                   RINPU397
500 FORMAT (5X,15I5)                                                  RINPU398
510 FORMAT (5X,8F8.3)                                                 RINPU399
520 FORMAT (1X,15HCF, EF, ZETAF =,1P3E20.8/1X,15HCB, EB, ZETAB =,3E20.RINPU400
   1 8)                                                               RINPU401
530 FORMAT (1X,A3,1X,22HSTOICHIOMETRIC COEFS =,15I5/(26X,15I5))       RINPU402
540 FORMAT (1X,A4,24HWARD SPECIES EXPONENTS =,8F8.3/(29X,8F8.3))      RINPU403
550 FORMAT (5X,5HNRE =,I5/2X,8HEPSCHM =,1PE20.8/5X,5HXKD =,1PE20.8/2X,RINPU404
   1 8HOMGCHM =,E20.8)                                                RINPU405
560 FORMAT (//5X,20HEQUILIBRIUM REACTION,I5/1X,20HAS, BS, CS, DS, ES =RINPU406
   1 ,1P5E18.8/1X,5HQEQ =,E18.8,10X,5HNLM =,I5)                       RINPU407
570 FORMAT (1X,A2,2H =,15I5/(5X,15I5))                                RINPU408
580 FORMAT (3X,7HSWIRL =,1PE20.8/2X,8HANGVEL =,E20.8/3X,7HTBODY =,E20.RINPU409
   1 8/4X,6HADIA =,E20.8/3X,7HAIRMU =,E20.8)                          RINPU410
    END                                                               RINPU411
```

```
      SUBROUTINE RSEDIT (IK,LUN)                                      RSEDIT 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                      COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                           COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,COMD   4
     1 EPSCHM                                                         COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                           COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP        COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                     COMD   8
      LEVEL 2, PSD, DELP                                              COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                             COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                     COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)            COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                          COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ) COMD  14
      LEVEL 2, VOL, MV, MC                                            COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                        COMD  16
      LEVEL 2, SPD, SPM                                               COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                        COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),COMD  19
```

```
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEQ(NERQ)
      INTEGER AN, BN, CN
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
      DIMENSION RDSDP(1), RMV(1)
      EQUIVALENCE (UG,RDSDP), (RMV,E)
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP
C +++
C +++ PRINTED OUTPUT
C +++ IK=0, PRINTS U,V; OTHERWISE, PRINTS UL,VL.
C +++
      LPR1=0
      LPR2=0
      IF (LPR.GT.1.AND.LUN.EQ.6) LPR1=1
      IF (LPR.GT.0.AND.LUN.EQ.12) LPR2=1
      LINES=99
      DO 50 J=1,NYP
```

```
      IJ=(J-1)*NXP+1
      DO 40 I=1,NXP
      IF (IK.EQ.0) GO TO 10
      UU=UL(IJ)
      VV=VL(IJ)
      WW=WL(IJ)
      GO TO 20
   10 UU=U(IJ)
      VV=V(IJ)
      WW=W(IJ)
   20 CONTINUE
      IF (LINES.LT.56) GO TO 30
      LINES=0
      IF (LPR1.GT.0) WRITE (6,110) NAME
      IF (LPR1.GT.0) WRITE (6,130) T,NCYC
      IF (LPR2.GT.0) WRITE (12,110) NAME
      IF (LPR2.GT.0) WRITE (12,130) T,NCYC
      IF (LPR1.GT.0) WRITE (6,120)
      IF (LPR2.GT.0) WRITE (12,120)
   30 CONTINUE
      IF (LPR1.GT.0) WRITE (6,100) I,J,X(IJ),Y(IJ),UU,VV,SIE(IJ),RO(IJ)
     1 ,WW,P(IJ),TEM(IJ),VOL(IJ),XMU(IJ)
      IF (LPR2.GT.0) WRITE (12,100) I,J,X(IJ),Y(IJ),UU,VV,SIE(IJ),RO(IJ)
     1 ,WW,P(IJ),TEM(IJ),VOL(IJ),XMU(IJ)
      LINES=LINES+1
      IJ=IJ+1
   40 CONTINUE
   50 CONTINUE
      IF (NSP.LE.1) GO TO 90
C +++
C +++ SPECIES OUTPUT
C +++
      IF (LPR1.GT.0) WRITE (6,140)
      IF (LPR2.GT.0) WRITE (12,140)
      DO 80 J=1,NY
      IJ=(J-1)*NXP
      DO 70 I=1,NX
      IJ=IJ+1
      DO 60 K=1,NSP
   60 TSPD(K)=SPD(IJ,K)/RO(IJ)
```

```
      IF (LPR1.GT.0) WRITE (6,150) I,J,(TSPD(K),K=1,NSP)               RSEDIT54
      IF (LPR2.GT.0) WRITE (12,150) I,J,(TSPD(K),K=1,NSP)              RSEDIT55
   70 CONTINUE                                                          RSEDIT56
   80 CONTINUE                                                          RSEDIT57
   90 CONTINUE                                                          RSEDIT58
      IF (LPR2.GT.0) CALL ADV (1)                                       RSEDIT59
      RETURN                                                            RSEDIT60
C +++                                                                   RSEDIT61
C +++ FORMAT BLOCK                                                      RSEDIT62
C +++                                                                   RSEDIT63
C                                                                       RSEDIT64
  100 FORMAT (1X,I3,1X,I3,1X,1P4E11.3,2E10.3,E11.3,4E10.3)              RSEDIT65
  110 FORMAT (1H1,8A10)                                                 RSEDIT66
  120 FORMAT (1H0,2X,1HI,3X,1HJ,6X,1HX,10X,1HY,10X,1HU,10X,1HV,10X,3HSIERSEDIT67
     1 ,7X,3HRHO,9X,1HW,9X,1HP,7X,3HTEM,7X,3HVOL,7X,3HXMU)              RSEDIT68
  130 FORMAT (3X,2HT=,1PE12.5,1X,6HCYCLE=,I5)                           RSEDIT69
  140 FORMAT (1H1,10X,22HSPECIES MASS FRACTIONS//5X,1HI,4X,1HJ,6X,1H1,10RSEDIT70
     1 X,1H2,10X,1H3,10X,1H4,10X,1H5,10X,1H6,10X,1H7,10X,1H8,10X,1H9,10XRSEDIT71
     2 ,2H10)                                                           RSEDIT72
  150 FORMAT (1X,2I5,1P10E11.3/(12X,10E11.3))                           RSEDIT73
      END                                                               RSEDIT74
```

```
      SUBROUTINE TAPIN                                                  TAPIN  2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
```

```
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)
      LEVEL 2, SPD, SPM
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEQ(NERQ)
      INTEGER AN, BN, CN
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
      DIMENSION RDSDP(1), RMV(1)
      EQUIVALENCE (UG,RDSDP), (RMV,E)
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP
C +++
C +++ DUMP TAPE INPUT FOR PROBLEM RESTART
C +++
      READ (7) NDUMP
      WRITE (6,30) NR
      WRITE (12,30) NR
      WRITE (59,30) NR
```

```
      IF (NDUMP.EQ.NR) GO TO 10                                         TAPIN 11
      WRITE (6,40) NDUMP,NR                                             TAPIN 12
      WRITE (12,40) NDUMP,NR                                            TAPIN 13
      WRITE (59,40) NDUMP,NR                                            TAPIN 14
      CALL EXIT                                                         TAPIN 15
   10 CONTINUE                                                          TAPIN 16
      READ (7) X,R,Y,P,PSD,DELP                                         TAPIN 17
      READ (7) XMU,COND,TEM,HK                                          TAPIN 18
      READ (7) RO,SIE                                                   TAPIN 19
      READ (7) U,UL,V,VL                                                TAPIN 20
      READ (7) VOL,MV,MC                                                TAPIN 21
      READ (7) SPD,SPM,CVT                                              TAPIN 22
      READ (7) RC,UREL,VREL,E,UP,VP,PL,MP,UG,VG,MVT,ROL,Q               TAPIN 23
      READ (7) AZMOM,WORK,CAPDTH,CAPDR,CYL,DX,DT,DY,DTSAV,ILNGPI,LPR    TAPIN 24
     1 ,NAME,NYMAX,NCYC,NR,NSP,NY,NYP,NX,NXP,NUMIT,OMCYL,PI,RADMOM      TAPIN 25
     2 ,RDXMAX,SIXTH,T,TWLFTH,TOUT,UTMAX,VMAX,VVORT,XCONV,XCONVZ,YCONV  TAPIN 26
     3 ,YCONVZ                                                          TAPIN 27
      READ (7) ABDC,GX,GY,STROKE,RPM,VPISTON,YPISTON,YPIST,DTMAX        TAPIN 28
      READ (7) WP,W,WL                                                  TAPIN 29
      DO 20 J=1,NY                                                      TAPIN 30
      DO 20 I=1,NX                                                      TAPIN 31
      IJ=(J-1)*NXP+I                                                    TAPIN 32
      DELP(IJ)=0.                                                       TAPIN 33
   20 CONTINUE                                                          TAPIN 34
      RETURN                                                            TAPIN 35
C                                                                       TAPIN 36
   30 FORMAT (/1X,16HWANT DUMP NUMBER,I5)                               TAPIN 37
   40 FORMAT (1X,19HWRONG DUMP NUMBER -,2I6)                            TAPIN 38
      END                                                               TAPIN 39
```

```
      SUBROUTINE TAPOUT                                                 TAPOUT 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
```

```
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX      COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
```

```
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
      DATA NDUMP /0/                                                    TAPOUT 4
C +++                                                                   TAPOUT 5
C +++ DUMP TAPE OUTPUT                                                  TAPOUT 6
C +++                                                                   TAPOUT 7
      REWIND 7                                                          TAPOUT 8
      NDUMP=NDUMP+1                                                     TAPOUT 9
      WRITE (7) NDUMP                                                   TAPOUT10
      WRITE (7) X,R,Y,P,PSD,DELP                                        TAPOUT11
      WRITE (7) XMU,COND,TEM,HK                                         TAPOUT12
      WRITE (7) RO,SIE                                                  TAPOUT13
      WRITE (7) U,UL,V,VL                                               TAPOUT14
      WRITE (7) VOL,MV,MC                                               TAPOUT15
      WRITE (7) SPD,SPM,CVT                                             TAPOUT16
      WRITE (7) RC,UREL,VREL,E,UP,VP,PL,MP,UG,VG,MVT,ROL,Q              TAPOUT17
      WRITE (7) AZMOM,WORK,CAPDTH,CAPDR,CYL,DX,DT,DY,DTSAV,ILNGPI,LPR   TAPOUT18
     1 ,NAME,NYMAX,NCYC,NR,NSP,NY,NYP,NX,NXP,NUMIT,OMCYL,PI,RADMOM      TAPOUT19
     2 ,RDXMAX,SIXTH,T,TWLFTH,TOUT,UTMAX,VMAX,VVORT,XCONV,XCONVZ,YCONV  TAPOUT20
     3 ,YCONVZ                                                          TAPOUT21
      WRITE (7) ABDC,GX,GY,STROKE,RPM,VPISTON,YPISTON,YPIST,DTMAX       TAPOUT22
      WRITE (7) WP,W,WL                                                 TAPOUT23
      WRITE (6,10) NDUMP,NCYC                                           TAPOUT24
      WRITE (12,10) NDUMP,NCYC                                          TAPOUT25
      WRITE (59,10) NDUMP,NCYC                                          TAPOUT26
      CALL EXIT                                                         TAPOUT27
C                                                                       TAPOUT28
   10 FORMAT (1X,19HTAPE DUMP COMPLETED,I4,3X,7HCYCLE =,I5)             TAPOUT29
      END                                                               TAPOUT30
```

```
      SUBROUTINE TEMPER                                                 TEMPER 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
```

```
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC
      LEVEL 2, PSD, DELP
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)
      LEVEL 2, XMU, COND, TEM, HK
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)
      LEVEL 2, VOL, MV, MC
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)
      LEVEL 2, SPD, SPM
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGUN/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEQ(NERQ)
      INTEGER AN, BN, CN
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
      DIMENSION RDSDP(1), RMV(1)
```

```
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
C +++                                                                   TEMPER 4
C +++ COMPUTE CVT, THE TOTAL SPECIFIC HEAT                               TEMPER 5
C +++                                                                   TEMPER 6
      DO 60 J=1,NY                                                      TEMPER 7
      IJ=(J-1)*NXP                                                      TEMPER 8
      DO 50 I=1,NX                                                      TEMPER 9
      IJ=IJ+1                                                           TEMPER10
      IF (TEM(IJ).GE.5000.) GO TO 70                                    TEMPER11
      IT=0.01*TEM(IJ)                                                   TEMPER12
   10 CONTINUE                                                          TEMPER13
      EHI=0.                                                            TEMPER14
      ELO=0.                                                            TEMPER15
      DO 20 K=1,NSP                                                     TEMPER16
      ELO=ELO+SPD(IJ,K)*EK(IT+1,K)                                      TEMPER17
      EHI=EHI+SPD(IJ,K)*EK(IT+2,K)                                      TEMPER18
   20 CONTINUE                                                          TEMPER19
      ELO=ELO/RO(IJ)                                                    TEMPER20
      EHI=EHI/RO(IJ)                                                    TEMPER21
      IF (SIE(IJ).LE.EHI) GO TO 30                                      TEMPER22
      IT=IT+1                                                           TEMPER23
      IF (IT.GT.49) GO TO 70                                            TEMPER24
      GO TO 10                                                          TEMPER25
   30 CONTINUE                                                          TEMPER26
      IF (SIE(IJ).GE.ELO) GO TO 40                                      TEMPER27
      IT=IT-1                                                           TEMPER28
      IF (IT.LT.0) GO TO 70                                             TEMPER29
      GO TO 10                                                          TEMPER30
   40 CONTINUE                                                          TEMPER31
      FR=(SIE(IJ)-ELO)/(EHI-ELO)                                        TEMPER32
      TEM(IJ)=(FLOAT(IT)+FR)*100.                                       TEMPER33
      CVT(IJ)=(EHI-ELO)*0.01                                            TEMPER34
   50 CONTINUE                                                          TEMPER35
   60 CONTINUE                                                          TEMPER36
      RETURN                                                            TEMPER37
   70 CONTINUE                                                          TEMPER38
      WRITE (59,80) NCYC,I,J,TEM(IJ),SIE(IJ),IT                         TEMPER39
      WRITE (12,80) NCYC,I,J,TEM(IJ),SIE(IJ),IT                         TEMPER40
```

```
      WRITE (6,80) NCYC,I,J,TEM(IJ),SIE(IJ),IT                          TEMPER41
      CALL EXIT                                                         TEMPER42
C +++                                                                   TEMPER43
   80 FORMAT (1X,44HTEMPERATURE OVERFLOW IN TEMPER, CYCLE,I,J,T=,3I5,   TEMPER44
     1 1PE13.4/1X,6HSIE,IT,E13.4,I5)                                    TEMPER45
      END                                                               TEMPER46
```

```
      SUBROUTINE TIMSTP                                                 TIMSTP 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
```

```
      2 Q(NXQ)
       COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
      1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
       COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
      1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
      2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
      3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
      4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
       COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
       COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
      1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
      2 QEQ(NERQ)
       INTEGER AN, BN, CN
       COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
      1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
      2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
       DIMENSION RDSDP(1), RMV(1)
       EQUIVALENCE (UG,RDSDP), (RMV,E)
       REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP
C +++
C +++ COMPUTE THE NEW TIME STEP, DT
C +++
       UTMAX=-1.E+20
       IF (NUMIT.LT.ITMIN.AND.NCYC.GT.3) DTMAX=1.02*DTMAX
       DTDIF=1.E+200
       DTCHEM=1.E+250
       DTSOND=1.E+250
       DO 20 J=1,NY
       IJ=(J-1)*NXP+1
       IJP=IJ+NXP
       DO 10 I=1,NX
       IPJ=IJ+1
       IPJP=IJP+1
       A=1./AMAX1(ABS(X(IPJP)-X(IJ)),ABS(X(IPJ)-X(IJP)))
       B=1./AMAX1(ABS(Y(IPJP)-Y(IJ)),ABS(Y(IJP)-Y(IPJ)))
       ATR=X(IPJP)*(Y(IJP)-Y(IPJ))-X(IPJ)*(Y(IJP)-Y(IPJP))-X(IJP)*(Y(IPJP
      1 )-Y(IPJ))
       ABL=X(IPJ)*(Y(IJP)-Y(IJ))+X(IJP)*(Y(IJ)-Y(IPJ))+X(IJ)*(Y(IPJ)-Y
      1 (IJP))
       AREA=0.5*(ATR+ABL)
```

```
      DIAG2=AMAX1((X(IJ)-X(IPJP))**2+(Y(IJ)-Y(IPJP))**2,(X(IPJ)-X(IJP))*TIMSTP25
     1 *2+(Y(IPJ)-Y(IJP))**2)                                          TIMSTP26
      AB=AREA*AREA/DIAG2                                                TIMSTP27
      XXMU=XMU(IJ)*AMAX1(1.333,RPR,RSC)/RO(IJ)                          TIMSTP28
      DTDIF=AMIN1(DTDIF,AB/AMAX1(XXMU,1.E-100))                         TIMSTP29
      UU=A*AMAX1(ABS(UREL(IJ)),ABS(UREL(IPJ)),ABS(UREL(IJP)),ABS(UREL   TIMSTP30
     1 (IJP+1)))                                                        TIMSTP31
      VV=B*AMAX1(ABS(VREL(IJ)),ABS(VREL(IPJ)),ABS(VREL(IJP)),ABS(VREL   TIMSTP32
     1 (IJP+1)))                                                        TIMSTP33
      UTMAX=AMAX1(UTMAX,UU,VV)                                          TIMSTP34
      IJ=IPJ                                                            TIMSTP35
      IJP=IJP+1                                                         TIMSTP36
   10 CONTINUE                                                          TIMSTP37
   20 CONTINUE                                                          TIMSTP38
      IF (UTMAX.EQ.0.) UTMAX=AZFAC                                      TIMSTP39
      IF (NCYC.EQ.0) RETURN                                             TIMSTP40
      DTDIF=DTDIF*0.4                                                   TIMSTP41
      DTCON=AZFAC/UTMAX                                                 TIMSTP42
      DT=AMIN1(1.1*DTSAV,DTCON,DTMAX,DTDIF,DTCHEM)                      TIMSTP43
      ILIM=1HB                                                          TIMSTP44
      IF (DT.EQ.1.1*DTSAV) ILIM=1HG                                     TIMSTP45
      IF (DT.EQ.DTCON) ILIM=1HC                                         TIMSTP46
      IF (DT.EQ.DTDIF) ILIM=1HD                                         TIMSTP47
      IF (DT.EQ.DTMAX) ILIM=1HM                                         TIMSTP48
      DTSAV=DT                                                          TIMSTP49
      RETURN                                                            TIMSTP50
      END                                                               TIMSTP51
```

```
      SUBROUTINE UNDROP                                                 UNDROP 2
      CALL GFR80 (1HU,7HCONCHAS,7,3H105,5HT3LDC,4HKEEP)                 UNDROP 3
      CALL GRPHLUN (12)                                                 UNDROP 4
      CALL LIB4020                                                      UNDROP 5
      CALL GRPHFTN                                                      UNDROP 6
      CALL SETFLSH                                                      UNDROP 7
      RETURN                                                            UNDROP 8
      END                                                               UNDROP 9
```

```
      SUBROUTINE VELPLT (IK)                                            VELPLT 2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU                           COMD  26
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU                 COMD  27
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),      COMD  28
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ), COMD  29
     2 Q(NXQ)                                                           COMD  30
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1COMD  31
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX       COMD  32
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,  COMD  33
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),   COMD  34
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,COMD  35
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,  COMD  36
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ           COMD  37
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)            COMD  38
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)COMD  39
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),  COMD  40
```

```
     2 QEQ(NERQ)                                                        COMD  41
      INTEGER AN, BN, CN                                                COMD  42
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),  COMD  43
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQCOMD  44
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)      COMD  45
      DIMENSION RDSDP(1), RMV(1)                                        COMD  46
      EQUIVALENCE (UG,RDSDP), (RMV,E)                                   COMD  47
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP                       COMD  48
C +++                                                                   VELPLT 4
      DATA VSCALE /1./                                                  VELPLT 5
C +++                                                                   VELPLT 6
C +++ DRAW THE VELOCITY VECTOR PLOT                                     VELPLT 7
C +++                                                                   VELPLT 8
      IF (VMAX.EQ.0) GO TO 70                                           VELPLT 9
      YMIN=1.E+250                                                      VELPLT10
      XMIN=1.E+250                                                      VELPLT11
      DO 10 I=1,NXP                                                     VELPLT12
      DO 10 J=1,NYP                                                     VELPLT13
      IJ=(J-1)*NXP+I                                                    VELPLT14
      XMIN=AMIN1(X(IJ),XMIN)                                            VELPLT15
      YMIN=AMIN1(Y(IJ),YMIN)                                            VELPLT16
   10 CONTINUE                                                          VELPLT17
      DROU=VSCALE/UTMAX                                                 VELPLT18
      CALL ADV (1)                                                      VELPLT19
      DO 60 J=1,NYP                                                     VELPLT20
      IJ=(J-1)*NXP+1                                                    VELPLT21
      IJP=IJ+NXP                                                        VELPLT22
      DO 50 I=1,NXP                                                     VELPLT23
      XA=X(IJ)                                                          VELPLT24
      YA=Y(IJ)                                                          VELPLT25
      IF (IK.EQ.1) GO TO 20                                             VELPLT26
      UU=U(IJ)                                                          VELPLT27
      VV=V(IJ)                                                          VELPLT28
      GO TO 30                                                          VELPLT29
   20 UU=UL(IJ)                                                         VELPLT30
      VV=VL(IJ)                                                         VELPLT31
   30 CONTINUE                                                          VELPLT32
      IX1=(XA-XMIN)*XCONV                                               VELPLT33
      IY1=950.0-(YA-YMIN)*YCONV                                         VELPLT34
      IX2=IX1+UU*DROU*XCONV                                             VELPLT35
```

```
      IY2=IY1-VV*DROU*YCONV                                          VELPLT36
      IF (I.GT.NOL.AND.I.LE.NOR.AND.J.GE.NOB.AND.J.LT.NOT) GO TO 40  VELPLT37
      IF (MAX0(IX1,IY1,IX2,IY2).GT.1023) GO TO 50                    VELPLT38
      IF (MIN0(IX1,IY1,IX2,IY2).LT.0) GO TO 50                       VELPLT39
      CALL DRV (IX1,IY1,IX2,IY2)                                     VELPLT40
      CALL PLT (IX1,IY1,42)                                          VELPLT41
   40 CONTINUE                                                       VELPLT42
   50 IJ=IJ+1                                                        VELPLT43
   60 CONTINUE                                                       VELPLT44
      CALL LINCNT (61)                                               VELPLT45
      WRITE (12,140) T,NCYC,VMAX                                     VELPLT46
   70 CONTINUE                                                       VELPLT47
C +++                                                                VELPLT48
C +++ CALL THE CONTOUR PLOTTING ROUTINE                               VELPLT49
C +++                                                                VELPLT50
      CALL CONTUR (1,0,NX,NY,P,X,Y,T,NCYC)                           VELPLT51
      CALL CONTUR (2,0,NX,NY,RO,X,Y,T,NCYC)                          VELPLT52
      CALL CONTUR (3,0,NX,NY,SIE,X,Y,T,NCYC)                         VELPLT53
      DO 80 J=1,NY                                                   VELPLT54
      IJ=(J-1)*NXP                                                   VELPLT55
      DO 80 I=1,NX                                                   VELPLT56
      IJ=IJ+1                                                        VELPLT57
   80 MP(IJ)=TEM(IJ)                                                 VELPLT58
      CALL CONTUR (6,0,NX,NY,MP,X,Y,T,NCYC)                          VELPLT59
      DO 90 J=1,NY                                                   VELPLT60
      IJ=(J-1)*NXP                                                   VELPLT61
      DO 90 I=1,NX                                                   VELPLT62
      IJ=IJ+1                                                        VELPLT63
   90 MP(IJ)=XMU(IJ)                                                 VELPLT64
      CALL CONTUR (7,0,NX,NY,MP,X,Y,T,NCYC)                          VELPLT65
      IF (SWIRL.LT.0.5) GO TO 110                                    VELPLT66
      DO 100 I=1,NX                                                  VELPLT67
      DO 100 J=1,NY                                                  VELPLT68
      IJ=(J-1)*NXP+I                                                 VELPLT69
      MP(IJ)=0.25*(W(IJ)+W(IJ+1)+W(IJ+NXP+1)+W(IJ+NXP))              VELPLT70
  100 CONTINUE                                                       VELPLT71
      CALL CONTUR (4,0,NX,NY,MP,X,Y,T,NCYC)                          VELPLT72
  110 CONTINUE                                                       VELPLT73
      IF (NR.LT.1.AND.NRE.LT.1) RETURN                               VELPLT74
      DO 130 K=1,NSP                                                 VELPLT75
```

```
      DO 120 J=1,NY                                                     VELPLT76
      IJ=(J-1)*NXP                                                      VELPLT77
      DO 120 I=1,NX                                                     VELPLT78
      IJ=IJ+1                                                           VELPLT79
  120 MP(IJ)=SPD(IJ,K)/RO(IJ)                                           VELPLT80
      CALL CONTUR (5,K,NX,NY,MP,X,Y,T,NCYC)                             VELPLT81
  130 CONTINUE                                                          VELPLT82
      RETURN                                                            VELPLT83
C                                                                       VELPLT84
  140 FORMAT (1X,3HT =,1PE14.6,2X,7HCYCLE =,I6,2X,6HVMAX =,E12.4)       VELPLT85
      END                                                               VELPLT86
```

```
      SUBROUTINE VINIT                                                  VINIT  2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD   2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD   3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD   4
     1 EPSCHM                                                           COMD   5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD   6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD   7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD   8
      LEVEL 2, PSD, DELP                                                COMD   9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD  10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD  11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD  12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD  13
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)   COMD  14
      LEVEL 2, VOL, MV, MC                                              COMD  15
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)                          COMD  16
      LEVEL 2, SPD, SPM                                                 COMD  17
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)                          COMD  18
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ), COMD  19
     1 RHOI(NSQ)                                                        COMD  20
      LEVEL 2, CVT                                                      COMD  21
      COMMON /KAH8/ CVT(NXQ)                                            COMD  22
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO                     COMD  23
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),        COMD  24
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)                                     COMD  25
```

```
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEQ(NERQ)
      INTEGER AN, BN, CN
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
      DIMENSION RDSDP(1), RMV(1)
      EQUIVALENCE (UG,RDSDP), (RMV,E)
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP
      ILNGPI=0
      DO 50 J=1,NYP
      IJ=(J-1)*NXP+1
      DO 40 I=1,NX
      IF (J.EQ.NYP) GO TO 30
      RO(IJ)=MC(IJ)/VOL(IJ)
      DO 10 K=1,NSP
   10 TSPD(K)=SPD(IJ,K)
      CALL EOS (P(IJ),SIE(IJ),IJ)
      PL(IJ)=P(IJ)
      ROL(IJ)=RO(IJ)
      E(IJ)=SIE(IJ)
      DO 20 K=1,NSP
      SPM(IJ,K)=SPD(IJ,K)*VOL(IJ)
   20 CONTINUE
   30 VL(IJ)=V(IJ)
      UL(IJ)=U(IJ)
```

```
      WL(IJ)=W(IJ)
      IJ=IJ+1
   40 CONTINUE
      UL(IJ)=U(IJ)
      VL(IJ)=V(IJ)
      WL(IJ)=W(IJ)
   50 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VISC
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,
     1 EPSCHM
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC
      LEVEL 2, PSD, DELP
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)
      LEVEL 2, XMU, COND, TEM, HK
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)
      LEVEL 2, VOL, MV, MC
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)
      LEVEL 2, SPD, SPM
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
      LEVEL 2, WP, ANGVEL, TBODY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBODY, ADIA, AIRMU
```

```
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEQ(NERQ)
      INTEGER AN, BN, CN
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
      DIMENSION RDSDP(1), RMV(1)
      EQUIVALENCE (UG,RDSDP), (RMV,E)
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP
C +++
C +++ DIFFUSION TERMS FOR ALL EQUATIONS
C +++
C
C     DEFINE CELL CENTERS, CELL INTERNAL ENERGIES, AND CELL CENTER
C       VISCOSITIES
C
      TWOTHD=2./3.
      HAFDT=0.5*DT
      DDT=HAFDT*DISS
      SQKD=XKD*XKD/1.4142
      DO 20 J=1,NY
      IJP=J*NXP+1
      IJ=IJP-NXP
      DO 10 I=1,NX
      IPJ=IJ+1
      IPJP=IJP+1
      X1=X(IPJ)
      X2=X(IPJP)
```

```
      X3=X(IJP)
      X4=X(IJ)
      Y1=Y(IPJ)
      Y2=Y(IPJP)
      Y3=Y(IJP)
      Y4=Y(IJ)
      R1=R(IPJ)
      R2=R(IPJP)
      R3=R(IJP)
      R4=R(IJ)
      U1=U(IPJ)
      U2=U(IPJP)
      U3=U(IJP)
      U4=U(IJ)
      V1=V(IPJ)
      V2=V(IPJP)
      V3=V(IJP)
      V4=V(IJ)
      DIV=((R1+R2)*((U1+U2)*(Y2-Y1)+(V1+V2)*(X1-X2))+(R2+R3)*((U2+U3)*
     1 (Y3-Y2)+(V2+V3)*(X2-X3))+(R3+R4)*((U3+U4)*(Y4-Y3)+(V4+V3)*(X3-X4)
     2 )+(R4+R1)*((U4+U1)*(Y1-Y4)+(V4+V1)*(X4-X1)))/(4.*VOL(IJ))
      PIXX=((R2+R1)*(U2+U1)*(Y2-Y1)+(R2+R3)*(U3+U2)*(Y3-Y2)+(R4+R3)*(U4
     1 +U3)*(Y4-Y3)+(R1+R4)*(U1+U4)*(Y1-Y4)-0.5*CYL*(U1+U2+U3+U4)*((X1
     2 -X3)*(Y2-Y4)+(X2-X4)*(Y3-Y1)))/(2.*VOL(IJ))
      PIYY=((R1+R2)*(V1+V2)*(X1-X2)+(R2+R3)*(V2+V3)*(X2-X3)+(R3+R4)*(V3
     1 +V4)*(X3-X4)+(R4+R1)*(V4+V1)*(X4-X1))/(2.*VOL(IJ))
      PIXY=((R1+R2)*((U1+U2)*(X1-X2)+(V1+V2)*(Y2-Y1))+(R2+R3)*((U2+U3)*
     1 (X2-X3)+(V2+V3)*(Y3-Y2))+(R3+R4)*((U3+U4)*(X3-X4)+(V3+V4)*(Y4-Y3)
     2 )+(R4+R1)*((U4+U1)*(X4-X1)+(V4+V1)*(Y1-Y4))-0.5*CYL*(V1+V2+V3+V4)
     3 *((X1-X3)*(Y2-Y4)+(X2-X4)*(Y3-Y1)))/(4.*VOL(IJ))
      PTH=CYL*((U1+U2+U3+U4)*((X1-X3)*(Y2-Y4)+(X2-X4)*(Y3-Y1)))/(4.*VOL
     1 (IJ))
      XCEN(IJ)=.25*(X(IJ)+X(IPJ)+X(IPJP)+X(IJP))
      YCEN(IJ)=.25*(Y(IJ)+Y(IPJ)+Y(IPJP)+Y(IJP))
      RCEN(IJ)=XCEN(IJ)*CYL+OMCYL
      RAREA=2./((X2-X4)*(Y3-Y1)-(X1-X3)*(Y4-Y2))
      PIRT=SWIRL*0.5*RAREA*RCEN(IJ)*((W(IPJP)/AMAX1(1.E-99,R2)-W(IJ)
     1 /AMAX1(1.E-99,R4))*(Y3-Y1)-(W(IPJ)/AMAX1(1.E-99,R1)-W(IJP)/AMAX1(
     2 1.E-99,R3))*(Y4-Y2))
      PIZT=SWIRL*0.5*RAREA*((W(IJ)-W(IPJP))*(X3-X1)-(W(IPJ)-W(IJP))*(X2
```

```
     1 -X4))                                                              VISC  63
      OFFDIG=PIXY*PIXY+PIRT*PIRT+PIZT*PIZT                                VISC  64
      MIP(IJ)=RO(IJ)*E(IJ)                                                VISC  65
      MUP(IJ)=0.5*(X(IPJ)*(Y(IPJP)-Y(IJ))+X(IPJP)*(Y(IJP)-Y(IPJ))+X(IJP)VISC  66
     1 *(Y(IJ)-Y(IPJP))+X(IJ)*(Y(IPJ)-Y(IJP)))                            VISC  67
      AREA=AMAX1((X1-X2)**2+(Y1-Y2)**2,(X2-X3)**2+(Y2-Y3)**2,(X3-X4)**2+VISC  68
     1 (Y3-Y4)**2,(X4-X1)**2+(Y4-Y1)**2)                                  VISC  69
      TIJ=TEM(IJ)                                                         VISC  70
      XMU(IJ)=XMUO*RO(IJ)+AIRMU*1.457E-05*TIJ*QSQRT(TIJ)/(TIJ+110.)+SQKDVISC  71
     1 *AREA*QSQRT(PIXX*PIXX+PIYY*PIYY+PTH*PTH+2.*OFFDIG)*RO(IJ)          VISC  72
      COND(IJ)=RPR*XMU(IJ)*CVT(IJ)                                        OUTPQ  8
      IJ=IPJ                                                              VISC  74
   10 IJP=IPJP                                                            VISC  75
   20 CONTINUE                                                            VISC  76
C +++ SMOOTH OUT THE SGS VISCOSITY                                        OUTPQ  9
      ALPHX=50.                                                           OUTPQ 10
      ALPHY=50.                                                           OUTPQ 11
      DO 30 J=1,NY                                                        VISC  78
      DO 30 I=1,NX                                                        VISC  79
      IJP=J*NXP+I                                                         VISC  80
      IJ=IJP-NXP                                                          VISC  81
      IJM=IJ-NXP                                                          VISC  82
      IPJ=IJ+1                                                            VISC  83
      IMJ=IJ-1                                                            VISC  84
      IF (I.EQ.1) IMJ=IJ                                                  VISC  86
      IF (I.EQ.NX) IPJ=IJ                                                 VISC  87
      IF (J.EQ.1) IJM=IJ                                                  VISC  88
      IF (J.EQ.NY) IJP=IJ                                                 VISC  89
      R(IJ)=(XMU(IJ)+ALPHX*(XMU(IPJ)+XMU(IMJ))+ALPHY*(XMU(IJP)+XMU(IJM))VISC  90
     1 )/(1.+2.*(ALPHX+ALPHY))                                            VISC  91
   30 CONTINUE                                                            VISC  92
      DO 40 J=1,NY                                                        VISC  93
      IJ=(J-1)*NXP                                                        VISC  94
      DO 40 I=1,NX                                                        VISC  95
      IJ=IJ+1                                                             VISC  96
      XMU(IJ)=R(IJ)                                                       VISC  97
      COND(IJ)=RPR*XMU(IJ)*CVT(IJ)                                        VISC  98
      R(IJ)=OMCYL+CYL*X(IJ)                                               VISC  99
   40 CONTINUE                                                            VISC 100
C +++                                                                     VISC 101
```

```
C +++ DIFFUSE SPECIES AND HEAT
C +++ SPD IS G/CM**3 AND MIP IS ERGS/CM**3
C +++
      DO 210 J=1,NY
      DO 200 I=1,NX
      IJP=J*NXP+I
      IJ=IJP-NXP
      IJM=IJ-NXP
      IPJ=IJ+1
      IMJ=IJ-1
      IPJP=IJP+1
C +++ SET UP TEMPORARY ARRAYS FOR THE NINE-POINT DIFFUSION SCHEME.
C +++ SCHEMATIC OF NUMBERING SCHEME FOR THE DIFFUSION STENCIL
C +++
C +++    C4    C3    C2
C +++       V3    V2
C +++    C5   C9=IJ  C1
C +++       V4    V1
C +++    C6    C7    C8
C +++
      IF (I.EQ.1) GO TO 70
      TC(4)=TC(3)
      TC(5)=TC(9)
      TC(6)=TC(7)
      TC(3)=TC(2)
      TC(9)=TC(1)
      TC(7)=TC(8)
      DO 50 K=1,NSP
      SPDC(4,K)=SPDC(3,K)
      SPDC(5,K)=SPDC(9,K)
      SPDC(6,K)=SPDC(7,K)
      SPDC(3,K)=SPDC(2,K)
      SPDC(9,K)=SPDC(1,K)
      SPDC(7,K)=SPDC(8,K)
   50 CONTINUE
      IF (I.EQ.NX) GO TO 100
      TC(1)=TEM(IPJ)
      TC(2)=TEM(IPJ)
      TC(8)=TEM(IPJ)
      IF (J.LT.NY) TC(2)=TEM(IPJP)
```

```
      IF (J.GT.1) TC(8)=TEM(IJM+1)
      DO 60 K=1,NSP
      SPDC(1,K)=SPM(IPJ,K)/MC(IPJ)
      SPDC(2,K)=SPDC(1,K)
      SPDC(8,K)=SPDC(1,K)
      IF (J.LT.NY) SPDC(2,K)=SPM(IPJP,K)/MC(IPJP)
      IF (J.GT.1) SPDC(8,K)=SPM(IJM+1,K)/MC(IJM+1)
   60 CONTINUE
      GO TO 100
   70 CONTINUE
      DO 80 KK=1,9
      TC(KK)=TEM(IJ)
      DO 80 K=1,NSP
      SPDC(KK,K)=SPM(IJ,K)/MC(IJ)
   80 CONTINUE
      TC(2)=TEM(IPJ)
      TC(1)=TEM(IPJ)
      TC(8)=TEM(IPJ)
      IF (J.LT.NY) TC(3)=TEM(IJP)
      IF (J.GT.1) TC(7)=TEM(IJM)
      IF (J.LT.NY) TC(2)=TEM(IPJP)
      IF (J.GT.1) TC(8)=TEM(IJM+1)
      TC(4)=TC(3)
      TC(6)=TC(7)
      TV(1)=0.25*(TC(5)+TC(6)+TC(7)+TC(9))
      TV(2)=0.25*(TC(3)+TC(4)+TC(5)+TC(9))
      DO 90 K=1,NSP
      SPDC(2,K)=SPM(IPJ,K)/MC(IPJ)
      SPDC(1,K)=SPDC(2,K)
      SPDC(8,K)=SPDC(2,K)
      IF (J.LT.NY) SPDC(3,K)=SPM(IJP,K)/MC(IJP)
      IF (J.GT.1) SPDC(7,K)=SPM(IJM,K)/MC(IJM)
      IF (J.LT.NY) SPDC(2,K)=SPM(IPJP,K)/MC(IPJP)
      IF (J.GT.1) SPDC(8,K)=SPM(IJM+1,K)/MC(IJM+1)
      SPDC(4,K)=SPDC(3,K)
      SPDC(6,K)=SPDC(7,K)
      SPDV(1,K)=0.25*(SPDC(5,K)+SPDC(6,K)+SPDC(7,K)+SPDC(9,K))
      SPDV(2,K)=0.25*(SPDC(3,K)+SPDC(4,K)+SPDC(5,K)+SPDC(9,K))
   90 CONTINUE
  100 CONTINUE
```

```
      TV(4)=TV(1)
      TV(3)=TV(2)
      TV(1)=0.25*(TC(1)+TC(9)+TC(7)+TC(8))
      TV(2)=0.25*(TC(1)+TC(2)+TC(3)+TC(9))
      DO 110 K=1,NSP
      SPDV(4,K)=SPDV(1,K)
      SPDV(3,K)=SPDV(2,K)
      SPDV(1,K)=0.25*(SPDC(1,K)+SPDC(9,K)+SPDC(7,K)+SPDC(8,K))
      SPDV(2,K)=0.25*(SPDC(1,K)+SPDC(2,K)+SPDC(3,K)+SPDC(9,K))
  110 CONTINUE
      HDTRV=HAFDT/VOL(IJ)
C +++ CALCULATE DIFFUSION RATES
      IF (I.EQ.1) GO TO 130
      IF (I.EQ.NOR.AND.J.GE.NOB.AND.J.LT.NOT) GO TO 130
      DXX=Y(IJ)-Y(IJP)
      DXY=YCEN(IMJ)-YCEN(IJ)
      DYY=XCEN(IMJ)-XCEN(IJ)
      DYX=X(IJ)-X(IJP)
      RA34=1./(DYY*DXX-DXY*DYX)
      ADXY=DXY*RA34
      ADXX=DXX*RA34
      ADYY=DYY*RA34
      ADYX=DYX*RA34
      RSUM=R(IJ)+R(IJP)
      ETAR=0.5*(XMU(IJ)+XMU(IMJ))*RSC
      ENTH=0.
      TEMP=0.5*(TEM(IMJ)+TEM(IJ))
      TB=0.01*TEMP
      IT=TB
      FR=TB-FLOAT(IT)
      DO 120 K=1,NSP
      SAVE=SPD(IJ,K)
      DIDX=(SPDC(5,K)-SPDC(9,K))*ADXX-(SPDV(4,K)-SPDV(3,K))*ADXY
      DIDY=(SPDV(4,K)-SPDV(3,K))*ADYY-(SPDC(5,K)-SPDC(9,K))*ADYX
      SPD(IJ,K)=SPD(IJ,K)+HDTRV*ETAR*RSUM*(DIDX*DXX-DIDY*DYX)
      ESUBK=(1.-FR)*EK(IT+1,K)+FR*EK(IT+2,K)
      HK(K)=ESUBK/TEMP+RGAS*RWT(K)
      ENTH=ENTH+(SPD(IJ,K)-SAVE)*HK(K)
  120 CONTINUE
      ETAL=0.5*(COND(IJ)+COND(IMJ))
```

```
      DIDX=(TC(5)-TC(9))*ADXX-(TV(4)-TV(3))*ADXY
      DIDY=(TV(4)-TV(3))*ADYY-(TC(5)-TC(9))*ADYX
      MIP(IJ)=MIP(IJ)+ENTH*TEMP+HDTRV*ETAL*RSUM*(DIDX*DXX-DIDY*DYX)
  130 CONTINUE
      IF (I.EQ.NX) GO TO 150
      IF (I.EQ.NOL-1.AND.J.GE.NOB.AND.J.LT.NOT) GO TO 150
      DXX=XCEN(IPJ)-XCEN(IJ)
      DXY=Y(IPJP)-Y(IPJ)
      DYY=YCEN(IPJ)-YCEN(IJ)
      DYX=X(IPJP)-X(IPJ)
      RA12=1./(DXX*DXY-DYY*DYX)
      ADXX=DXX*RA12
      ADXY=DXY*RA12
      ADYY=DYY*RA12
      ADYX=DYX*RA12
      RSUM=R(IPJ)+R(IPJP)
      ETAR=0.5*(XMU(IJ)+XMU(IPJ))*RSC
      ENTH=0.
      TEMP=0.5*(TEM(IPJ)+TEM(IJ))
      TB=0.01*TEMP
      IT=TB
      FR=TB-FLOAT(IT)
      DO 140 K=1,NSP
      SAVE=SPD(IJ,K)
      DIDX=(SPDC(1,K)-SPDC(9,K))*ADXY-(SPDV(2,K)-SPDV(1,K))*ADYY
      DIDY=(SPDV(2,K)-SPDV(1,K))*ADXX-(SPDC(1,K)-SPDC(9,K))*ADYX
      SPD(IJ,K)=SPD(IJ,K)+HDTRV*ETAR*RSUM*(DIDX*DXY-DIDY*DYX)
      ESUBK=(1.-FR)*EK(IT+1,K)+FR*EK(IT+2,K)
      HK(K)=ESUBK/TEMP+RGAS*RWT(K)
      ENTH=ENTH+(SPD(IJ,K)-SAVE)*HK(K)
  140 CONTINUE
      ETAL=0.5*(COND(IJ)+COND(IPJ))
      DIDX=(TC(1)-TC(9))*ADXY-(TV(2)-TV(1))*ADYY
      DIDY=(TV(2)-TV(1))*ADXX-(TC(1)-TC(9))*ADYX
      MIP(IJ)=MIP(IJ)+ENTH*TEMP+HDTRV*ETAL*RSUM*(DIDX*DXY-DIDY*DYX)
  150 CONTINUE
      IF (J.EQ.1) GO TO 170
      IF (J.EQ.NOT.AND.I.GE.NOL.AND.I.LT.NOR) GO TO 170
      DXX=XCEN(IJM)-XCEN(IJ)
      DXY=Y(IPJ)-Y(IJ)
```

```
      DYY=YCEN(IJM)-YCEN(IJ)
      DYX=X(IPJ)-X(IJ)
      RA41=1./(DXX*DXY-DYY*DYX)
      ADXX=DXX*RA41
      ADXY=DXY*RA41
      ADYY=DYY*RA41
      ADYX=DYX*RA41
      RSUM=R(IJ)+R(IPJ)
      ETAR=0.5*(XMU(IJ)+XMU(IJM))*RSC
      ENTH=0.
      TEMP=0.5*(TEM(IJM)+TEM(IJ))
      TB=0.01*TEMP
      IT=TB
      FR=TB-FLOAT(IT)
      DO 160 K=1,NSP
      SAVE=SPD(IJ,K)
      DIDX=(SPDC(7,K)-SPDC(9,K))*ADXY-(SPDV(1,K)-SPDV(4,K))*ADYY
      DIDY=(SPDV(1,K)-SPDV(4,K))*ADXX-(SPDC(7,K)-SPDC(9,K))*ADYX
      SPD(IJ,K)=SPD(IJ,K)+HDTRV*ETAR*RSUM*(DIDX*DXY-DIDY*DYX)
      ESUBK=(1.-FR)*EK(IT+1,K)+FR*EK(IT+2,K)
      HK(K)=ESUBK/TEMP+RGAS*RWT(K)
      ENTH=ENTH+(SPD(IJ,K)-SAVE)*HK(K)
  160 CONTINUE
      ETAL=0.5*(COND(IJ)+COND(IJM))
      DIDX=(TC(7)-TC(9))*ADXY-(TV(1)-TV(4))*ADYY
      DIDY=(TV(1)-TV(4))*ADXX-(TC(7)-TC(9))*ADYX
      MIP(IJ)=MIP(IJ)+ENTH*TEMP+HDTRV*ETAL*RSUM*(DIDX*DXY-DIDY*DYX)
  170 CONTINUE
      IF (J.EQ.NY) GO TO 190
      IF (J.EQ.NOB-1.AND.I.GE.NOL.AND.I.LT.NOR) GO TO 190
      DXX=XCEN(IJP)-XCEN(IJ)
      DXY=Y(IJP)-Y(IPJP)
      DYY=YCEN(IJP)-YCEN(IJ)
      DYX=X(IJP)-X(IPJP)
      RA23=1./(DXX*DXY-DYY*DYX)
      ADXX=RA23*DXX
      ADXY=RA23*DXY
      ADYY=RA23*DYY
      ADYX=RA23*DYX
      RSUM=R(IJP)+R(IPJP)
```

```
      ETAR=0.5*(XMU(IJ)+XMU(IJP))*RSC
      ENTH=0.
      TEMP=0.5*(TEM(IJP)+TEM(IJ))
      TB=0.01*TEMP
      IT=TB
      FR=TB-FLOAT(IT)
      DO 180 K=1,NSP
      SAVE=SPD(IJ,K)
      DIDX=(SPDC(3,K)-SPDC(9,K))*ADXY-(SPDV(3,K)-SPDV(2,K))*ADYY
      DIDY=(SPDV(3,K)-SPDV(2,K))*ADXX-(SPDC(3,K)-SPDC(9,K))*ADYX
      SPD(IJ,K)=SPD(IJ,K)+HDTRV*ETAR*RSUM*(DIDX*DXY-DIDY*DYX)
      ESUBK=(1.-FR)*EK(IT+1,K)+FR*EK(IT+2,K)
      HK(K)=ESUBK/TEMP+RGAS*RWT(K)
      ENTH=ENTH+(SPD(IJ,K)-SAVE)*HK(K)
  180 CONTINUE
      ETAL=0.5*(COND(IJ)+COND(IJP))
      DIDX=(TC(3)-TC(9))*ADXY-(TV(3)-TV(2))*ADYY
      DIDY=(TV(3)-TV(2))*ADXX-(TC(3)-TC(9))*ADYX
      MIP(IJ)=MIP(IJ)+ENTH*TEMP+HDTRV*ETAL*RSUM*(DIDX*DXY-DIDY*DYX)
  190 CONTINUE
  200 CONTINUE
  210 CONTINUE
C +++
C +++ EXAMPLE OF A FIXED TEMPERATURE BOUNDARY FOR THE RIGHT SIDE
C +++
      IF (ADIA.GT.0.5) GO TO 230
      DO 220 J=1,NY
      IJ=J*NXP
      IJM=IJ-1
      IJP=IJ+NXP
      DR=0.5*QSQRT((X(IJ)-X(IJM))**2+(Y(IJ)-Y(IJM))**2)
      AREA=QSQRT((X(IJP)-X(IJ))**2+(Y(IJP)-Y(IJ))**2)*(R(IJ)+R(IJP))*0.5
      FLUX=COND(IJM)*(TEM(IJM)-TBDDY)/DR
      MIP(IJM)=MIP(IJM)-DT*FLUX*AREA/VOL(IJM)
  220 CONTINUE
  230 CONTINUE
C
C     COMPUTE VERTEX MOMENTA AND VERTEX DENSITIES
C
      DO 290 J=1,NYP
```

```
      IJ=(J-1)*NXP
      DO 280 I=1,NXP
      IJ=IJ+1
      IJM=IJ-NXP
      MUP(IJ)=U(IJ)*MV(IJ)
      MVP(IJ)=V(IJ)*MV(IJ)
      SUM=0.
      SUM1=0.
      IMJ=IJ-1
      IMJM=IJM-1
      IF (I.EQ.1.OR.J.EQ.1) GO TO 240
      SUM=SUM+RO(IMJM)
      SUM1=SUM1+1.
  240 IF (I.EQ.1.OR.J.EQ.NYP) GO TO 250
      SUM=SUM+RO(IMJ)
      SUM1=SUM1+1.
  250 IF (I.EQ.NXP.OR.J.EQ.NYP) GO TO 260
      SUM=SUM+RO(IJ)
      SUM1=SUM1+1.
  260 IF (I.EQ.NXP.OR.J.EQ.1) GO TO 270
      SUM=SUM+RO(IJM)
      SUM1=SUM1+1.
  270 VRO(IJ)=SUM/SUM1
  280 CONTINUE
  290 CONTINUE
C +++
C +++ MOMENTUM DIFFUSION
C +++
      DO 300 J=1,NYP
      IJ=(J-1)*NXP
      DO 300 I=1,NXP
      IJ=IJ+1
      WL(IJ)=WL(IJ)*R(IJ)
  300 CONTINUE
      TWOTHD=2./3.
      HAFDT=0.5*DT
      DDT=HAFDT*DISS
      DO 320 J=1,NY
      IJP=J*NXP
      IJ=IJP-NXP
```

```
      DO 310 I=1,NX
      IJP=IJP+1
      IPJP=IJP+1
      IJ=IJ+1
      IPJ=IJ+1
      X1=X(IPJ)
      X2=X(IPJP)
      X3=X(IJP)
      X4=X(IJ)
      Y1=Y(IPJ)
      Y2=Y(IPJP)
      Y3=Y(IJP)
      Y4=Y(IJ)
      R1=R(IPJ)
      R2=R(IPJP)
      R3=R(IJP)
      R4=R(IJ)
      U1=U(IPJ)
      U2=U(IPJP)
      U3=U(IJP)
      U4=U(IJ)
      V1=V(IPJ)
      V2=V(IPJP)
      V3=V(IJP)
      V4=V(IJ)
      DIV=((R1+R2)*((U1+U2)*(Y2-Y1)+(V1+V2)*(X1-X2))+(R2+R3)*((U2+U3)*
     1 (Y3-Y2)+(V2+V3)*(X2-X3))+(R3+R4)*((U3+U4)*(Y4-Y3)+(V4+V3)*(X3-X4)
     2 )+(R4+R1)*((U4+U1)*(Y1-Y4)+(V4+V1)*(X4-X1)))/(4.*VOL(IJ))
      PIXX=((R2+R1)*(U2+U1)*(Y2-Y1)+(R2+R3)*(U3+U2)*(Y3-Y2)+(R4+R3)*(U4
     1 +U3)*(Y4-Y3)+(R1+R4)*(U1+U4)*(Y1-Y4)-0.5*CYL*(U1+U2+U3+U4)*((X1
     2 -X3)*(Y2-Y4)+(X2-X4)*(Y3-Y1)))/(2.*VOL(IJ))
      PIYY=((R1+R2)*(V1+V2)*(X1-X2)+(R2+R3)*(V2+V3)*(X2-X3)+(R3+R4)*(V3
     1 +V4)*(X3-X4)+(R4+R1)*(V4+V1)*(X4-X1))/(2.*VOL(IJ))
      PIXY=((R1+R2)*((U1+U2)*(X1-X2)+(V1+V2)*(Y2-Y1))+(R2+R3)*((U2+U3)*
     1 (X2-X3)+(V2+V3)*(Y3-Y2))+(R3+R4)*((U3+U4)*(X3-X4)+(V3+V4)*(Y4-Y3)
     2 )+(R4+R1)*((U4+U1)*(X4-X1)+(V4+V1)*(Y1-Y4))-0.5*CYL*(V1+V2+V3+V4)
     3 *((X1-X3)*(Y2-Y4)+(X2-X4)*(Y3-Y1)))/(4.*VOL(IJ))
      PTH=CYL*((U1+U2+U3+U4)*((X1-X3)*(Y2-Y4)+(X2-X4)*(Y3-Y1)))/(4.*VOL
     1 (IJ))
      RAREA=2./((X2-X4)*(Y3-Y1)-(X1-X3)*(Y4-Y2))
```

```
      PIRT=SWIRL*0.5*RAREA*RCEN(IJ)*((W(IPJP)/AMAX1(1.E-99,R2)-W(IJ)
     1 /AMAX1(1.E-99,R4))*(Y3-Y1)-(W(IPJ)/AMAX1(1.E-99,R1)-W(IJP)/AMAX1(
     2 1.E-99,R3))*(Y4-Y2))
      PIZT=SWIRL*0.5*RAREA*((W(IJ)-W(IPJP))*(X3-X1)-(W(IPJ)-W(IJP))*(X2
     1 -X4))
      MIP(IJ)=MIP(IJ)+DDT*(PIXX*PIXX+PIYY*PIYY+PTH*PTH+2.*(PIXY*PIXY
     1 +PIRT*PIRT+PIZT*PIZT-TWOTHD*DIV*DIV))*XMU(IJ)
      PIXX=XMU(IJ)*(PIXX-TWOTHD*DIV)
      PIYY=XMU(IJ)*(PIYY-TWOTHD*DIV)
      PIXY=XMU(IJ)*PIXY
      PTH=CYL*XMU(IJ)*(PTH-TWOTHD*DIV)
      PTH=0.25*PTH*((X1-X3)*(Y2-Y4)+(X2-X4)*(Y3-Y1))
      PIRT=PIRT*XMU(IJ)*RCEN(IJ)
      PIZT=PIZT*XMU(IJ)*RCEN(IJ)
      UL(IPJ)=UL(IPJ)+HAFDT*(0.5*(R2+R4)*(PIXX*(Y4-Y2)+PIXY*(X2-X4))-PTH
     1 )/MV(IPJ)
      UL(IPJP)=UL(IPJP)+HAFDT*(0.5*(R3+R1)*(PIXX*(Y1-Y3)+PIXY*(X3-X1))
     1 -PTH)/MV(IPJP)
      UL(IJP)=UL(IJP)+HAFDT*(0.5*(R4+R2)*(PIXX*(Y2-Y4)+PIXY*(X4-X2))-PTH
     1 )/MV(IJP)
      UL(IJ)=UL(IJ)+HAFDT*(0.5*(R1+R3)*(PIXX*(Y3-Y1)+PIXY*(X1-X3))-PTH)
     1 /MV(IJ)
      VL(IPJ)=VL(IPJ)+HAFDT*(0.5*(R2+R4)*(PIXY*(Y4-Y2)+PIYY*(X2-X4)))/MV
     1 (IPJ)
      VL(IPJP)=VL(IPJP)+HAFDT*(0.5*(R3+R1)*(PIXY*(Y1-Y3)+PIYY*(X3-X1)))
     1 /MV(IPJP)
      VL(IJP)=VL(IJP)+HAFDT*(0.5*(R4+R2)*(PIXY*(Y2-Y4)+PIYY*(X4-X2)))/MV
     1 (IJP)
      VL(IJ)=VL(IJ)+HAFDT*(0.5*(R1+R3)*(PIXY*(Y3-Y1)+PIYY*(X1-X3)))/MV
     1 (IJ)
      WL(IPJ)=WL(IPJ)+HAFDT*0.5*(R2+R4)*(PIRT*(Y4-Y2)+PIZT*(X2-X4))/MV
     1 (IPJ)
      WL(IJP)=WL(IJP)+HAFDT*0.5*(R2+R4)*(PIRT*(Y2-Y4)+PIZT*(X4-X2))/MV
     1 (IJP)
      WL(IPJP)=WL(IPJP)+HAFDT*0.5*(R1+R3)*(PIRT*(Y1-Y3)+PIZT*(X3-X1))/MV
     1 (IPJP)
      WL(IJ)=WL(IJ)+HAFDT*0.5*(R1+R3)*(PIRT*(Y3-Y1)+PIZT*(X1-X3))/MV(IJ)
  310 CONTINUE
  320 CONTINUE
      DO 330 J=1,NYP
```

```
      IJ=(J-1)*NXP                                                      VISC 462
      DO 330 I=1,NXP                                                    VISC 463
      IJ=IJ+1                                                           VISC 464
      WL(IJ)=WL(IJ)/AMAX1(1.E-99,R(IJ))                                 VISC 465
  330 CONTINUE                                                          VISC 466
      CALL BC (UL,VL,WL)                                                VISC 467
C +++                                                                   VISC 468
C +++ CONVERT BACK TO SPECIFIC QUANTITIES - SPECIES MASS BECOMES        VISC 469
C +++   SPECIES DENSITY, INTERNAL ENERGY BECOMES SPECIFIC INTERNAL      VISC 470
C +++   ENERGY                                                          VISC 471
C +++                                                                   VISC 472
      DO 360 J=1,NY                                                     VISC 473
      IJ=(J-1)*NXP+1                                                    VISC 474
      DO 350 I=1,NX                                                     VISC 475
      XX=0.                                                             VISC 476
      DO 340 K=1,NSP                                                    VISC 477
      XX=XX+SPD(IJ,K)                                                   VISC 478
  340 CONTINUE                                                          VISC 479
      ROL(IJ)=XX                                                        VISC 480
      E(IJ)=MIP(IJ)/XX                                                  VISC 481
  350 IJ=IJ+1                                                           VISC 482
  360 CONTINUE                                                          VISC 483
      RETURN                                                            VISC 484
      END                                                               VISC 485


      SUBROUTINE ZONES                                                  ZONES   2
      PARAMETER (NXQ=700, NRQ=3, NSQ=12, NERQ=6)                        COMD    2
      COMMON X(NXQ), R(NXQ), Y(NXQ), P(NXQ)                             COMD    3
      COMMON /HKRAM/ EK(51,NSQ), NRE, NCHEM, HTFORM(NSQ), XKD, OMGCHM,  COMD    4
     1 EPSCHM                                                           COMD    5
      LEVEL 2, YL, FL, NCHOP, DYCHOP, FCHOP                             COMD    6
      COMMON /CHOP/ YL(100), FL(100,NSQ), NCHOP, DYCHOP, FCHOP          COMD    7
      COMMON /BLK/ ITMIN, NOL, NOR, NOB, NOT, ANC                       COMD    8
      LEVEL 2, PSD, DELP                                                COMD    9
      COMMON /PTRIAL/ PSD(NXQ), DELP(NXQ)                               COMD   10
      LEVEL 2, XMU, COND, TEM, HK                                       COMD   11
      COMMON /KAH1/ XMU(NXQ), COND(NXQ), TEM(NXQ), HK(NSQ)              COMD   12
      COMMON /KAH2/ RO(NXQ), SIE(NXQ), NDUMP                            COMD   13
```

```
      COMMON /KAH3/ U(NXQ), UL(NXQ), V(NXQ), VL(NXQ), W(NXQ), WL(NXQ)
      LEVEL 2, VOL, MV, MC
      COMMON /KAH4/ VOL(NXQ), MV(NXQ), MC(NXQ)
      LEVEL 2, SPD, SPM
      COMMON /KAH6/ SPD(NXQ,NSQ), SPM(NXQ,NSQ)
      COMMON /KAH7/ GAM1(NSQ), TSPD(NSQ), CV(NSQ), GAMMA(NSQ), WT(NSQ),
     1 RHOI(NSQ)
      LEVEL 2, CVT
      COMMON /KAH8/ CVT(NXQ)
      LEVEL 2, RCEN, XCEN, YCEN, MIP, MUP, MVP, VRO
      COMMON /TEMPCH/ RCEN(NXQ), XCEN(NXQ), YCEN(NXQ), MIP(NXQ),
     1 MUP(NXQ), MVP(NXQ), VRO(NXQ)
      LEVEL 2, WP, ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /SWRL/ WP(NXQ), ANGVEL, TBDDY, ADIA, AIRMU
      COMMON /RSC/ RC(NXQ), UREL(NXQ), VREL(NXQ), E(NXQ), UP(NXQ),
     1 VP(NXQ), PL(NXQ), MP(NXQ), UG(NXQ), VG(NXQ), MVT(NXQ), ROL(NXQ),
     2 Q(NXQ)
      COMMON /RSC1/ ABDC, GX, GY, STROKE, RPM, VPISTON, YPISTON, YPIST(1
     1 00), DTMAX, ILIM, XMUO, RPR, RSC, DISS, XIGNIT, WORK, NYMAX
      COMMON /RSC2/ AO, AOM, AZMOM, AZFAC, BO, CAPDTH, CAPDR, CYL, DX,
     1 DT, DY, DTSAV, EPS, ILNGPI, IREZ, ITMAX, LAMZER, LPR, NAME(8),
     2 NCLAST, NCYC, NFOUT, NPOUT, NR, NSP, NY, NYP, NX, NXP, NUMIT, OM,
     3 OMCYL, PEPS, PI, RADMOM, RDXMAX, RGAS, SIXTH, SWIRL, T, TWLFTH,
     4 TOUT, UTMAX, VMAX, VVORT, XCONV, XCONVZ, YCONV, YCONVZ
      COMMON /MARGON/ TV(4), TC(9), SPDV(4,NSQ), SPDC(9,NSQ)
      COMMON /CHEME/ AN(NSQ,NERQ), BN(NSQ,NERQ), CN(NSQ,NERQ), NLM(NERQ)
     1 , AS(NERQ), BS(NERQ), CS(NERQ), DS(NERQ), ES(NERQ), PROG(NERQ),
     2 QEQ(NERQ)
      INTEGER AN, BN, CN
      COMMON /RAMCHM/ RWT(NSQ), AM(NSQ,NRQ), BM(NSQ,NRQ), CM(NSQ,NRQ),
     1 NELEM(NRQ), AE(NSQ,NRQ), BE(NSQ,NRQ), CF(NRQ), EF(NRQ), ZETAF(NRQ
     2 ), CB(NRQ), EB(NRQ), ZETAB(NRQ), TCUT, DOMEGA(NRQ), QR(NRQ)
      DIMENSION RDSDP(1), RMV(1)
      EQUIVALENCE (UG,RDSDP), (RMV,E)
      REAL MC, MP, MV, MVT, LAMZER, MIP, MUP, MVP
C +++
C +++ PLOT THE MESH ON FILM
C +++
      YMIN=1.E+250
      DO 10 J=1,NYP
```

```
      IJ=(J-1)*NXP
      DO 10 I=1,NXP
      IJ=IJ+1
   10 YMIN=AMIN1(YMIN,Y(IJ))
      DO 30 J=1,NY
      IJ=(J-1)*NXP+1
      IJP=IJ+NXP
      DO 20 I=1,NX
      IPJ=IJ+1
      IPJP=IJP+1
      X1=X(IPJ)
      Y1=Y(IPJ)-YMIN
      X2=X(IPJP)
      Y2=Y(IPJP)-YMIN
      X3=X(IJP)
      Y3=Y(IJP)-YMIN
      X4=X(IJ)
      Y4=Y(IJ)-YMIN
      IX1=X1*XCONV
      IY1=950.-Y1*YCONV
      IX2=X2*XCONV
      IY2=950.-Y2*YCONV
      IX3=X3*XCONV
      IY3=950.-Y3*YCONV
      IX4=X4*XCONV
      IY4=950.-Y4*YCONV
      CALL DRV (IX4,IY4,IX3,IY3)
      CALL DRV (IX4,IY4,IX1,IY1)
      IF (I.EQ.NX) CALL DRV (IX1,IY1,IX2,IY2)
      IF (J.EQ.NY) CALL DRV (IX2,IY2,IX3,IY3)
      IJP=IJP+1
   20 IJ=IJ+1
   30 CONTINUE
      CALL LINCNT (61)
      WRITE (12,40) T,NCYC,NAME
      RETURN
C
   40 FORMAT (1X,2HT=,1PE13.5,1X,6HCYCLE=,I6,2X,8A10)
      END
```

APPENDIX B

DATA DECK FOR SAMPLE PROBLEM

```
CONCHAS TEST PROBLEM 7/20/79
    NSP       12
    NR         3
    NFOUT     10
    NPOUT    100
    LPR        2
    ITMAX    100
    NX        11
    NY        10
    NRE        6
   EPSCHM          2.00000000E-02
    OMCHM          1.00000000E+00
    XKD            1.30000000E-01
    DX             5.23600000E-01
    DY             3.45670000E-01
XIGNIT             5.00000000E-02
    SIEI           7.43400000E+02
    OM             1.50000000E+00
    PEPS           1.00000000E-04
    EPS            1.00000000E-06
    AZFAC      0.1
    NCLAST   200
    NOL        8
    NOR       12
    NOB        1
    NOT        3
    ITMIN     18
    AO         0.8
    BO         0.1
    AOM        0.8
    IREZ       2
    LAMZER         0.01000000E+00
    DTMAX          1.25000000E-05
    DT             1.25000000E-05
    CYL            1.00000000E+00
    ANC        0.05
    RGAS           8.31430000E+07
    RPM            5.00000000E+03
    STROKE         9.55000000E+00
    ABDC           1.20000000E+02
```

41	GX	0.00000000E+00
42	GY	0.00000000E+00
43	XMUO	4.00000000E+02
44	RPR	1.10000000E+00
45	RSC	1.00000000E+00
46	DISS	1.00000000E+00
47	TCUT	6.00000000E+02
48	SWIRL	1.00000000E+00
49	ANGVEL	2.00000000E+03
50	TBODY	4.00000000E+02
51	ADIA	1.00000000E+00
52	AIRMU	1.00000000E+00
53	RHO1	5.28240000E-04
54	GAMMA1	1.03000000E+00
55	WT1	1.14000000E+02
56	HTF1	-5.03100000E+01
57	RHO2	1.95100000E-03
58	GAMMA2	1.40000000E+00
59	WT2	3.20000000E+01
60	HTF2	0.00000000E+00
61	RHO3	8.50200000E-03
62	GAMMA3	1.40000000E+00
63	WT3	2.80000000E+01
64	HTF3	0.00000000E+00
65	RHO4	0.00000000E-05
66	GAMMA4	1.20000000E+00
67	WT4	4.40000000E+01
68	HTF4	-9.39650000E+01
69	RHO5	0.00000000E+00
70	GAMMA5	1.22000000E+00
71	WT5	1.80000000E+01
72	HTF5	-5.71030000E+01
73	RHO6	0.00000000E+00
74	GAMMA6	1.66670000E+00
75	WT6	1.00000000E+00
76	HTF6	5.16310000E+01
77	RHO7	0.00000000E+00
78	GAMMA7	1.40000000E+00
79	WT7	2.00000000E+00
80	HTF7	0.00000000E+00

```
      RHO8          0.00000000E+00
      GAMMA8        1.66670000E+00
      WT8           1.60000000E+01
      HTF8          5.89890000E+01
      RHO9          0.00000000E+00
      GAMMA9        1.66670000E+00
      WT9           1.40000000E+01
      HTF9          1.12520000E+02
      RHO10         0.00000000E+00
      GAMA10        1.40000000E+00
      WT10          1.70000000E+01
      HTF10         9.28900000E+00
      RHO11         0.00000000E+00
      GAMA11        1.40000000E+00
      WT11          2.80000000E+01
      HTF11        -2.72000000E+01
      RHO12         0.00000000E+00
      GAMA12        1.40000000E+00
      WT12          3.00000000E+01
      HTF12         2.14560000E+01
      CF1           5.00000000E+12
      EF1           1.57800000E+04
      ZETAF1        0.00000000E+00
      CB1           0.00000000E+00
      EB1           0.00000000E+00
      ZETAB1        0.00000000E+00
 AM1       2    25     0     0     0     0     0     0     0     0     0     0
 BM1       0     0     0    16    18     0     0     0     0     0     0     0
 AE1     1.000    1.000    0.000    0.000    0.000    0.000    0.000    0.000
         0.000    0.000    0.000    0.000
 BE1     0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
         0.000    0.000    0.000    0.000
      CF2           7.14000000E+13
      EF2           3.79970000E+04
      ZETAF2        0.00000000E+00
      CB2           1.50000000E+13
      EB2           0.00000000E+00
      ZETAB2        0.00000000E+00
 AM2       0     0     1     0     0     0     0     1     0     0     0     0
 BM2       0     0     0     0     0     0     0     0     1     0     0     1
```

```
121  AE2     0.000    0.000    1.000    0.000    0.000    0.000    0.000    1.000
122          0.000    0.000    0.000    0.000
123  BE2     0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
124          1.000    0.000    0.000    1.000
125     CF3           1.20000000E+10
126     EF3           2.76800000E+03
127     ZETAF3        1.00000000E+00
128     CB3           3.20000000E+09
129     EB3           1.96780000E+04
130     ZETAB3        1.00000000E+00
131  AM3       0     1     0     0     0     0     0     0     1     0     0     0
132  BM3       0     0     0     0     0     0     0     1     0     0     0     1
133  AE3     0.000    1.000    0.000    0.000    0.000    0.000    0.000    0.000
134          1.000    0.000    0.000    0.000
135  BE3     0.000    0.000    0.000    0.000    0.000    0.000    0.000    1.000
136          0.000    0.000    0.000    1.000
137     AS1           0.99020700E+00
138     BS1          -5.17916000E+01
139     CS1           0.99307400E+00
140     DS1          -0.34342800E+00
141     ES1           0.01116680E+00
142  AN1       0     0     0     0     0     0     1     0     0     0     0     0
143  BN1       0     0     0     0     0     2     0     0     0     0     0     0
144     AS2           0.43131000E+00
145     BS2          -5.96554000E+01
146     CS2           3.50335000E+00
147     DS2          -0.34001600E+00
148     ES2           0.01587150E+00
149  AN2       0     1     0     0     0     0     0     0     0     0     0     0
150  BN2       0     0     0     0     0     0     0     2     0     0     0     0
151     AS3           0.79470900E+00
152     BS3          -1.13208000E+02
153     CS3           3.16837000E+00
154     DS3          -0.44381400E+00
155     ES3           0.02696990E+00
156  AN3       0     0     1     0     0     0     0     0     0     0     0     0
157  BN3       0     0     0     0           0     0     0     2     0     0     0
158     AS4          -0.65293900E+00
159     BS4          -9.82320000E+00
160     CS4           3.93033000E+00
```

```
161      DS4           0.16349000E+00
162      ES4          -0.01428650E+00
163   AN4       0    1    0    0    0    0    1    0    0    0    0    0
164   BN4       0    0    0    0    0    0    0    0    0    2    0    0
165      AS5           1.15888200E+00
166      BS5          -7.68472000E+01
167      CS5           8.53215500E+00
168      DS5          -0.86832000E+00
169      ES5           0.04634710E+00
170   AN5       0    1    0    0    2    0    0    0    0    0    0    0
171   BN5       0    0    0    0    0    0    0    0    0    4    0    0
172      AS6           0.98087500E+00
173      BS6           6.84453000E+01
174      CS6          -1.05938000E+01
175      DS6           0.57426000E+00
176      ES6          -0.04145700E+00
177   AN6       0    1    0    0    0    0    0    0    0    0    2    0
178   BN6       0    0    0    2    0    0    0    0    0    0    0    0
179      NCHOP     10
```

APPENDIX C

SELECTED OUTPUT FOR THE CONCHAS TEST PROBLEM

```
                CONCHAS TWO DIMENSIONAL HYDRODYNAMICS PROGRAM

CONCHAS TEST PROBLEM 7/20/73
     NSP =    12                NP =     3
   NFOUT =    10             NPOUT =   100
     LPR =     2             ITMAX =   100
      NX =    11                NY =    10
     NRE =     6
  EPSCHM =        2.00000000E-02
     XKD =        1.30000000E-01
  OMGCHM =        1.00000000E+00
    DX             .52360000E+00
    DY             .34567000E+00
  XIGNIT           5.00000000E-02
     SIEI          7.43400000E+02
     OM            1.50000000E+00
     PEPS          1.00000000E-04
     EPS           1.00000000E-06
    AZFAC      .10000
  NCLAST =   200
     NOL =     8
     NOR =    12
     NOB =     1
     NOT =     3
   ITMIN =    18
    AO         .80000
    BO         .10000
    AOM        .80000
    IREZ       2
  LAMZER =        1.00000000E-02
   DTMAX =        1.25000000E-05
      DT =        1.25000000E-05
     CYL =        1.00000000E+00
    ANC        .05000
     RGAS          8.31430000E+07
     RPM =        5.00000000E+03
  STROKE =        9.55000000E+00
    ABDC =        1.20000000E+02
      GX =        0.
      GY =        0.
    XMUO =        4.00000000E+02
     RPR =        1.10000000E+00
     RSC =        1.00000000E+00
    DISS =        1.00000000E+00
    TCUT =        6.00000000E+02
   SWIRL =        1.00000000E+00
  ANGVEL =        2.00000000E+03
   TBDDY =        4.00000000E+02
    ADIA =        1.00000000E+00
   AIRMU =        1.00000000E+00
```

SPECIES DATA

K	RHOI	CV	GAMMA	WT	HTFORM
1	5.282400E-04	2.431082E+07	1.030000E+00	1.140000E+02	-2.104970E+12
2	1.951000E-03	6.495547E+06	1.400000E+00	3.200000E+01	0.
3	8.502000E-03	7.423482E+06	1.400000E+00	2.800000E+01	0.
4	0.	9.448058E+06	1.200000E+00	4.400000E+01	-3.931496E+12
5	0.	2.099571E+07	1.220000E+00	1.800000E+01	-2.381190E+12
6	0.	1.247083E+08	1.666700E+00	1.000000E+00	2.160241E+12
7	0.	1.039288E+08	1.400000E+00	2.000000E+00	0.
8	0.	7.794267E+06	1.666700E+00	1.600000E+01	2.468100E+12
9	0.	8.907733E+06	1.666700E+00	1.400000E+01	4.707837E+12
10	0.	1.222691E+07	1.400000E+00	1.700000E+01	3.886518E+11
11	0.	7.423482E+06	1.400000E+00	2.800000E+01	-1.138048E+12
12	0.	6.928583E+06	1.400000E+00	3.000000E+01	8.977170E+11

REACTION DATA

```
    K          QR
    1        1.016994E+14
CF, EF, ZETAF =      5.00000000E+12       1.57800000E+04       0.
CB, EB, ZETAB =      0.                   0.                   0.
LHS STOICHIOMETRIC COEFS =    2   25    0    0    0    0    0    0    0    0    0    0
RHS STOICHIOMETRIC COEFS =    0    0    0   16   18    0    0    0    0    0    0    0
 FORWARD SPECIES EXPONENTS =  1.000   1.000   0.000   0.000   0.000   0.000   0.000   0.000
                              0.000   0.000   0.000   0.000
BACKWARD SPECIES EXPONENTS =  0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
                              0.000   0.000   0.000   0.000
    2      -3.137456E+12
CF, EF, ZETAF =      7.14000000E+13       3.79970000E+04       0.
CB, EB, ZETAB =      1.50000000E+13       0.                   0.
LHS STOICHIOMETRIC COEFS =    0    0    1    0    0    0    0    1    0    0    0    0
RHS STOICHIOMETRIC COEFS =    0    0    0    0    0    0    0    0    1    0    0    1
 FORWARD SPECIES EXPONENTS =  0.000   0.000   1.000   0.000   0.000   0.000   0.000   1.000
                              0.000   0.000   0.000   0.000
BACKWARD SPECIES EXPONENTS =  0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
                              1.000   0.000   0.000   1.000
    3        1.342018E+12
CF, EF, ZETAF =      1.20000000E+10       2.76800000E+03       1.00000000E+00
CB, EB, ZETAB =      3.20000000E+02       1.96780000E+04       1.00000000E+00
LHS STOICHIOMETRIC COEFS =    0    1    0    0    0    0    0    0    1    0    0    0
RHS STOICHIOMETRIC COEFS =    0    0    0    0    0    0    0    1    0    0    0    1
 FORWARD SPECIES EXPONENTS =  0.000   1.000   0.000   0.000   0.000   0.000   0.000   0.000
                              1.000   0.000   0.000   0.000
BACKWARD SPECIES EXPONENTS =  0.000   0.000   0.000   0.000   0.000   0.000   0.000   1.000
                              0.000   0.000   0.000   1.000


    EQUILIBRIUM REACTION    1
AS, BS, CS, DS, ES =    9.90207000E-01    -5.17916000E+01    9.93074000E-01    -3.43428000E-01    1.11668000E-02
QEQ =    -4.32048208E+12            NLM =     2
AN =     0    0    0    0    0    0    1    0    0    0    0    0
BN =     0    0    0    0    0    2    0    0    0    0    0    0
CN =     6    7    0    0    0    0    0    0    0    0    0    0


    EQUILIBRIUM REACTION    2
AS, BS, CS, DS, ES =    4.31310000E-01    -5.95554000E+01    3.50335000E+00    -3.40016000E-01    1.58715000E-02
QEQ =    -4.93619952E+12            NLM =     2
AN =     0    1    0    0    0    0    0    0    0    0    0    0
BN =     0    0    0    0    0    0    0    2    0    0    0    0
CN =     2    8    0    0    0    0    0    0    0    0    0    0
```

```
     EQUILIBRIUM REACTION     3
AS, BS, CS, DS, ES =     7.94709000E-01    -1.13208000E+02     3.16837000E+00    -4.43814000E-01     2.69699000E-02
QEQ =     -9.41567360E+12              NLM =     2
AN =      0     0     1     0     0     0     0     0     0     0     0     0
BN =      0     0     0     0     0     0     0     0     2     0     0     0
CN =      3     9     0     0     0     0     0     0     0     0     0     0


     EQUILIBRIUM REACTION     4
AS, BS, CS, DS, ES =    -6.52339000E-01    -9.82320000E+00     3.93033000E+00     1.63490000E-01    -1.42865000E-02
QEQ =     -7.77303520E+11              NLM =     3
AN =      0     1     0     0     0     0     1     0     0     0     0     0
BN =      0     0     0     0     0     0     0     0     0     2     0     0
CN =      2     7    10     0     0     0     0     0     0     0     0     0


     EQUILIBRIUM REACTION     5
AS, BS, CS, DS, ES =     1.15888200E+00    -7.63472000E+01     8.53215500E+00    -8.68320000E-01     4.63471000E-02
QEQ =     -6.33298608E+12              NLM =     3
AN =      0     1     0     0     2     0     0     0     0     0     0     0
BN =      0     0     0     0     0     0     0     0     0     4     0     0
CN =      2     5    10     0     0     0     0     0     0     0     0     0


     EQUILIBRIUM REACTION     6
AS, BS, CS, DS, ES =     9.80875000E-01     6.84453000E+01    -1.05938000E+01     5.74260000E-01    -4.14570000E-02
QEQ =      5.58689520E+12              NLM =     3
AN =      0     1     0     0     0     0     0     0     0     0     2     0
BN =      0     0     0     2     0     0     0     0     0     0     0     0
CN =      2     4    11     0     0     0     0     0     0     0     0     0



CHOPPER PARAMETERS - NCHOP =  10
  HALF PERIOD =  3.77482E-02  DYCHOP =
MASS= 3.48513355E+00 U MOM= 0.             V MOM= 0.             SIE= 2.0722327E+10 TOT E= 8.8279875E+10CHEM E=, 5.7478468E+10
  WORK = 0.                ANG MOMENTUM = 1.9699795E+04  GMS NO = 0.
```

CONCHAS TEST PROBLEM 7/20/72
T= 0.   CYCLE=   0

I	J	X	Y	U	V	SIE	RHO	W	P	TEM	VOL	XMU
1	1	0.	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.739E-02	0.
2	1	5.236E-01	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	1.422E-01	0.
3	1	1.047E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	2.369E-01	0.
4	1	1.571E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	3.317E-01	0.
5	1	2.094E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.265E-01	0.
6	1	2.618E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	5.212E-01	0.
7	1	3.142E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	6.159E-01	0.
8	1	3.665E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	7.107E-01	0.
9	1	4.189E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	8.055E-01	0.
10	1	4.712E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	9.003E-01	0.
11	1	5.236E+00	7.163E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	9.951E-01	0.
12	1	5.760E+00	7.163E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	2	0.	7.508E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.739E-02	0.
2	2	5.236E-01	7.508E+00	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.

3	2	1.047E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	2	1.571E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	
5	2	2.094E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	2	2.618E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	2	3.142E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.159E-01	0.	
8	2	3.665E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	7.108E-01	0.	
9	2	4.189E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	8.055E-01	0.	
10	2	4.712E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	9.003E-01	0.	
11	2	5.236E+00	7.508E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	9.951E-01	0.	
12	2	5.760E+00	7.508E+00	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	3	0.	7.854E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.738E-02	0.	
2	3	5.236E-01	7.854E+00	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.	
3	3	1.047E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	3	1.571E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	
5	3	2.094E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	3	2.618E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	3	3.142E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.159E-01	0.	
8	3	3.665E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	7.108E-01	0.	
9	3	4.189E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	8.055E-01	0.	
10	3	4.712E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	9.003E-01	0.	
11	3	5.236E+00	7.854E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	9.951E-01	0.	
12	3	5.760E+00	7.854E+00	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	4	0.	8.200E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.738E-02	0.	
2	4	5.236E-01	8.200E+00	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.	
3	4	1.047E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	4	1.571E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	
5	4	2.094E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	4	2.618E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	4	3.142E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.159E-01	0.	
8	4	3.665E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	7.330E+03	2.282E+07	7.434E+02	7.108E-01	0.	
9	4	4.189E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	8.378E+03	2.282E+07	7.434E+02	8.055E-01	0.	
10	4	4.712E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	9.425E+03	2.282E+07	7.434E+02	9.003E-01	0.	
11	4	5.236E+00	8.200E+00	0.	0.	5.946E+09	1.098E-02	1.047E+04	2.282E+07	7.434E+02	9.951E-01	0.	
12	4	5.760E+00	8.200E+00	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	5	0.	8.545E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.738E-02	0.	
2	5	5.236E-01	8.545E+00	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.	
3	5	1.047E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	5	1.571E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	
5	5	2.094E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	5	2.618E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	5	3.142E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.159E-01	0.	
8	5	3.665E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	7.330E+03	2.282E+07	7.434E+02	7.108E-01	0.	

CONCHAS TEST PROBLEM 7/20/79
T= 0. CYCLE= 0

I	J	X	Y	U	V	SIE	RHO	W	P	TEM	VOL	XMU	
9	5	4.189E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	8.378E+03	2.282E+07	7.434E+02	8.055E-01	0.	
10	5	4.712E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	9.425E+03	2.282E+07	7.434E+02	9.003E-01	0.	
11	5	5.236E+00	8.545E+00	0.	0.	5.946E+09	1.098E-02	1.047E+04	2.282E+07	7.434E+02	9.951E-01	0.	
12	5	5.760E+00	8.545E+00	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	6	0.	8.891E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.738E-02	0.	
2	6	5.236E-01	8.891E+00	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.	
3	6	1.047E+00	8.891E+00	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	6	1.571E+00	8.891E+00	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	
5	6	2.094E+00	8.891E+00	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	6	2.618E+00	8.891E+00	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	6	3.142E+00	8.891E+00	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.159E-01	0.	
8	6	3.665E+00	8.891E+00	0.	0.	5.946E+09	1.098E-02	7.330E+03	2.282E+07	7.434E+02	7.108E-01	0.	
9	6	4.189E+00	8.891E+00	0.	0.	5.946E+09	1.098E-02	8.378E+03	2.282E+07	7.434E+02	8.055E-01	0.	
10	6	4.712E+00	8.891E+00	0.	0.	5.946E+09	1.098E-02	9.425E+03	2.282E+07	7.434E+02	9.003E-01	0.	

11	6	5.236E+00	8.991E+00	0.	0.	5.946E+09	1.098E-02	1.047E+04	2.282E+07	7.434E+02	9.951E-01	0.	
12	6	5.760E+00	8.991E+00	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	7	0.	9.237E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.739E-02	0.	
2	7	5.236E-01	9.237E+00	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.	
3	7	1.047E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	7	1.571E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	
5	7	2.094E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	7	2.618E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	7	3.142E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.160E-01	0.	
8	7	3.665E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	7.330E+03	2.282E+07	7.434E+02	7.108E-01	0.	
9	7	4.189E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	8.378E+03	2.282E+07	7.434E+02	8.055E-01	0.	
10	7	4.712E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	9.425E+03	2.282E+07	7.434E+02	9.003E-01	0.	
11	7	5.236E+00	9.237E+00	0.	0.	5.946E+09	1.098E-02	1.047E+04	2.282E+07	7.434E+02	9.951E-01	0.	
12	7	5.760E+00	9.237E+00	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	8	0.	9.582E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.739E-02	0.	
2	8	5.236E-01	9.582E+00	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.	
3	8	1.047E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	8	1.571E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	
5	8	2.094E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	8	2.618E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	8	3.142E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.160E-01	0.	
8	8	3.665E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	7.330E+03	2.282E+07	7.434E+02	7.108E-01	0.	
9	8	4.189E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	8.378E+03	2.282E+07	7.434E+02	8.055E-01	0.	
10	8	4.712E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	9.425E+03	2.282E+07	7.434E+02	9.003E-01	0.	
11	8	5.236E+00	9.582E+00	0.	0.	5.946E+09	1.098E-02	1.047E+04	2.282E+07	7.434E+02	9.951E-01	0.	
12	8	5.760E+00	9.582E+00	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	9	0.	9.928E+00	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.739E-02	0.	
2	9	5.236E-01	9.928E+00	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.	
3	9	1.047E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	9	1.571E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	
5	9	2.094E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	9	2.618E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	9	3.142E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.160E-01	0.	
8	9	3.665E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	7.330E+03	2.282E+07	7.434E+02	7.108E-01	0.	
9	9	4.189E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	8.378E+03	2.282E+07	7.434E+02	8.055E-01	0.	
10	9	4.712E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	9.425E+03	2.282E+07	7.434E+02	9.003E-01	0.	
11	9	5.236E+00	9.928E+00	0.	0.	5.946E+09	1.098E-02	1.047E+04	2.282E+07	7.434E+02	9.951E-01	0.	
12	9	5.760E+00	9.928E+00	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	10	0.	1.027E+01	0.	0.	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	4.739E-02	0.	
2	10	5.236E-01	1.027E+01	0.	0.	5.946E+09	1.098E-02	1.047E+03	2.282E+07	7.434E+02	1.422E-01	0.	
3	10	1.047E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	2.094E+03	2.282E+07	7.434E+02	2.369E-01	0.	
4	10	1.571E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	3.142E+03	2.282E+07	7.434E+02	3.317E-01	0.	

CONCHAS TEST PROBLEM 7/20/79
T= 0. CYCLE= 0

I	J	X	Y	U	V	SIE	RHO	W	P	TEM	VOL	XMU	
5	10	2.094E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	4.189E+03	2.282E+07	7.434E+02	4.265E-01	0.	
6	10	2.618E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	5.236E+03	2.282E+07	7.434E+02	5.212E-01	0.	
7	10	3.142E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	6.283E+03	2.282E+07	7.434E+02	6.160E-01	0.	
8	10	3.665E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	7.330E+03	2.282E+07	7.434E+02	7.108E-01	0.	
9	10	4.189E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	8.378E+03	2.282E+07	7.434E+02	8.055E-01	0.	
10	10	4.712E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	9.425E+03	2.282E+07	7.434E+02	9.003E-01	0.	
11	10	5.236E+00	1.027E+01	0.	0.	5.946E+09	1.098E-02	1.047E+04	2.282E+07	7.434E+02	9.951E-01	0.	
12	10	5.760E+00	1.027E+01	0.	0.	-I	0.	0.	0.	0.	0.		-I
1	11	0.	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.		-I
2	11	5.236E-01	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.		-I
3	11	1.047E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.		-I
4	11	1.571E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.		-I
5	11	2.094E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.		-I

6	11	2.618E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
7	11	3.142E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
8	11	3.665E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
9	11	4.189E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
10	11	4.712E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
11	11	5.236E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
12	11	5.760E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I

SPECIES MASS FRACTIONS

I	J	1	2	3	4	5	6	7	8	9	10
1	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								

3	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	3	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	4	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	5	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								

1	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	6	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	7	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								

10	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	8	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	9	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
2	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
3	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
4	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
5	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
6	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
7	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
8	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	10	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								

NCYC = 0 DT = 1.250000E-05 T = 0. NUMIT = 0 GRIND = 0.00

Y(PISTON) = 7.1625E+00 V(PISTON) = 0. PRESSURE = 2.2822E+07

MASS= 3.48513356E+00 U MOM= 3.15301241E+02 V MOM= 2.08797451E+03 SIE= 2.0726749E+10 TOT E= 8.8281784E+10CHEM E=, 6.7478157E+10

WORK = 6.6368266E+07 ANG MOMENTUM = 1.9247668E+04 GMS NO = 0.

CONCHAS TEST PROBLEM 7/20/79
T= 1.25000E-05 CYCLE= 1

I	J	X	Y	U	V	SIE	RHO	W	P	TEM	VOL	XMU
1	1	0.	7.190E+00	0.	2.157E+03	5.946E+09	1.136E-02	0.	2.361E+07	7.434E+02	4.739E-02	4.504E+00
2	1	5.236E-01	7.190E+00	0.	2.157E+03	5.946E+09	1.136E-02	0.	2.361E+07	7.434E+02	1.421E-01	4.558E+00
3	1	1.047E+00	7.190E+00	0.	2.157E+03	5.946E+09	1.136E-02	0.	2.361E+07	7.434E+02	2.369E-01	4.692E+00
4	1	1.571E+00	7.190E+00	0.	2.157E+03	5.947E+09	1.136E-02	0.	2.361E+07	7.435E+02	3.316E-01	4.778E+00
5	1	2.094E+00	7.190E+00	0.	2.157E+03	5.947E+09	1.136E-02	0.	2.362E+07	7.435E+02	4.264E-01	4.914E+00
6	1	2.618E+00	7.190E+00	0.	2.157E+03	5.948E+09	1.137E-02	0.	2.363E+07	7.436E+02	5.211E-01	4.922E+00
7	1	3.142E+00	7.190E+00	0.	2.157E+03	5.947E+09	1.127E-02	0.	2.343E+07	7.435E+02	6.159E-01	4.913E+00
8	1	3.665E+00	7.190E+00	0.	2.157E+03	5.946E+09	1.098E-02	0.	2.283E+07	7.434E+02	7.107E-01	4.534E+00
9	1	4.189E+00	7.190E+00	0.	2.157E+03	5.946E+09	1.098E-02	0.	2.283E+07	7.434E+02	8.054E-01	4.393E+00
10	1	4.712E+00	7.190E+00	0.	2.157E+03	5.946E+09	1.098E-02	0.	2.283E+07	7.434E+02	9.002E-01	4.393E+00
11	1	5.236E+00	7.190E+00	0.	2.157E+03	5.946E+09	1.098E-02	0.	2.283E+07	7.434E+02	9.949E-01	4.393E+00
12	1	5.760E+00	7.190E+00	0.	2.157E+03	-1	0.	0.	0.	0.	0.	-I
1	2	0.	7.535E+00	0.	1.192E+03	5.946E+09	1.118E-02	0.	2.324E+07	7.434E+02	4.739E-02	4.439E+00
2	2	5.236E-01	7.535E+00	2.214E+01	1.186E+03	5.946E+09	1.118E-02	1.050E+03	2.324E+07	7.434E+02	1.422E-01	4.453E+00
3	2	1.047E+00	7.535E+00	4.569E+01	1.191E+03	5.946E+09	1.119E-02	2.029E+03	2.324E+07	7.434E+02	2.369E-01	4.499E+00
4	2	1.571E+00	7.535E+00	6.359E+01	1.183E+03	5.946E+09	1.119E-02	3.019E+03	2.325E+07	7.434E+02	3.317E-01	4.527E+00
5	2	2.094E+00	7.535E+00	9.104E+01	1.191E+03	5.946E+09	1.118E-02	4.016E+03	2.324E+07	7.434E+02	4.265E-01	4.565E+00
6	2	2.618E+00	7.535E+00	8.267E+01	1.173E+03	5.946E+09	1.119E-02	4.988E+03	2.326E+07	7.434E+02	5.212E-01	4.768E+00
7	2	3.142E+00	7.535E+00	4.297E+02	9.855E+02	5.947E+09	1.117E-02	5.892E+03	2.321E+07	7.435E+02	6.159E-01	4.595E+00
8	2	3.665E+00	7.535E+00	0.	2.157E+03	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	7.108E-01	4.945E+00
9	2	4.189E+00	7.535E+00	0.	2.157E+03	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	8.055E-01	4.719E+00
10	2	4.712E+00	7.535E+00	0.	2.157E+03	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	9.003E-01	4.757E+00
11	2	5.236E+00	7.535E+00	0.	2.157E+03	5.946E+09	1.098E-02	0.	2.282E+07	7.434E+02	9.951E-01	4.626E+00
12	2	5.760E+00	7.535E+00	0.	2.157E+03	-I	0.	0.	0.	0.	0.	-I
1	3	0.	7.881E+00	0.	6.511E+02	5.946E+09	1.109E-02	0.	2.304E+07	7.434E+02	4.692E-02	4.431E+00
2	3	5.236E-01	7.881E+00	2.512E+01	6.565E+02	5.946E+09	1.109E-02	1.137E+03	2.304E+07	7.434E+02	1.408E-01	4.405E+00
3	3	1.047E+00	7.881E+00	4.960E+01	6.501E+02	5.946E+09	1.109E-02	2.137E+03	2.304E+07	7.434E+02	2.346E-01	4.393E+00
4	3	1.571E+00	7.881E+00	7.403E+01	6.607E+02	5.946E+09	1.109E-02	3.169E+03	2.304E+07	7.434E+02	3.285E-01	4.393E+00
5	3	2.094E+00	7.881E+00	8.516E+01	6.343E+02	5.946E+09	1.110E-02	4.202E+03	2.306E+07	7.434E+02	4.223E-01	4.393E+00
6	3	2.618E+00	7.881E+00	1.219E+02	6.723E+02	5.946E+09	1.109E-02	5.268E+03	2.304E+07	7.434E+02	5.161E-01	4.550E+00
7	3	3.142E+00	7.881E+00	-3.346E+01	2.632E+02	5.947E+09	1.120E-02	6.232E+03	2.328E+07	7.435E+02	6.100E-01	4.848E+00
8	3	3.665E+00	7.881E+00	0.	2.157E+03	5.949E+09	1.134E-02	0.	2.358E+07	7.437E+02	7.038E-01	4.892E+00
9	3	4.189E+00	7.881E+00	0.	2.157E+03	5.950E+09	1.136E-02	0.	2.363E+07	7.438E+02	7.977E-01	5.051E+00
10	3	4.712E+00	7.881E+00	0.	2.157E+03	5.951E+09	1.134E-02	0.	2.359E+07	7.439E+02	8.915E-01	4.959E+00
11	3	5.236E+00	7.881E+00	0.	2.157E+03	5.948E+09	1.153E-02	0.	2.396E+07	7.436E+02	9.854E-01	5.261E+00
12	3	5.760E+00	7.881E+00	0.	2.157E+03	-I	0.	0.	0.	0.	0.	-I
1	4	0.	8.223E+00	0.	3.625E+02	5.946E+09	1.103E-02	0.	2.293E+07	7.434E+02	4.692E-02	4.431E+00
2	4	5.236E-01	8.223E+00	2.523E+01	3.568E+02	5.946E+09	1.103E-02	1.132E+03	2.293E+07	7.434E+02	1.408E-01	4.405E+00
3	4	1.047E+00	8.223E+00	4.966E+01	3.634E+02	5.946E+09	1.103E-02	2.135E+03	2.293E+07	7.434E+02	2.346E-01	4.393E+00
4	4	1.571E+00	8.223E+00	7.326E+01	3.520E+02	5.946E+09	1.104E-02	3.165E+03	2.294E+07	7.434E+02	3.285E-01	4.393E+00
5	4	2.094E+00	8.223E+00	8.437E+01	3.750E+02	5.946E+09	1.104E-02	4.205E+03	2.294E+07	7.434E+02	4.223E-01	4.393E+00
6	4	2.618E+00	8.223E+00	9.705E+01	2.980E+02	5.946E+09	1.106E-02	5.272E+03	2.299E+07	7.434E+02	5.161E-01	4.393E+00
7	4	3.142E+00	8.223E+00	-1.999E+02	4.035E+02	5.946E+09	1.110E-02	6.125E+03	2.308E+07	7.434E+02	6.100E-01	4.550E+00
8	4	3.665E+00	8.223E+00	-2.742E+02	9.691E+02	5.946E+09	1.116E-02	7.137E+03	2.319E+07	7.434E+02	7.038E-01	4.690E+00
9	4	4.189E+00	8.223E+00	9.150E+01	1.295E+03	5.946E+09	1.118E-02	7.987E+03	2.323E+07	7.434E+02	7.977E-01	4.719E+00
10	4	4.712E+00	8.223E+00	1.434E+02	1.065E+03	5.946E+09	1.123E-02	8.988E+03	2.334E+07	7.434E+02	8.915E-01	5.023E+00
11	4	5.236E+00	8.223E+00	-8.907E+01	1.555E+03	5.949E+09	1.118E-02	9.670E+03	2.325E+07	7.437E+02	9.854E-01	5.163E+00
12	4	5.760E+00	8.223E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	5	0.	8.565E+00	0.	1.917E+02	5.946E+09	1.101E-02	0.	2.287E+07	7.434E+02	4.692E-02	4.431E+00
2	5	5.236E-01	8.565E+00	2.577E+01	1.966E+02	5.946E+09	1.101E-02	1.123E+03	2.287E+07	7.434E+02	1.408E-01	4.405E+00
3	5	1.047E+00	8.565E+00	5.225E+01	1.933E+02	5.946E+09	1.101E-02	2.131E+03	2.287E+07	7.434E+02	2.346E-01	4.393E+00
4	5	1.571E+00	8.565E+00	6.928E+01	2.026E+02	5.946E+09	1.101E-02	3.162E+03	2.287E+07	7.434E+02	3.285E-01	4.393E+00
5	5	2.094E+00	8.565E+00	9.510E+01	1.894E+02	5.946E+09	1.101E-02	4.207E+03	2.289E+07	7.434E+02	4.223E-01	4.393E+00
6	5	2.618E+00	8.565E+00	4.572E+01	2.077E+02	5.946E+09	1.102E-02	5.239E+03	2.291E+07	7.434E+02	5.161E-01	4.393E+00
7	5	3.142E+00	8.565E+00	7.679E+00	3.200E+02	5.946E+09	1.105E-02	6.269E+03	2.296E+07	7.434E+02	6.100E-01	4.393E+00
8	5	3.665E+00	8.565E+00	2.335E+01	5.071E+02	5.946E+09	1.107E-02	7.343E+03	2.300E+07	7.434E+02	7.038E-01	4.393E+00

CONCHAS TEST PROBLEM 7/20/79
T= 1.25000E-05 CYCLE= 1

I	J	X	Y	U	V	STE	RHO	W	P	TEM	VOL	XMU
9	5	4.189E+00	8.565E+00	1.058E+02	5.971E+02	5.946E+09	1.109E-02	8.403E+03	2.306E+07	7.434E+02	7.977E-01	4.393E+00
10	5	4.712E+00	8.565E+00	1.064E+02	7.297E+02	5.946E+09	1.110E-02	9.360E+03	2.306E+07	7.434E+02	8.915E-01	4.659E+00
11	5	5.236E+00	8.565E+00	3.025E+02	6.354E+02	5.949E+09	1.111E-02	1.005E+04	2.310E+07	7.437E+02	9.854E-01	5.196E+00
12	5	5.760E+00	8.565E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	6	0.	8.908E+00	0.	9.953E+01	5.946E+09	1.099E-02	0.	2.284E+07	7.434E+02	4.692E-02	4.431E+00
2	6	5.236E-01	8.908E+00	2.965E+01	9.897E+01	5.946E+09	1.099E-02	1.111E+03	2.284E+07	7.434E+02	1.409E-01	4.405E+00
3	6	1.047E+00	8.908E+00	5.087E+01	1.047E+02	5.946E+09	1.099E-02	2.124E+03	2.284E+07	7.434E+02	2.346E-01	4.393E+00
4	6	1.571E+00	8.908E+00	7.729E+01	1.053E+02	5.946E+09	1.099E-02	3.159E+03	2.284E+07	7.434E+02	3.285E-01	4.393E+00
5	6	2.094E+00	8.908E+00	8.262E+01	1.121E+02	5.946E+09	1.099E-02	4.198E+03	2.285E+07	7.434E+02	4.223E-01	4.393E+00
6	6	2.618E+00	8.908E+00	8.533E+01	1.350E+02	5.946E+09	1.100E-02	5.238E+03	2.287E+07	7.434E+02	5.161E-01	4.393E+00
7	6	3.142E+00	8.908E+00	8.275E+01	1.969E+02	5.946E+09	1.101E-02	6.281E+03	2.289E+07	7.434E+02	6.109E-01	4.393E+00
8	6	3.665E+00	8.908E+00	1.112E+02	2.604E+02	5.946E+09	1.103E-02	7.332E+03	2.292E+07	7.434E+02	7.039E-01	4.393E+00
9	6	4.189E+00	8.908E+00	1.272E+02	3.390E+02	5.946E+09	1.103E-02	8.367E+03	2.293E+07	7.434E+02	7.977E-01	4.393E+00
10	6	4.712E+00	8.908E+00	1.944E+02	3.653E+02	5.946E+09	1.105E-02	9.424E+03	2.296E+07	7.434E+02	8.915E-01	4.659E+00
11	6	5.236E+00	8.908E+00	1.755E+02	3.436E+02	5.949E+09	1.106E-02	1.004E+04	2.299E+07	7.437E+02	9.854E-01	5.196E+00
12	6	5.760E+00	8.908E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	7	0.	9.250E+00	0.	3.524E+01	5.946E+09	1.099E-02	0.	2.283E+07	7.434E+02	4.692E-02	4.431E+00
2	7	5.236E-01	9.250E+00	2.953E+01	3.770E+01	5.946E+09	1.098E-02	1.096E+03	2.283E+07	7.434E+02	1.409E-01	4.405E+00
3	7	1.047E+00	9.250E+00	5.972E+01	4.674E+01	5.946E+09	1.098E-02	2.117E+03	2.283E+07	7.434E+02	2.346E-01	4.393E+00
4	7	1.571E+00	9.250E+00	7.492E+01	5.613E+01	5.946E+09	1.098E-02	3.153E+03	2.283E+07	7.434E+02	3.285E-01	4.393E+00
5	7	2.094E+00	9.250E+00	9.433E+01	6.362E+01	5.946E+09	1.098E-02	4.194E+03	2.283E+07	7.434E+02	4.223E-01	4.393E+00
6	7	2.618E+00	9.250E+00	1.026E+02	8.341E+01	5.946E+09	1.099E-02	5.236E+03	2.284E+07	7.434E+02	5.161E-01	4.393E+00
7	7	3.142E+00	9.250E+00	1.230E+02	1.076E+02	5.946E+09	1.099E-02	6.281E+03	2.285E+07	7.434E+02	6.109E-01	4.393E+00
8	7	3.665E+00	9.250E+00	1.379E+02	1.466E+02	5.946E+09	1.100E-02	7.324E+03	2.286E+07	7.434E+02	7.039E-01	4.393E+00
9	7	4.189E+00	9.250E+00	1.706E+02	1.745E+02	5.946E+09	1.101E-02	8.372E+03	2.288E+07	7.434E+02	7.977E-01	4.393E+00
10	7	4.712E+00	9.250E+00	1.789E+02	1.903E+02	5.946E+09	1.102E-02	9.415E+03	2.290E+07	7.434E+02	8.915E-01	4.659E+00
11	7	5.236E+00	9.250E+00	1.573E+02	1.741E+02	5.949E+09	1.104E-02	1.007E+04	2.295E+07	7.437E+02	9.854E-01	5.196E+00
12	7	5.760E+00	9.250E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	8	0.	9.592E+00	0.	-4.129E+01	5.946E+09	1.099E-02	0.	2.285E+07	7.434E+02	4.692E-02	4.431E+00
2	8	5.236E-01	9.592E+00	4.744E+01	-1.615E+01	5.946E+09	1.098E-02	1.084E+03	2.283E+07	7.434E+02	1.409E-01	4.405E+00
3	8	1.047E+00	9.592E+00	6.300E+01	6.564E+00	5.946E+09	1.098E-02	2.107E+03	2.282E+07	7.434E+02	2.346E-01	4.393E+00
4	8	1.571E+00	9.592E+00	8.966E+01	2.478E+01	5.946E+09	1.098E-02	3.146E+03	2.281E+07	7.434E+02	3.285E-01	4.393E+00
5	8	2.094E+00	9.592E+00	9.345E+01	3.855E+01	5.946E+09	1.098E-02	4.191E+03	2.282E+07	7.434E+02	4.223E-01	4.393E+00
6	8	2.618E+00	9.592E+00	1.184E+02	4.164E+01	5.946E+09	1.098E-02	5.233E+03	2.282E+07	7.434E+02	5.161E-01	4.393E+00
7	8	3.142E+00	9.592E+00	1.352E+02	6.027E+01	5.946E+09	1.098E-02	6.278E+03	2.283E+07	7.434E+02	6.109E-01	4.393E+00
8	8	3.665E+00	9.592E+00	1.599E+02	7.345E+01	5.946E+09	1.099E-02	7.323E+03	2.284E+07	7.434E+02	7.039E-01	4.393E+00
9	8	4.189E+00	9.592E+00	1.780E+02	9.047E+01	5.946E+09	1.099E-02	8.369E+03	2.285E+07	7.434E+02	7.977E-01	4.393E+00
10	8	4.712E+00	9.592E+00	1.858E+02	9.624E+01	5.946E+09	1.101E-02	9.415E+03	2.287E+07	7.434E+02	8.915E-01	4.659E+00
11	8	5.236E+00	9.592E+00	1.459E+02	8.879E+01	5.949E+09	1.102E-02	1.011E+04	2.292E+07	7.437E+02	9.854E-01	5.196E+00
12	8	5.760E+00	9.592E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	9	0.	9.935E+00	0.	-1.254E+02	5.953E+09	1.100E-02	0.	2.289E+07	7.442E+02	4.692E-02	4.439E+00
2	9	5.236E-01	9.935E+00	6.011E+01	-1.236E+02	5.946E+09	1.100E-02	1.059E+03	2.286E+07	7.434E+02	1.409E-01	4.463E+00
3	9	1.047E+00	9.935E+00	1.273E+02	-2.806E+01	5.946E+09	1.097E-02	2.089E+03	2.280E+07	7.434E+02	2.346E-01	4.499E+00
4	9	1.571E+00	9.935E+00	7.323E+01	2.724E+01	5.946E+09	1.098E-02	3.143E+03	2.282E+07	7.434E+02	3.285E-01	4.527E+00
5	9	2.094E+00	9.935E+00	1.043E+02	5.744E+00	5.946E+09	1.098E-02	4.183E+03	2.281E+07	7.434E+02	4.223E-01	4.565E+00
6	9	2.618E+00	9.935E+00	1.205E+02	2.265E+01	5.946E+09	1.098E-02	5.228E+03	2.282E+07	7.434E+02	5.161E-01	4.594E+00
7	9	3.142E+00	9.935E+00	1.449E+02	2.254E+01	5.946E+09	1.098E-02	6.272E+03	2.282E+07	7.434E+02	6.109E-01	4.642E+00
8	9	3.665E+00	9.935E+00	1.659E+02	3.400E+01	5.946E+09	1.098E-02	7.317E+03	2.283E+07	7.434E+02	7.039E-01	4.680E+00
9	9	4.189E+00	9.935E+00	1.943E+02	3.655E+01	5.946E+09	1.099E-02	8.362E+03	2.284E+07	7.434E+02	7.977E-01	4.719E+00
10	9	4.712E+00	9.935E+00	1.903E+02	4.763E+01	5.946E+09	1.100E-02	9.412E+03	2.286E+07	7.434E+02	8.915E-01	5.023E+00
11	9	5.236E+00	9.935E+00	1.384E+02	4.967E+01	5.949E+09	1.102E-02	1.015E+04	2.291E+07	7.437E+02	9.854E-01	5.153E+00
12	9	5.760E+00	9.935E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	10	0.	1.028E+01	0.	-8.774E+02	5.245E+09	1.067E-02	0.	2.315E+07	7.757E+02	4.692E-02	4.504E+00
2	10	5.236E-01	1.028E+01	4.231E+02	-3.158E+02	5.947E+09	1.096E-02	9.455E+02	2.279E+07	7.435E+02	1.409E-01	4.558E+00
3	10	1.047E+00	1.028E+01	7.295E+01	7.509E+01	5.946E+09	1.098E-02	1.968E+03	2.283E+07	7.434E+02	2.346E-01	4.692E+00
4	10	1.571E+00	1.028E+01	7.379E+01	-2.993E+01	5.947E+09	1.097E-02	2.973E+03	2.281E+07	7.435E+02	3.285E-01	4.799E+00

CONCHAS TEST PROBLEM 7/20/79
T= 1.25000E-05 CYCLE= 1

I	J	X	Y	U	V	SIE	RHO	W	P	TEM	VOL	XMU
5	10	2.094E+00	1.028E+01	9.137E+01	9.112E+00	5.947E+09	1.098E-02	3.963E+03	2.282E+07	7.435E+02	4.223E-01	4.914E+00
6	10	2.618E+00	1.028E+01	1.113E+02	-5.451E+00	5.948E+09	1.098E-02	4.955E+03	2.282E+07	7.436E+02	5.161E-01	5.030E+00
7	10	3.142E+00	1.028E+01	1.316E+02	3.445E+00	5.948E+09	1.098E-02	5.941E+03	2.282E+07	7.437E+02	6.100E-01	5.146E+00
8	10	3.665E+00	1.028E+01	1.512E+02	9.693E-01	5.949E+09	1.098E-02	6.927E+03	2.283E+07	7.437E+02	7.038E-01	5.261E+00
9	10	4.189E+00	1.028E+01	1.657E+02	7.974E+00	5.950E+09	1.098E-02	7.908E+03	2.284E+07	7.439E+02	7.977E-01	5.377E+00
10	10	4.712E+00	1.028E+01	1.678E+02	3.469E+00	5.951E+09	1.099E-02	8.899E+03	2.286E+07	7.440E+02	8.915E-01	5.324E+00
11	10	5.236E+00	1.028E+01	1.465E+02	3.307E+01	5.948E+09	1.101E-02	9.854E+03	2.288E+07	7.436E+02	9.854E-01	5.494E+00
12	10	5.760E+00	1.028E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	11	0.	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
2	11	5.236E-01	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
3	11	1.047E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
4	11	1.571E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
5	11	2.094E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
6	11	2.618E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
7	11	3.142E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
8	11	3.665E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
9	11	4.189E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
10	11	4.712E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
11	11	5.236E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
12	11	5.760E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I

SPECIES MASS FRACTIONS

I	J	1	2	3	4	5	6	7	8	9	10		
1	1	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
2	1	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
3	1	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
4	1	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
5	1	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
6	1	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
7	1	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
8	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	1	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	2	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
2	2	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
3	2	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
4	2	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.

5	2	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
6	2	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
7	2	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
8	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
9	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
10	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
11	2	4.810E-02	1.777E-01	7.742E-01	0.	0.	0.	0.	0.	0.	0.
		0.	0.								
1	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
2	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
3	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
4	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
5	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
6	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
7	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
8	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
9	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
10	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
11	3	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
1	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
2	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
3	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
4	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
5	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
6	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
7	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
8	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
9	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
10	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
11	4	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
1	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
2	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								

3	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
4	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
5	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
6	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
7	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
8	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
9	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
10	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
11	5	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
1	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
2	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
3	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
4	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
5	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
6	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
7	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
8	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
9	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
10	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
11	6	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
1	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
2	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
3	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
4	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
5	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
6	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
7	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
8	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
9	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
10	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.
11	7	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.	0.	0.

1	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
2	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
3	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
4	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
5	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
6	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
7	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
8	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
9	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
10	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
11	8	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
1	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
2	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
3	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
4	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
5	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
6	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
7	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
8	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
9	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
10	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
11	9	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
1	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
2	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
3	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
4	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
5	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
6	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
7	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
8	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								
9	10	4.810E-02	1.777E-01	7.742E-01	6.842E-07	3.149E-07	0.	0.	0.	0.	0.
		0.	0.								

```
   10    10  4.810E-02  1.777E-01  7.742E-01  6.842E-07  3.149E-07  0.          0.          0.          0.          0.
               0.         0.
   11    10  4.810E-02  1.777E-01  7.742E-01  6.842E-07  3.149E-07  0.          0.          0.          0.          0.
               0.         0.
NCYC =     1 DT =  1.250000E-05 T =  1.250000E-05 NUMIT =  17 GRIND = 31.12
    Y(PISTON) =  7.1895E+00 V(PISTON) =  2.1570E+03 PRESSURE =  2.2884E+07 M
NCYC =     2 DT =  1.250000E-05 T =  2.500000E-05 NUMIT =  18 GRIND = 13.85
    Y(PISTON) =  7.2164E+00 V(PISTON) =  2.1487E+03 PRESSURE =  2.3024E+07 M
NCYC =     3 DT =  1.250000E-05 T =  3.750000E-05 NUMIT =  17 GRIND =  2.00
    Y(PISTON) =  7.2432E+00 V(PISTON) =  2.1403E+03 PRESSURE =  2.3282E+07 M
NCYC =     4 DT =  1.250000E-05 T =  5.000000E-05 NUMIT =  18 GRIND =  2.04
    Y(PISTON) =  7.2699E+00 V(PISTON) =  2.1318E+03 PRESSURE =  2.3693E+07 M
NCYC =     5 DT =  1.250000E-05 T =  6.250000E-05 NUMIT =  18 GRIND =  2.04
    Y(PISTON) =  7.2965E+00 V(PISTON) =  2.1232E+03 PRESSURE =  2.4227E+07 M
NCYC =     6 DT =  1.250000E-05 T =  7.500000E-05 NUMIT =  17 GRIND =  2.00
    Y(PISTON) =  7.3230E+00 V(PISTON) =  2.1145E+03 PRESSURE =  2.4779E+07 M
NCYC =     7 DT =  1.275000E-05 T =  8.775000E-05 NUMIT =  18 GRIND =  2.03
    Y(PISTON) =  7.3499E+00 V(PISTON) =  2.1055E+03 PRESSURE =  2.5249E+07 M
NCYC =     8 DT =  1.275000E-05 T =  1.005000E-04 NUMIT =  19 GRIND =  2.07
    Y(PISTON) =  7.3767E+00 V(PISTON) =  2.0965E+03 PRESSURE =  2.5577E+07 M
NCYC =     9 DT =  1.275000E-05 T =  1.132500E-04 NUMIT =  19 GRIND =  2.07
    Y(PISTON) =  7.4034E+00 V(PISTON) =  2.0873E+03 PRESSURE =  2.5792E+07 M
MASS= 3.48513356E+00 U MOM=-5.15335836E+02 V MOM= 3.55991651E+03 SIE= 2.1368239E+10 TOT E= 8.8899113E+10CHEM E=. 6.7474237E+10
  WORK = 6.7103040E+08    ANG MOMENTUM = 1.6286118E+04  GMS NO = 0.
NCYC =    10 DT =  1.275000E-05 T =  1.260000E-04 NUMIT =  19 GRIND = 14.92
    Y(PISTON) =  7.4299E+00 V(PISTON) =  2.0781E+03 PRESSURE =  2.5963E+07 M
NCYC =    11 DT =  1.275000E-05 T =  1.387500E-04 NUMIT =  16 GRIND = 15.96
    Y(PISTON) =  7.4564E+00 V(PISTON) =  2.0688E+03 PRESSURE =  2.6152E+07 M
NCYC =    12 DT =  1.300500E-05 T =  1.517550E-04 NUMIT =  19 GRIND =  2.08
    Y(PISTON) =  7.4832E+00 V(PISTON) =  2.0592E+03 PRESSURE =  2.6398E+07 M
NCYC =    13 DT =  1.300500E-05 T =  1.647600E-04 NUMIT =  20 GRIND =  2.12
    Y(PISTON) =  7.5099E+00 V(PISTON) =  2.0495E+03 PRESSURE =  2.6699E+07 M
NCYC =    14 DT =  1.300500E-05 T =  1.777650E-04 NUMIT =  20 GRIND =  2.13
```

CONCHAS TEST PROBLEM 7/20/79
T= 9.06372E-04 CYCLE= 100

I	J	X	Y	U	V	SIE	RHO	W	P	TEM	VOL	XMU
1	1	0.	8.788E+00	0.	1.355E+03	1.707E+10	1.448E-02	0.	7.536E+07	1.824E+03	5.930E-02	7.135E+00
2	1	5.236E-01	8.788E+00	0.	1.355E+03	1.088E+10	2.050E-02	0.	7.167E+07	1.242E+03	1.779E-01	9.017E+00
3	1	1.047E+00	8.788E+00	0.	1.355E+03	8.952E+09	2.464E-02	0.	7.279E+07	1.054E+03	2.965E-01	9.904E+00
4	1	1.571E+00	8.788E+00	0.	1.355E+03	8.385E+09	2.558E-02	0.	7.138E+07	9.976E+02	4.151E-01	1.103E+01
5	1	2.094E+00	8.788E+00	0.	1.355E+03	8.247E+09	2.570E-02	0.	7.070E+07	9.835E+02	5.337E-01	1.102E+01
6	1	2.618E+00	8.788E+00	0.	1.355E+03	8.187E+09	2.535E-02	0.	6.929E+07	9.773E+02	6.523E-01	1.091E+01
7	1	3.142E+00	8.788E+00	0.	1.355E+03	8.179E+09	2.521E-02	0.	6.887E+07	9.766E+02	7.709E-01	9.856E+00
8	1	3.665E+00	8.788E+00	0.	1.355E+03	7.308E+09	8.775E-03	0.	2.234E+07	8.878E+02	8.895E-01	5.853E+00
9	1	4.189E+00	8.788E+00	0.	1.355E+03	6.981E+09	8.775E-03	0.	2.150E+07	8.536E+02	1.008E+00	4.121E+00
10	1	4.712E+00	8.788E+00	0.	1.355E+03	6.910E+09	8.775E-03	0.	2.132E+07	8.462E+02	1.127E+00	4.121E+00
11	1	5.236E+00	8.788E+00	0.	1.355E+03	6.899E+09	8.775E-03	0.	2.129E+07	8.451E+02	1.245E+00	4.121E+00
12	1	5.760E+00	8.788E+00	0.	1.355E+03	-I	0.	0.	0.	0.	0.	-I
1	2	0.	9.221E+00	0.	1.042E+04	2.454E+10	9.954E-03	0.	7.226E+07	2.502E+03	3.492E-02	5.281E+00
2	2	5.236E-01	9.221E+00	3.540E+03	5.869E+03	2.327E+10	1.023E-02	2.044E+02	7.116E+07	2.391E+03	1.047E-01	5.500E+00
3	2	1.047E+00	9.221E+00	2.492E+03	1.037E+03	1.228E+10	1.831E-02	7.383E+02	7.114E+07	1.376E+03	1.746E-01	8.205E+00
4	2	1.571E+00	9.221E+00	4.378E+03	3.532E+02	8.979E+09	2.410E-02	8.611E+02	7.139E+07	1.057E+03	2.444E-01	9.973E+00
5	2	2.094E+00	9.221E+00	3.791E+03	6.226E+02	8.319E+09	2.518E-02	1.494E+03	6.976E+07	9.908E+02	3.142E-01	1.075E+01
6	2	2.618E+00	9.221E+00	2.560E+03	6.103E+02	8.222E+09	2.549E-02	1.677E+03	6.998E+07	9.810E+02	3.841E-01	1.066E+01
7	2	3.142E+00	9.221E+00	1.549E+03	4.972E+02	8.191E+09	2.507E-02	1.467E+03	6.855E+07	9.778E+02	4.539E-01	9.520E+00
8	2	3.665E+00	9.221E+00	0.	1.355E+03	7.685E+09	1.490E-02	0.	3.875E+07	9.264E+02	5.237E-01	7.706E+00
9	2	4.189E+00	9.221E+00	0.	1.355E+03	7.555E+09	1.490E-02	0.	3.820E+07	9.132E+02	5.936E-01	6.546E+00
10	2	4.712E+00	9.221E+00	0.	1.355E+03	7.553E+09	1.490E-02	0.	3.820E+07	9.130E+02	6.634E-01	6.347E+00
11	2	5.236E+00	9.221E+00	0.	1.355E+03	7.547E+09	1.490E-02	0.	3.817E+07	9.124E+02	7.332E-01	5.532E+00
12	2	5.760E+00	9.221E+00	0.	1.355E+03	-I	0.	0.	0.	0.	0.	-I
1	3	0.	9.476E+00	0.	5.553E+03	2.544E+10	9.442E-03	0.	7.139E+07	2.587E+03	1.960E-02	4.369E+00
2	3	5.236E-01	9.476E+00	3.139E+03	6.869E+03	2.493E+10	9.379E-03	5.521E+02	6.960E+07	2.542E+03	5.879E-02	4.891E+00
3	3	1.047E+00	9.476E+00	1.581E+03	1.112E+03	1.931E+10	1.232E-02	7.557E+02	7.173E+07	2.029E+03	9.799E-02	6.768E+00
4	3	1.571E+00	9.476E+00	5.522E+03	1.713E+02	9.986E+09	2.154E-02	1.285E+03	6.925E+07	1.146E+03	1.372E-01	9.195E+00
5	3	2.094E+00	9.476E+00	4.267E+03	6.073E+02	8.464E+09	2.527E-02	1.679E+03	7.118E+07	1.006E+03	1.764E-01	1.028E+01
6	3	2.618E+00	9.476E+00	2.984E+03	1.843E+02	8.225E+09	2.500E-02	2.392E+03	6.856E+07	9.812E+02	2.155E-01	1.074E+01
7	3	3.142E+00	9.476E+00	1.318E+03	5.974E+02	8.197E+09	2.553E-02	2.408E+03	6.990E+07	9.785E+02	2.547E-01	1.065E+01
8	3	3.665E+00	9.476E+00	0.	1.355E+03	8.197E+09	2.438E-02	0.	6.673E+07	9.785E+02	2.939E-01	9.601E+00
9	3	4.189E+00	9.476E+00	0.	1.355E+03	8.179E+09	2.527E-02	0.	6.906E+07	9.766E+02	3.331E-01	9.308E+00
10	3	4.712E+00	9.476E+00	0.	1.355E+03	8.203E+09	2.394E-02	0.	6.555E+07	9.790E+02	3.723E-01	9.518E+00
11	3	5.236E+00	9.476E+00	0.	1.355E+03	8.216E+09	2.535E-02	0.	6.953E+07	9.803E+02	4.115E-01	9.201E+00
12	3	5.760E+00	9.476E+00	0.	1.355E+03	-I	0.	0.	0.	0.	0.	-I
1	4	0.	9.619E+00	0.	7.103E+03	2.594E+10	9.130E-03	0.	7.042E+07	2.632E+03	1.960E-02	4.141E+00
2	4	5.236E-01	9.619E+00	3.012E+03	3.641E+03	2.535E+10	9.318E-03	1.083E+03	7.042E+07	2.580E+03	5.879E-02	4.387E+00
3	4	1.047E+00	9.619E+00	8.874E+02	4.149E+03	2.278E+10	1.016E-02	6.125E+02	6.901E+07	2.346E+03	9.798E-02	5.993E+00
4	4	1.571E+00	9.619E+00	5.883E+03	1.206E+03	1.066E+10	2.055E-02	1.382E+03	7.068E+07	1.221E+03	1.372E-01	8.358E+00
5	4	2.094E+00	9.619E+00	4.188E+03	1.927E+02	8.571E+09	2.450E-02	1.507E+03	6.968E+07	1.016E+03	1.764E-01	1.018E+01
6	4	2.618E+00	9.619E+00	3.316E+03	9.652E+01	8.235E+09	2.548E-02	2.890E+03	7.003E+07	9.823E+02	2.155E-01	1.050E+01
7	4	3.142E+00	9.619E+00	1.399E+03	9.023E+02	8.195E+09	2.487E-02	2.126E+03	6.805E+07	9.782E+02	2.547E-01	1.062E+01
8	4	3.665E+00	9.619E+00	8.107E+02	7.815E+02	8.191E+09	2.517E-02	1.567E+03	6.886E+07	9.778E+02	2.939E-01	1.055E+01
9	4	4.189E+00	9.619E+00	9.454E+01	1.661E+03	8.180E+09	2.437E-02	9.939E+02	6.659E+07	9.757E+02	3.331E-01	1.050E+01
10	4	4.712E+00	9.619E+00	2.619E+02	5.539E+02	8.194E+09	2.501E-02	7.677E+02	6.846E+07	9.792E+02	3.723E-01	1.020E+01
11	4	5.236E+00	9.619E+00	-7.234E+02	2.092E+03	8.202E+09	2.414E-02	4.327E+02	6.610E+07	9.789E+02	4.115E-01	1.043E+01
12	4	5.760E+00	9.619E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	5	0.	9.762E+00	0.	4.648E+03	2.619E+10	9.005E-03	0.	7.016E+07	2.655E+03	1.960E-02	4.066E+00
2	5	5.236E-01	9.762E+00	1.817E+03	3.295E+03	2.555E+10	9.187E-03	3.964E+02	6.987E+07	2.597E+03	5.879E-02	4.083E+00
3	5	1.047E+00	9.762E+00	2.462E+03	4.074E+03	2.392E+10	9.650E-03	1.467E+03	6.889E+07	2.450E+03	9.798E-02	5.434E+00
4	5	1.571E+00	9.762E+00	4.590E+03	1.548E+03	1.134E+10	1.936E-02	5.159E+02	7.025E+07	1.287E+03	1.372E-01	7.962E+00
5	5	2.094E+00	9.762E+00	4.575E+03	-2.764E+02	8.663E+09	2.441E-02	2.473E+03	7.008E+07	1.025E+03	1.764E-01	9.912E+00
6	5	2.618E+00	9.762E+00	3.100E+03	5.092E+02	8.248E+09	2.515E-02	1.867E+03	6.919E+07	9.836E+02	2.155E-01	1.052E+01
7	5	3.142E+00	9.762E+00	1.756E+03	4.627E+02	8.190E+09	2.525E-02	3.355E+03	6.906E+07	9.777E+02	2.547E-01	1.042E+01
8	5	3.665E+00	9.762E+00	6.073E+02	1.009E+03	8.187E+09	2.472E-02	1.586E+03	6.757E+07	9.774E+02	2.939E-01	1.042E+01

CONCHAS TEST PROBLEM 7/20/79
T= 9.06372E-04 CYCLE= 100

I	J	X	Y	U	V	SIE	RHO	W	P	TEM	VOL	XMU
9	5	4.189E+00	9.762E+00	5.044E+02	1.132E+03	8.179E+09	2.473E-02	2.472E+03	6.810E+07	9.756E+02	3.331E-01	1.033E+01
10	5	4.712E+00	9.762E+00	-1.835E+02	7.355E+02	8.181E+09	2.446E-02	9.474E+02	6.683E+07	9.758E+02	3.723E-01	1.036E+01
11	5	5.236E+00	9.762E+00	1.480E+02	1.647E+03	8.203E+09	2.474E-02	1.070E+03	6.777E+07	9.790E+02	4.115E-01	1.021E+01
12	5	5.760E+00	9.762E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	6	0.	9.904E+00	0.	3.646E+03	2.649E+10	8.876E-03	0.	6.991E+07	2.681E+03	1.960E-02	3.941E+00
2	6	5.236E-01	9.904E+00	1.448E+03	2.644E+03	2.559E+10	9.116E-03	1.287E+03	6.948E+07	2.601E+03	5.879E-02	4.025E+00
3	6	1.047E+00	9.904E+00	3.194E+03	3.575E+03	2.444E+10	9.444E-03	4.651E+02	6.887E+07	2.497E+03	9.799E-02	5.150E+00
4	6	1.571E+00	9.904E+00	3.866E+03	1.022E+03	1.180E+10	1.868E-02	1.379E+03	7.018E+07	1.331E+03	1.372E-01	7.749E+00
5	6	2.094E+00	9.904E+00	4.566E+03	5.631E+01	8.739E+09	2.409E-02	1.220E+03	6.969E+07	1.033E+03	1.764E-01	9.846E+00
6	6	2.618E+00	9.904E+00	3.091E+03	2.453E+02	8.253E+09	2.529E-02	3.009E+03	6.964E+07	9.841E+02	2.155E-01	1.038E+01
7	6	3.142E+00	9.904E+00	1.548E+03	6.280E+02	8.192E+09	2.501E-02	2.216E+03	6.840E+07	9.779E+02	2.547E-01	1.040E+01
8	6	3.665E+00	9.904E+00	7.944E+02	7.222E+02	8.184E+09	2.499E-02	3.120E+03	6.829E+07	9.771E+02	2.939E-01	1.025E+01
9	6	4.189E+00	9.904E+00	2.971E+02	1.038E+03	8.190E+09	2.454E-02	2.227E+03	6.731E+07	9.767E+02	3.331E-01	1.024E+01
10	6	4.712E+00	9.904E+00	8.993E+01	7.121E+02	8.180E+09	2.476E-02	1.917E+03	6.766E+07	9.767E+02	3.723E-01	1.017E+01
11	6	5.236E+00	9.904E+00	-1.243E+01	1.320E+03	8.202E+09	2.444E-02	1.162E+03	6.692E+07	9.789E+02	4.115E-01	1.023E+01
12	6	5.760E+00	9.904E+00	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	7	0.	1.005E+01	0.	2.370E+03	2.653E+10	8.839E-03	0.	6.971E+07	2.685E+03	1.960E-02	3.897E+00
2	7	5.236E-01	1.005E+01	1.370E+03	2.345E+03	2.563E+10	9.054E-03	3.084E+02	6.911E+07	2.605E+03	5.879E-02	3.968E+00
3	7	1.047E+00	1.005E+01	3.230E+03	2.388E+03	2.459E+10	9.404E-03	1.209E+03	6.903E+07	2.512E+03	9.799E-02	5.064E+00
4	7	1.571E+00	1.005E+01	3.371E+03	9.589E+02	1.195E+10	1.836E-02	4.487E+02	6.974E+07	1.345E+03	1.372E-01	7.692E+00
5	7	2.094E+00	1.005E+01	4.537E+03	8.655E+01	8.756E+09	2.414E-02	1.916E+03	6.995E+07	1.035E+03	1.764E-01	9.794E+00
6	7	2.618E+00	1.005E+01	2.873E+03	3.003E+02	8.254E+09	2.515E-02	1.629E+03	6.925E+07	9.843E+02	2.155E-01	1.049E+01
7	7	3.142E+00	1.005E+01	1.557E+03	5.058E+02	8.192E+09	2.514E-02	2.996E+03	6.877E+07	9.780E+02	2.547E-01	1.035E+01
8	7	3.665E+00	1.005E+01	6.900E+02	6.577E+02	8.186E+09	2.482E-02	2.436E+03	6.786E+07	9.773E+02	2.939E-01	1.033E+01
9	7	4.189E+00	1.005E+01	3.696E+02	7.995E+02	8.181E+09	2.480E-02	2.940E+03	6.778E+07	9.768E+02	3.331E-01	1.018E+01
10	7	4.712E+00	1.005E+01	8.316E+01	6.489E+02	8.181E+09	2.458E-02	1.848E+03	6.717E+07	9.768E+02	3.723E-01	1.022E+01
11	7	5.236E+00	1.005E+01	2.037E+02	1.009E+03	8.199E+09	2.452E-02	1.458E+03	6.741E+07	9.786E+02	4.115E-01	1.014E+01
12	7	5.760E+00	1.005E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	8	0.	1.019E+01	0.	1.859E+03	2.674E+10	8.756E-03	0.	6.956E+07	2.703E+03	1.960E-02	3.871E+00
2	8	5.236E-01	1.019E+01	1.528E+03	1.720E+03	2.564E+10	9.037E-03	7.765E+02	6.901E+07	2.605E+03	5.879E-02	3.962E+00
3	8	1.047E+00	1.019E+01	2.826E+03	1.464E+03	2.453E+10	9.406E-03	3.607E+02	6.888E+07	2.506E+03	9.799E-02	5.061E+00
4	8	1.571E+00	1.019E+01	3.021E+03	4.756E+02	1.171E+10	1.867E-02	9.343E+02	6.969E+07	1.322E+03	1.372E-01	7.834E+00
5	8	2.094E+00	1.019E+01	4.091E+03	2.728E+02	8.704E+09	2.421E-02	9.691E+02	6.981E+07	1.029E+03	1.764E-01	9.960E+00
6	8	2.618E+00	1.019E+01	2.731E+03	1.973E+02	8.249E+09	2.521E-02	2.190E+03	6.938E+07	9.837E+02	2.155E-01	1.054E+01
7	8	3.142E+00	1.019E+01	1.458E+03	5.093E+02	8.196E+09	2.505E-02	1.950E+03	6.854E+07	9.783E+02	2.547E-01	1.057E+01
8	8	3.665E+00	1.019E+01	6.540E+02	4.818E+02	8.187E+09	2.490E-02	2.725E+03	6.810E+07	9.774E+02	2.939E-01	1.039E+01
9	8	4.189E+00	1.019E+01	2.512E+02	6.354E+02	8.185E+09	2.470E-02	2.257E+03	6.752E+07	9.772E+02	3.331E-01	1.037E+01
10	8	4.712E+00	1.019E+01	1.710E+02	4.910E+02	8.183E+09	2.457E-02	2.062E+03	6.744E+07	9.770E+02	3.723E-01	1.020E+01
11	8	5.236E+00	1.019E+01	1.717E+02	7.564E+02	8.200E+09	2.452E-02	1.267E+03	6.712E+07	9.787E+02	4.115E-01	1.017E+01
12	8	5.760E+00	1.019E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	9	0.	1.033E+01	0.	6.393E+02	2.683E+10	8.716E-03	0.	6.948E+07	2.711E+03	1.960E-02	3.855E+00
2	9	5.236E-01	1.033E+01	1.796E+03	1.297E+03	2.570E+10	9.010E-03	5.248E+01	6.895E+07	2.611E+03	5.879E-02	4.041E+00
3	9	1.047E+00	1.033E+01	2.518E+03	5.722E+02	2.429E+10	9.476E-03	6.854E+02	6.874E+07	2.484E+03	9.799E-02	5.291E+00
4	9	1.571E+00	1.033E+01	2.223E+03	2.067E+02	1.108E+10	1.957E-02	2.458E+02	6.961E+07	1.262E+03	1.372E-01	8.127E+00
5	9	2.094E+00	1.033E+01	3.431E+03	2.445E+02	8.588E+09	2.451E-02	1.131E+03	6.987E+07	1.018E+03	1.764E-01	1.040E+01
6	9	2.618E+00	1.033E+01	2.434E+03	1.719E+02	8.238E+09	2.510E-02	1.170E+03	6.925E+07	9.826E+02	2.155E-01	1.094E+01
7	9	3.142E+00	1.033E+01	1.321E+03	4.449E+02	8.198E+09	2.507E-02	1.807E+03	6.863E+07	9.785E+02	2.547E-01	1.069E+01
8	9	3.665E+00	1.033E+01	5.244E+02	3.264E+02	8.191E+09	2.485E-02	1.741E+03	6.798E+07	9.778E+02	2.939E-01	1.063E+01
9	9	4.189E+00	1.033E+01	2.534E+02	4.512E+02	8.187E+09	2.473E-02	1.923E+03	6.763E+07	9.774E+02	3.331E-01	1.045E+01
10	9	4.712E+00	1.033E+01	1.076E+02	3.129E+02	8.187E+09	2.462E-02	1.476E+03	6.732E+07	9.774E+02	3.723E-01	1.034E+01
11	9	5.236E+00	1.033E+01	2.582E+02	5.167E+02	8.198E+09	2.456E-02	1.071E+03	6.723E+07	9.785E+02	4.115E-01	1.015E+01
12	9	5.760E+00	1.033E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	10	0.	1.048E+01	0.	-1.133E+02	2.646E+10	8.814E-03	0.	6.935E+07	2.679E+03	1.960E-02	3.944E+00
2	10	5.236E-01	1.048E+01	1.806E+03	4.460E+02	2.588E+10	8.933E-03	3.004E+02	6.918E+07	2.627E+03	5.879E-02	4.073E+00
3	10	1.047E+00	1.048E+01	2.515E+03	2.118E+02	2.399E+10	9.523E-03	2.355E+01	6.828E+07	2.459E+03	9.799E-02	5.559E+00
4	10	1.571E+00	1.048E+01	8.520E+02	1.451E+01	1.035E+10	2.097E-02	4.107E+02	6.993E+07	1.191E+03	1.372E-01	8.611E+00

CONCHAS TEST PROBLEM 7/20/79
T= 9.06372E-04 CYCLE= 100

I	J	X	Y	U	V	SIE	RHO	W	P	TEM	VOL	XMU
5	10	2.094E+00	1.048E+01	2.115E+03	-1.118E+01	8.454E+09	2.481E-02	3.254E+02	6.974E+07	1.005E+03	1.754E-01	1.081E+01
6	10	2.618E+00	1.048E+01	1.824E+03	1.532E+02	8.224E+09	2.522E-02	9.029E+02	6.922E+07	9.812E+02	2.155E-01	1.114E+01
7	10	3.142E+00	1.048E+01	9.517E+02	3.217E+02	8.206E+09	2.506E-02	7.112E+02	6.866E+07	9.793E+02	2.547E-01	1.092E+01
8	10	3.665E+00	1.048E+01	5.191E+02	1.237E+02	8.187E+09	2.485E-02	1.135E+03	6.795E+07	9.774E+02	2.939E-01	1.071E+01
9	10	4.189E+00	1.048E+01	2.081E+02	3.065E+02	8.195E+09	2.471E-02	8.992E+02	6.761E+07	9.782E+02	3.331E-01	1.058E+01
10	10	4.712E+00	1.048E+01	1.253E+02	9.280E+01	8.184E+09	2.465E-02	8.791E+02	6.738E+07	9.771E+02	3.723E-01	1.036E+01
11	10	5.236E+00	1.048E+01	2.096E+02	2.949E+02	8.203E+09	2.451E-02	5.626E+02	6.713E+07	9.790E+02	4.115E-01	1.017E+01
12	10	5.760E+00	1.048E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
1	11	0.	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
2	11	5.236E-01	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
3	11	1.047E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
4	11	1.571E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
5	11	2.094E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
6	11	2.618E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
7	11	3.142E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
8	11	3.665E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
9	11	4.189E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
10	11	4.712E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
11	11	5.236E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I
12	11	5.760E+00	1.062E+01	0.	0.	-I	0.	0.	0.	0.	0.	-I

SPECIES MASS FRACTIONS

I	J	1	2	3	4	5	6	7	8	9	10
1	1	2.312E-02	8.999E-02	7.742E-01	7.714E-02	3.548E-02	-6.045E-09	-6.134E-08	4.708E-07	-4.313E-11	3.992E-05
		-5.722E-06	1.025E-05								
2	1	3.994E-02	1.490E-01	7.742E-01	2.521E-02	1.160E-02	-5.221E-10	-9.277E-09	-3.509E-08	-2.662E-12	-5.083E-08
		-5.735E-07	2.663E-06								
3	1	4.556E-02	1.688E-01	7.742E-01	7.837E-03	3.607E-03	2.897E-09	4.759E-08	2.496E-07	8.676E-15	4.161E-06
		3.361E-06	7.719E-07								
4	1	4.707E-02	1.740E-01	7.742E-01	3.187E-03	1.467E-03	1.150E-09	1.699E-08	8.129E-08	1.286E-17	1.161E-06
		1.226E-06	1.755E-07								
5	1	4.738E-02	1.751E-01	7.742E-01	2.226E-03	1.025E-03	2.633E-10	3.684E-09	1.696E-08	-1.365E-17	2.207E-07
		2.689E-07	2.689E-08								
6	1	4.744E-02	1.753E-01	7.742E-01	2.063E-03	9.495E-04	3.790E-11	5.113E-10	2.320E-09	-4.029E-18	2.840E-08
		3.757E-08	2.849E-09								
7	1	4.744E-02	1.753E-01	7.742E-01	2.060E-03	9.482E-04	3.200E-12	4.213E-11	1.922E-10	-5.212E-19	2.264E-09
		3.106E-09	1.876E-10								
8	1	4.788E-02	1.769E-01	7.742E-01	6.857E-04	3.156E-04	2.567E-13	3.319E-12	1.543E-11	-5.722E-20	1.773E-10
		2.451E-10	1.223E-11								
9	1	4.798E-02	1.772E-01	7.742E-01	3.926E-04	1.807E-04	1.298E-14	1.655E-13	7.920E-13	-3.816E-21	8.979E-12
		1.223E-11	5.273E-13								
10	1	4.799E-02	1.773E-01	7.742E-01	3.582E-04	1.649E-04	5.223E-16	6.579E-15	3.259E-14	-2.015E-22	3.661E-13
		4.861E-13	1.861E-14								
11	1	4.799E-02	1.773E-01	7.742E-01	3.620E-04	1.666E-04	2.032E-17	2.531E-16	1.307E-15	-1.036E-23	1.460E-14
		1.869E-14	6.407E-16								
1	2	5.535E-03	2.904E-02	7.742E-01	1.277E-01	5.938E-02	2.175E-06	3.191E-05	1.284E-04	1.460E-08	1.520E-03
		2.401E-03	1.160E-04								
2	2	5.245E-03	2.760E-02	7.742E-01	1.302E-01	6.011E-02	1.065E-06	1.913E-05	8.113E-05	5.483E-09	1.152E-03
		1.379E-03	3.053E-05								
3	2	3.641E-02	1.366E-01	7.742E-01	3.610E-02	1.661E-02	5.560E-09	1.013E-07	4.524E-07	2.847E-11	9.082E-06
		7.262E-06	4.164E-06								
4	2	4.541E-02	1.682E-01	7.742E-01	8.300E-03	3.820E-03	3.521E-09	5.351E-08	2.592E-07	4.463E-15	3.980E-06
		3.845E-06	9.341E-07								

5	2	4.714E-02	1.743E-01	7.742E-01	2.972E-03	1.368E-03	1.162E-09	1.665E-08	7.724E-08	-6.128E-19	1.054E-06
		1.210E-06	1.606E-07								
6	2	4.740E-02	1.752E-01	7.742E-01	2.172E-03	9.997E-04	1.916E-10	2.625E-09	1.187E-08	-1.571E-17	1.496E-07
		1.925E-07	1.790E-08								
7	2	4.743E-02	1.753E-01	7.742E-01	2.094E-03	9.638E-04	1.691E-11	2.242E-10	1.006E-09	-2.457E-18	1.200E-08
		1.653E-08	1.164E-09								
8	2	4.772E-02	1.763E-01	7.742E-01	1.178E-03	5.422E-04	9.209E-13	1.190E-11	5.393E-11	-1.924E-19	6.169E-10
		8.803E-10	4.775E-11								
9	2	4.776E-02	1.765E-01	7.742E-01	1.055E-03	4.855E-04	4.387E-14	5.572E-13	2.584E-12	-1.125E-20	2.889E-11
		4.129E-11	1.832E-12								
10	2	4.776E-02	1.765E-01	7.742E-01	1.069E-03	4.921E-04	1.856E-15	2.326E-14	1.112E-13	-5.607E-22	1.226E-12
		1.724E-12	6.577E-14								
11	2	4.775E-02	1.764E-01	7.742E-01	1.090E-03	5.015E-04	7.274E-17	9.004E-16	4.476E-15	-2.620E-23	4.890E-14
		6.671E-14	2.212E-15								
1	3	1.154E-03	1.519E-02	7.741E-01	1.369E-01	6.504E-02	4.643E-06	6.667E-05	1.662E-04	3.285E-08	1.952E-03
		5.113E-03	2.714E-04								
2	3	1.685E-03	1.644E-02	7.742E-01	1.372E-01	6.455E-02	3.385E-06	5.132E-05	1.410E-04	2.190E-08	1.737E-03
		3.884E-03	1.075E-04								
3	3	1.759E-02	7.090E-02	7.742E-01	9.387E-02	4.314E-02	1.931E-08	4.413E-07	4.402E-06	1.038E-10	1.362E-04
		2.788E-05	1.009E-05								
4	3	4.278E-02	1.590E-01	7.742E-01	1.642E-02	7.555E-03	5.702E-09	9.313E-08	5.442E-07	1.047E-13	1.125E-05
		6.519E-06	2.059E-06								
5	3	4.680E-02	1.731E-01	7.742E-01	4.008E-03	1.845E-03	2.043E-09	2.935E-08	1.368E-07	3.937E-17	1.952E-06
		2.132E-06	3.483E-07								
6	3	4.737E-02	1.751E-01	7.742E-01	2.280E-03	1.049E-03	3.794E-10	5.202E-09	2.337E-08	-4.224E-17	2.975E-07
		3.814E-07	4.095E-08								
7	3	4.742E-02	1.753E-01	7.742E-01	2.119E-03	9.753E-04	3.251E-11	4.301E-10	1.913E-09	-6.297E-18	2.282E-08
		3.173E-08	2.448E-09								
8	3	4.740E-02	1.752E-01	7.742E-01	2.161E-03	9.947E-04	1.926E-12	2.346E-11	1.050E-10	-4.803E-19	1.123E-09
		1.739E-09	9.984E-11								
9	3	4.740E-02	1.752E-01	7.742E-01	2.174E-03	1.001E-03	8.290E-14	1.044E-12	4.771E-12	-2.569E-20	5.257E-11
		7.749E-11	3.478E-12								
10	3	4.738E-02	1.751E-01	7.742E-01	2.231E-03	1.027E-03	3.836E-15	4.769E-14	2.241E-13	-1.275E-21	2.434E-12
		3.543E-12	1.350E-13								
11	3	4.736E-02	1.751E-01	7.742E-01	2.296E-03	1.057E-03	1.492E-16	1.830E-15	8.952E-15	-5.387E-23	9.597E-14
		1.360E-13	4.366E-15								
1	4	2.443E-04	1.303E-02	7.740E-01	1.369E-01	6.596E-02	6.720E-06	9.178E-05	1.961E-04	5.007E-08	2.201E-03
		5.952E-03	4.547E-04								
2	4	8.437E-04	1.419E-02	7.741E-01	1.379E-01	6.551E-02	4.519E-06	6.658E-05	1.581E-04	3.068E-08	1.901E-03
		5.083E-03	1.767E-04								
3	4	7.011E-03	3.345E-02	7.742E-01	1.259E-01	5.786E-02	4.637E-07	9.206E-06	5.466E-05	2.052E-09	8.542E-04
		6.334E-04	1.557E-05								
4	4	4.067E-02	1.516E-01	7.742E-01	2.293E-02	1.055E-02	1.602E-08	3.145E-07	2.004E-06	2.448E-11	3.670E-05
		2.133E-05	2.861E-06								
5	4	4.650E-02	1.720E-01	7.742E-01	4.938E-03	2.273E-03	2.803E-09	4.161E-08	2.065E-07	5.613E-16	3.201E-06
		2.990E-06	5.121E-07								
6	4	4.734E-02	1.750E-01	7.742E-01	2.370E-03	1.091E-03	5.177E-10	7.085E-09	3.188E-08	-9.303E-17	4.119E-07
		5.194E-07	5.993E-08								
7	4	4.742E-02	1.753E-01	7.742E-01	2.123E-03	9.770E-04	4.741E-11	6.251E-10	2.765E-09	-1.262E-17	3.297E-08
		4.616E-08	3.775E-09								
8	4	4.740E-02	1.752E-01	7.742E-01	2.159E-03	9.938E-04	2.554E-12	3.274E-11	1.456E-10	-8.223E-19	1.652E-09
		2.428E-09	1.475E-10								
9	4	4.740E-02	1.752E-01	7.742E-01	2.166E-03	9.970E-04	1.203E-13	1.509E-12	6.842E-12	-4.428E-20	7.510E-11
		1.122E-10	5.270E-12								
10	4	4.738E-02	1.751E-01	7.742E-01	2.226E-03	1.025E-03	5.066E-15	6.263E-14	2.922E-13	-1.962E-21	3.147E-12
		4.659E-12	1.790E-13								
11	4	4.737E-02	1.751E-01	7.742E-01	2.269E-03	1.044E-03	2.235E-16	2.723E-15	1.320E-14	-9.023E-23	1.400E-13
		2.026E-13	6.456E-15								
1	5	7.510E-05	1.278E-02	7.739E-01	1.362E-01	6.604E-02	7.638E-06	1.010E-04	2.131E-04	5.923E-08	2.323E-03
		7.699E-03	6.135E-04								
2	5	5.294E-04	1.345E-02	7.741E-01	1.378E-01	6.582E-02	5.234E-06	7.534E-05	1.695E-04	3.659E-08	1.993E-03
		5.779E-03	2.362E-04								

3	5	3.374E-03	2.126E-02	7.742E-01	1.352E-01	6.264E-02	1.455E-06	2.512E-05	9.383E-05	7.811E-09	1.294E-03	1.833E-03	2.810E-05
4	5	3.839E-02	1.453E-01	7.742E-01	2.842E-02	1.308E-02	1.459E-08	2.532E-07	9.512E-07	7.763E-11	1.357E-05	1.846E-05	3.787E-06
5	5	4.620E-02	1.710E-01	7.742E-01	5.869E-03	2.701E-03	3.168E-09	4.655E-08	2.253E-07	8.741E-16	3.371E-06	3.358E-06	6.830E-07
6	5	4.731E-02	1.749E-01	7.742E-01	2.449E-03	1.127E-03	6.496E-10	8.897E-09	4.022E-08	-1.799E-16	5.255E-07	6.519E-07	7.865E-08
7	5	4.741E-02	1.752E-01	7.742E-01	2.130E-03	9.804E-04	6.140E-11	8.059E-10	3.553E-09	-2.444E-17	4.233E-08	5.955E-08	5.038E-09
8	5	4.741E-02	1.752E-01	7.742E-01	2.149E-03	9.889E-04	3.344E-12	4.260E-11	1.885E-10	-1.437E-18	2.124E-09	3.163E-09	1.961E-10
9	5	4.740E-02	1.752E-01	7.742E-01	2.167E-03	9.973E-04	1.616E-13	2.013E-12	9.078E-12	-7.445E-20	9.872E-11	1.498E-10	7.104E-12
10	5	4.739E-02	1.752E-01	7.742E-01	2.206E-03	1.015E-03	6.992E-15	8.568E-14	3.981E-13	-3.292E-21	4.233E-12	6.384E-12	2.418E-13
11	5	4.737E-02	1.751E-01	7.742E-01	2.262E-03	1.041E-03	3.391E-16	4.094E-15	1.976E-14	-1.586E-22	2.067E-13	3.052E-13	9.431E-15
1	6	4.857E-05	1.311E-02	7.739E-01	1.348E-01	6.586E-02	8.981E-06	1.117E-04	2.451E-04	7.515E-08	2.531E-03	8.623E-03	7.533E-04
2	6	4.045E-04	1.313E-02	7.741E-01	1.378E-01	6.596E-02	5.490E-06	7.874E-05	1.718E-04	3.838E-08	2.021E-03	6.009E-03	2.829E-04
3	6	1.948E-03	1.685E-02	7.742E-01	1.380E-01	6.442E-02	2.360E-06	3.875E-05	1.144E-04	1.367E-08	1.511E-03	2.892E-03	4.446E-05
4	6	3.766E-02	1.410E-01	7.742E-01	3.221E-02	1.483E-02	2.040E-08	3.361E-07	9.983E-07	1.176E-10	1.401E-05	2.508E-05	4.747E-06
5	6	4.599E-02	1.703E-01	7.742E-01	6.520E-03	3.001E-03	3.502E-09	5.258E-08	2.462E-07	1.496E-15	3.602E-06	3.309E-06	8.270E-07
6	6	4.729E-02	1.748E-01	7.742E-01	2.500E-03	1.151E-03	7.433E-10	1.014E-08	4.551E-08	-3.383E-16	5.208E-07	7.438E-07	9.169E-08
7	6	4.741E-02	1.752E-01	7.742E-01	2.133E-03	9.818E-04	7.079E-11	9.233E-10	4.055E-09	-4.316E-17	4.805E-08	6.830E-08	5.807E-09
8	6	4.741E-02	1.752E-01	7.742E-01	2.147E-03	9.882E-04	3.984E-12	5.033E-11	2.219E-10	-2.331E-18	2.475E-09	3.741E-09	2.302E-10
9	6	4.740E-02	1.752E-01	7.742E-01	2.164E-03	9.961E-04	1.949E-13	2.403E-12	1.082E-11	-1.135E-19	1.161E-10	1.792E-10	8.276E-12
10	6	4.739E-02	1.752E-01	7.742E-01	2.199E-03	1.012E-03	9.129E-15	1.107E-13	5.140E-13	-5.214E-21	5.387E-12	8.261E-12	3.009E-13
11	6	4.738E-02	1.751E-01	7.742E-01	2.250E-03	1.036E-03	4.839E-16	5.783E-15	2.792E-14	-2.627E-22	2.877E-13	4.318E-13	1.261E-14
1	7	5.113E-05	1.314E-02	7.738E-01	1.346E-01	6.582E-02	9.207E-06	1.139E-04	2.491E-04	7.721E-08	2.556E-03	8.741E-03	8.482E-04
2	7	3.680E-04	1.305E-02	7.741E-01	1.378E-01	6.599E-02	5.613E-06	8.021E-05	1.736E-04	3.923E-08	2.034E-03	6.112E-03	3.160E-04
3	7	1.484E-03	1.548E-02	7.742E-01	1.387E-01	6.499E-02	2.736E-06	4.451E-05	1.199E-04	1.610E-08	1.573E-03	3.334E-03	5.491E-05
4	7	3.724E-02	1.396E-01	7.742E-01	3.350E-02	1.543E-02	2.094E-08	3.418E-07	9.285E-07	1.228E-10	1.318E-05	2.560E-05	5.359E-06
5	7	4.594E-02	1.701E-01	7.742E-01	6.675E-03	3.072E-03	3.908E-09	5.648E-08	2.566E-07	1.600E-15	3.573E-06	4.108E-06	9.004E-07
6	7	4.729E-02	1.748E-01	7.742E-01	2.504E-03	1.153E-03	7.959E-10	1.063E-08	4.713E-08	-5.682E-16	5.030E-07	7.817E-07	9.554E-08
7	7	4.741E-02	1.752E-01	7.742E-01	2.138E-03	9.841E-04	7.351E-11	9.504E-10	4.151E-09	-6.474E-17	4.956E-08	7.042E-08	5.832E-09
8	7	4.741E-02	1.752E-01	7.742E-01	2.148E-03	9.886E-04	4.184E-12	5.228E-11	2.301E-10	-3.232E-18	2.529E-09	3.893E-09	2.293E-10
9	7	4.740E-02	1.752E-01	7.742E-01	2.169E-03	9.981E-04	2.156E-13	2.627E-12	1.184E-11	-1.549E-19	1.251E-10	1.962E-10	8.561E-12
10	7	4.739E-02	1.752E-01	7.742E-01	2.196E-03	1.011E-03	1.101E-14	1.320E-13	6.147E-13	-7.435E-21	5.343E-12	9.869E-12	3.366E-13
11	7	4.738E-02	1.751E-01	7.742E-01	2.245E-03	1.033E-03	6.498E-16	7.691E-15	3.721E-14	-3.994E-22	3.784E-13	5.751E-13	1.571E-14

1	8	5.502E-05	1.341E-02	7.738E-01	1.337E-01	6.567E-02	1.016E-05	1.208E-04	2.724E-04	8.947E-09	2.597E-03
		9.344E-03	9.485E-04								
2	8	3.902E-04	1.311E-02	7.741E-01	1.377E-01	6.596E-02	5.602E-06	7.990E-05	1.739E-04	3.920E-09	2.035E-03
		6.096E-03	3.365E-04								
3	8	1.526E-03	1.557E-02	7.742E-01	1.387E-01	6.496E-02	2.623E-06	4.318E-05	1.163E-04	1.518E-09	1.542E-03
		3.227E-03	5.544E-05								
4	8	3.784E-02	1.417E-01	7.742E-01	3.166E-02	1.458E-02	1.615E-08	2.668E-07	7.247E-07	9.305E-11	1.041E-05
		1.992E-05	5.336E-06								
5	8	4.608E-02	1.706E-01	7.742E-01	6.252E-03	2.878E-03	4.494E-09	6.585E-08	3.021E-07	1.294E-15	4.341E-06
		4.776E-06	8.746E-07								
6	8	4.731E-02	1.749E-01	7.742E-01	2.460E-03	1.132E-03	8.016E-10	1.095E-08	4.805E-09	-8.487E-15	5.132E-07
		7.977E-07	8.873E-08								
7	8	4.741E-02	1.752E-01	7.742E-01	2.142E-03	9.859E-04	7.062E-11	9.051E-10	3.940E-09	-8.403E-17	4.545E-08
		6.717E-08	5.183E-09								
8	8	4.741E-02	1.752E-01	7.742E-01	2.154E-03	9.913E-04	4.063E-12	5.015E-11	2.206E-10	-3.925E-19	2.381E-09
		3.742E-09	2.040E-10								
9	8	4.740E-02	1.752E-01	7.742E-01	2.175E-03	1.001E-03	2.229E-13	2.683E-12	1.213E-11	-1.890E-19	1.259E-10
		2.008E-10	8.056E-12								
10	8	4.739E-02	1.752E-01	7.742E-01	2.200E-03	1.012E-03	1.233E-14	1.462E-13	6.840E-13	-9.440E-21	6.953E-12
		1.095E-11	3.436E-13								
11	8	4.738E-02	1.751E-01	7.742E-01	2.241E-03	1.032E-03	7.928E-16	9.197E-15	4.462E-14	-5.255E-22	4.494E-13
		5.878E-13	1.741E-14								
1	9	5.259E-05	1.358E-02	7.737E-01	1.330E-01	6.557E-02	1.089E-05	1.265E-04	2.892E-04	9.825E-09	2.791E-03
		9.754E-03	1.049E-03								
2	9	4.325E-04	1.328E-02	7.741E-01	1.375E-01	6.587E-02	5.723E-06	8.060E-05	1.786E-04	4.071E-09	2.065E-03
		6.177E-03	3.551E-04								
3	9	1.830E-03	1.659E-02	7.742E-01	1.384E-01	6.456E-02	2.191E-06	3.722E-05	1.057E-04	1.214E-09	1.441E-03
		2.760E-03	5.044E-05								
4	9	3.949E-02	1.474E-01	7.742E-01	2.659E-02	1.224E-02	7.722E-09	1.319E-07	3.816E-07	4.170E-11	5.574E-06
		9.766E-06	4.713E-06								
5	9	4.640E-02	1.717E-01	7.742E-01	5.266E-03	2.424E-03	4.781E-09	7.011E-08	3.211E-07	6.499E-16	4.555E-06
		5.086E-06	7.331E-07								
6	9	4.733E-02	1.750E-01	7.742E-01	2.377E-03	1.094E-03	7.462E-10	9.995E-09	4.381E-09	-1.093E-15	5.455E-07
		7.365E-07	7.209E-08								
7	9	4.741E-02	1.752E-01	7.742E-01	2.145E-03	9.873E-04	6.285E-11	7.945E-10	3.440E-09	-9.205E-17	3.872E-08
		5.912E-08	4.110E-09								
8	9	4.740E-02	1.752E-01	7.742E-01	2.160E-03	9.942E-04	3.834E-12	4.672E-11	2.057E-10	-4.266E-19	2.176E-09
		3.493E-09	1.728E-10								
9	9	4.740E-02	1.752E-01	7.742E-01	2.183E-03	1.005E-03	2.250E-13	2.681E-12	1.216E-11	-2.126E-19	1.243E-10
		2.009E-10	7.396E-12								
10	9	4.739E-02	1.752E-01	7.742E-01	2.205E-03	1.015E-03	1.307E-14	1.537E-13	7.220E-13	-1.084E-20	7.252E-12
		1.152E-11	3.338E-13								
11	9	4.738E-02	1.751E-01	7.742E-01	2.241E-03	1.031E-03	8.634E-16	1.007E-14	4.909E-14	-6.114E-22	4.899E-13
		7.545E-13	1.785E-14								
1	10	5.001E-05	1.294E-02	7.737E-01	1.349E-01	6.587E-02	8.969E-06	1.127E-04	2.409E-04	7.336E-09	2.504E-03
		8.579E-03	1.071E-03								
2	10	4.437E-04	1.353E-02	7.741E-01	1.368E-01	6.575E-02	6.308E-06	8.576E-05	1.946E-04	4.698E-09	2.178E-03
		6.509E-03	3.752E-04								
3	10	2.322E-03	1.785E-02	7.742E-01	1.378E-01	6.407E-02	1.743E-06	3.089E-05	9.344E-05	9.092E-09	1.321E-03
		2.264E-03	4.319E-05								
4	10	4.141E-02	1.542E-01	7.742E-01	2.059E-02	9.479E-03	4.078E-08	7.169E-07	3.107E-06	8.330E-12	4.828E-05
		5.122E-05	3.933E-06								
5	10	4.676E-02	1.729E-01	7.742E-01	4.156E-03	1.913E-03	4.592E-09	6.586E-08	2.931E-07	5.207E-15	4.990E-06
		4.802E-06	5.369E-07								
6	10	4.737E-02	1.751E-01	7.742E-01	2.276E-03	1.048E-03	6.116E-10	7.959E-09	3.415E-09	-1.046E-15	4.029E-07
		5.899E-07	4.997E-08								
7	10	4.741E-02	1.752E-01	7.742E-01	2.150E-03	9.895E-04	5.208E-11	6.475E-10	2.792E-09	-7.478E-17	3.944E-08
		4.832E-08	2.930E-09								
8	10	4.740E-02	1.752E-01	7.742E-01	2.161E-03	9.947E-04	3.525E-12	4.252E-11	1.876E-10	-3.944E-19	1.951E-09
		3.184E-09	1.429E-10								
9	10	4.739E-02	1.752E-01	7.742E-01	2.190E-03	1.008E-03	2.216E-13	2.622E-12	1.193E-11	-2.182E-19	1.207E-10
		1.966E-10	6.783E-12								

```
   10   10  4.739E-02  1.752E-01  7.742E-01  2.207E-03  1.016E-03  1.335E-14  1.563E-13  7.361E-13 -1.150E-20  7.344E-12
            1.172E-11  3.228E-13
   11   10  4.738E-02  1.751E-01  7.742E-01  2.242E-03  1.032E-03  8.675E-16  1.008E-14  4.931E-14 -6.262E-22  4.888E-13
            7.557E-13  1.706E-14
NCYC =  100 DT =  3.196575E-06 T =  9.063719E-04 NUMIT =  23 GRIND = 14.21
   Y(PISTON) =  8.7883E+00 V(PISTON) =  1.3547E+03 PRESSURE =  6.7134E+07 C
NCYC =  101 DT =  2.402663E-06 T =  9.087746E-04 NUMIT =  19 GRIND = 16.97
   Y(PISTON) =  8.7916E+00 V(PISTON) =  1.3520E+03 PRESSURE =  6.7434E+07 C
NCYC =  102 DT =  1.969723E-06 T =  9.107443E-04 NUMIT =  17 GRIND =  2.91
   Y(PISTON) =  8.7942E+00 V(PISTON) =  1.3499E+03 PRESSURE =  6.7684E+07 C
NCYC =  103 DT =  1.773524E-06 T =  9.125178E-04 NUMIT =  16 GRIND =  2.81
   Y(PISTON) =  8.7966E+00 V(PISTON) =  1.3479E+03 PRESSURE =  6.7914E+07 C
NCYC =  104 DT =  1.664396E-06 T =  9.141822E-04 NUMIT =  16 GRIND =  2.79
   Y(PISTON) =  8.7989E+00 V(PISTON) =  1.3461E+03 PRESSURE =  6.8135E+07 C
NCYC =  105 DT =  1.602593E-06 T =  9.157848E-04 NUMIT =  16 GRIND =  2.82
   Y(PISTON) =  8.8010E+00 V(PISTON) =  1.3443E+03 PRESSURE =  6.8353E+07 C
NCYC =  106 DT =  1.574676E-06 T =  9.173595E-04 NUMIT =  16 GRIND =  2.81
   Y(PISTON) =  8.8031E+00 V(PISTON) =  1.3426E+03 PRESSURE =  6.8572E+07 C
NCYC =  107 DT =  1.583515E-06 T =  9.189430E-04 NUMIT =  16 GRIND =  2.77
   Y(PISTON) =  8.8052E+00 V(PISTON) =  1.3408E+03 PRESSURE =  6.8799E+07 C
NCYC =  108 DT =  1.662607E-06 T =  9.206056E-04 NUMIT =  16 GRIND =  2.78
   Y(PISTON) =  8.8075E+00 V(PISTON) =  1.3390E+03 PRESSURE =  6.9045E+07 C
NCYC =  109 DT =  1.812329E-06 T =  9.224179E-04 NUMIT =  16 GRIND =  2.74
   Y(PISTON) =  8.8099E+00 V(PISTON) =  1.3370E+03 PRESSURE =  6.9321E+07 G
MASS= 3.48513356E+00 U MOM= 4.67484722E+03 V MOM= 3.12780329E+03 SIE= 3.1890590E+10 TOT E= 9.5106550E+10CHEM E=, 6.3203468E+10
  WORK = 6.5148359E+09   ANG MOMENTUM = 3.9764491E+03  GMS NO = 2.2924990E-05
NCYC =  110 DT =  1.993562E-06 T =  9.244115E-04 NUMIT =  16 GRIND = 14.21
   Y(PISTON) =  8.8126E+00 V(PISTON) =  1.3348E+03 PRESSURE =  6.9637E+07 G
NCYC =  111 DT =  2.192919E-06 T =  9.266044E-04 NUMIT =  18 GRIND = 16.85
   Y(PISTON) =  8.8155E+00 V(PISTON) =  1.3324E+03 PRESSURE =  7.0000E+07 G
NCYC =  112 DT =  2.412211E-06 T =  9.290165E-04 NUMIT =  19 GRIND =  2.85
   Y(PISTON) =  8.8187E+00 V(PISTON) =  1.3297E+03 PRESSURE =  7.0420E+07 G
NCYC =  113 DT =  2.653432E-06 T =  9.316700E-04 NUMIT =  19 GRIND =  2.85
```

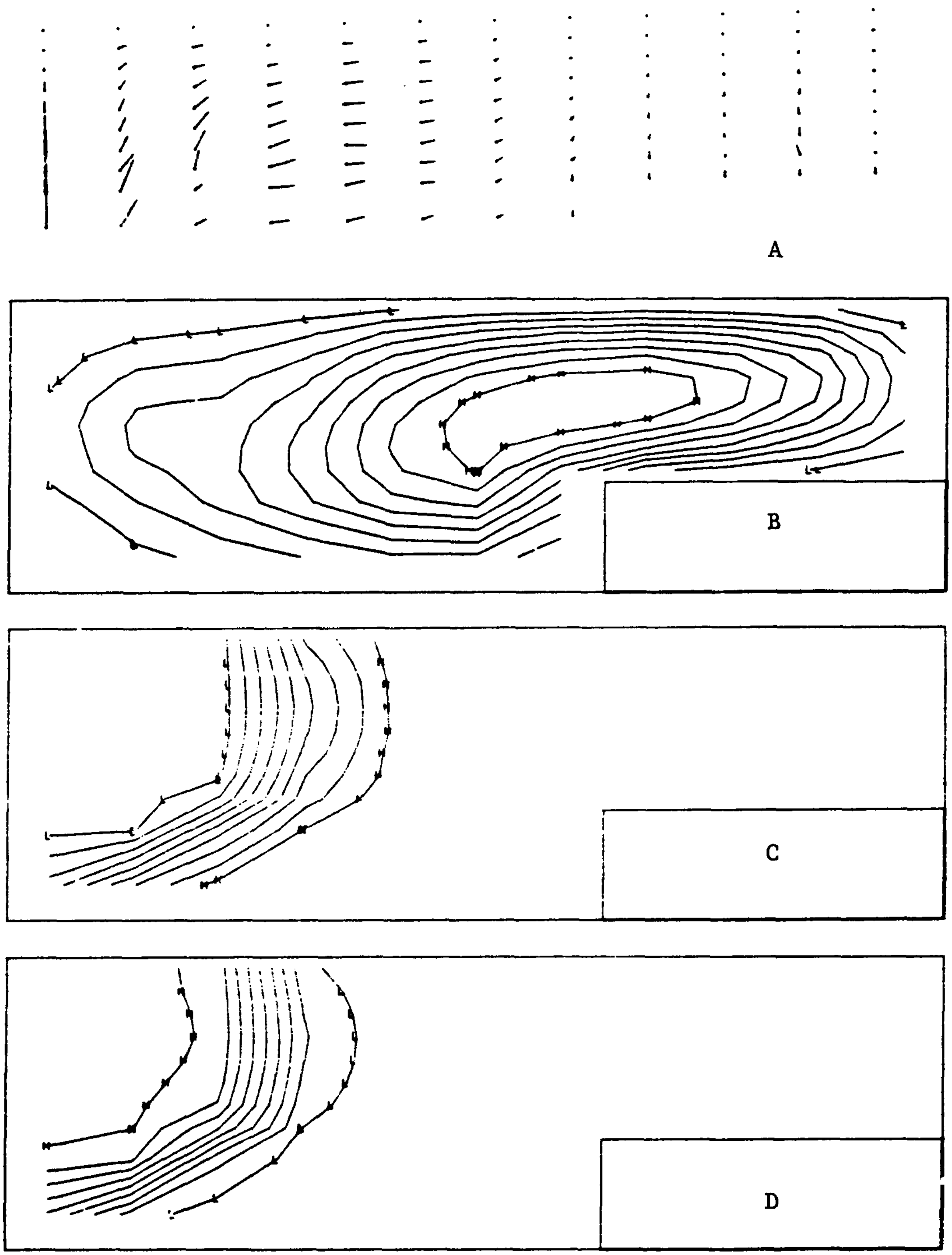

Fig. 5. Velocity vector plot and typical contour plots from cycle 100 (t = 9.063719×10^{-4} s). The maximum speed in the velocity vector plot is 1.0416×10^{4} cm/s. In the swirl velocity plot B, the high (H) and (L) contour values are 2.428×10^{3} and 3.152×10^{2} cm/s respectively. The high and low isopycnic values in plot C are 2.400×10^{-2} g/cm^3 and 1.041×10^{-2} g/cm^3 respectively. The high and low isotherm values in plot D are 2538 K and 1150 K respectively. All contour values are equally spaced between H and L. The isopycnics and isotherms clearly mark the location of the flame front.

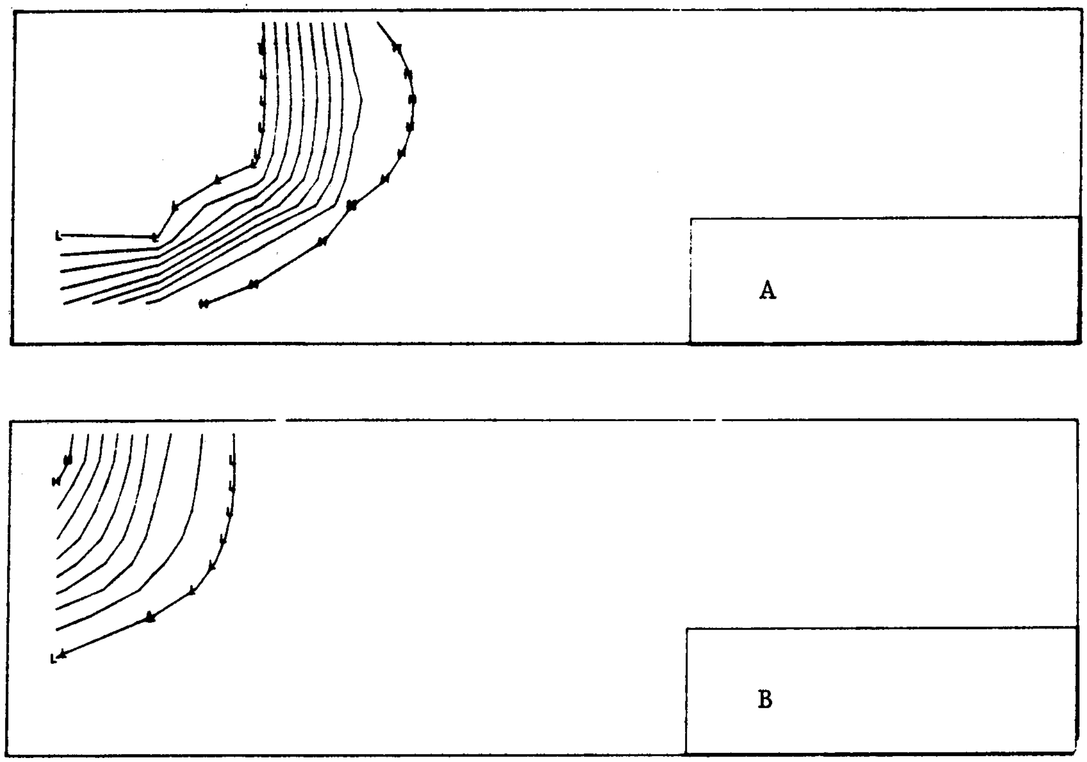

Fig. 6. *Isopleths of mass fractions of fuel (plot A) and NO (plot B). The high and low contour values are 4.270 x* 10^{-2} *and 4.787 x* 10^{-3} *in plot A and 9.635 x* 10^{-4} *and 1.071 x* 10^{-4} *in plot B. The plots for all the major species (fuel,* O_2*,* CO_2*, and* H_2O*) are similar to plot A. The mass fraction of* N_2 *is essentially constant. The plots for all other species resemble plot B.*

APPENDIX D

THE SECOND TEST PROBLEM:

PROGRAM MODIFICATIONS TO CREATE A SPECIFIED INFLOW BOUNDARY CONDITION

For many applications, such as modeling an intake valve, it is necessary to specified an inflow boundary condition. The appendix presents code modifications and the modified data deck for calculating a gas jet flowing into a quiescent medium. The jet is two cells wide at the left edge of the top boundary. The jet material is pure octane (species number 1) at $\rho = 0.06$ g/cm^3 and I = 2×10^{10} ergs/g flowing in at a speed of 4000 cm/s. The following code changes are presented in CDC UPDATE format, and the *INSERT cards are self-explanatory. The sequence numbers correspond to those in Appendix A.

```
*IDENT JET
*INSERT BC.27
      IF (I .LE. 3) VX(IJ2)=-4000.
*INSERT CCFLUX.60
      IF (I.LE. 3 .AND. J.EQ.NY) S3=S4=0.
*INSERT CCFLUX.84
      IF (I.GT.2 .OR. J.NE.NY) GO TO 113
      XMAS=4000.*0.06*DT*(R(IPJP)**2-R(IJP)**2)*0.5
      SPM(IJ,1)=SPM(IJ,1)+XMAS
      SIE(IJ)=(SIE(IJ)*MP(IJ)+XMAS*2.E+10)/(MP(IJ)+XMAS)
      MP(IJ)=MP(IJ)+XMAS
  113 CONTINUE
```

The data deck is similar to the previous one, but it is listed in its entirety to help avoid confusion.

```
 INFLOW TEST PROBLEM 7/20/79
    NSP       12
    NR         3
    NFOUT     10
    NPOUT    100
    LPR        2
    ITMAX    100
    NX        11
    NY        10
    NRE        6
   EPSCHM        2.00000000E-02
    OMCHM        1.00000000E+00
    XKO          1.30000000E-01
    DX           5.23600000E-01
    DY           3.45670000E-01
 XIGNIT          0.00000000E-02
    SIEI         7.43400000E+02
    OM           1.50000000E+00
    PEPS         1.00000000E-04
    EPS          1.00000000E-06
    AZFAC     0.1
    NCLAST  200
    NOL        8
    NOR       12
    NOB        1
    NOT        3
    ITMIN     18
    AO        0.8
    BO        0.1
```

30	AOM	0.8
31	IREZ	2
32	LAMZER	0.01000000E+00
33	DTMAX	1.25000000E-05
34	DT	1.25000000E-06
35	CYL	1.00000000E+00
36	ANC	0.05
37	RGAS	8.31430000E+07
38	RPM	0.00000000E+03
39	STROKE	9.55000000E+00
40	ABDC	1.20000000E+02
41	GX	0.00000000E+00
42	GY	0.00000000E+00
43	XMUO	4.00000000E+02
44	RPR	1.10000000E+00
45	RSC	1.00000000E+00
46	DISS	1.00000000E+00
47	TCUT	9.90000000E+02
48	SWIRL	1.00000000E+00
49	ANGVEL	2.00000000E+03
50	TBDDY	4.00000000E+02
51	ADIA	1.00000000E+00
52	AIRMU	1.00000000E+00
53	RHO1	0.00000000E-04
54	GAMMA1	1.03000000E+00
55	WT1	1.14000000E+02
56	HTF1	-5.03100000E+01
57	RHO2	1.95100000E-03
58	GAMMA2	1.40000000E+00
59	WT2	3.20000000E+01
60	HTF2	0.00000000E+00
61	RHO3	8.50200000E-03
62	GAMMA3	1.40000000E+00
63	WT3	2.80000000E+01
64	HTF3	0.00000000E+00
65	RHO4	0.00000000E-05
66	GAMMA4	1.20000000E+00
67	WT4	4.40000000E+01
68	HTF4	-9.39650000E+01
69	RHO5	0.00000000E+00
70	GAMMA5	1.22000000E+00
71	WT5	1.80000000E+01
72	HTF5	-5.71030000E+01
73	RHO6	0.00000000E+00
74	GAMMA6	1.66670000E+00
75	WT6	1.00000000E+00
76	HTF6	5.16310000E+01
77	RHO7	0.00000000E+00
78	GAMMA7	1.40000000E+00
79	WT7	2.00000000E+00
80	HTF7	0.00000000E+00
81	RHO8	0.00000000E+00
82	GAMMA8	1.66670000E+00
83	WT8	1.60000000E+01
84	HTF8	5.89890000E+01
85	RHO9	0.00000000E+00
86	GAMMA9	1.66670000E+00
87	WT9	1.40000000E+01
88	HTF9	1.12520000E+02
89	RHO10	0.00000000E+00
90	GAMA10	1.40000000E+00
91	WT10	1.70000000E+01
92	HTF10	9.28900000E+00
93	RHO11	0.00000000E+00
94	GAMA11	1.40000000E+00
95	WT11	2.80000000E+01
96	HTF11	-2.72000000E+01
97	RHO12	0.00000000E+00
98	GAMA12	1.40000000E+00
99	WT12	3.00000000E+01

```
     HTF12         2.14560000E+01
     CF1           5.00000000E+12
     EF1           1.57800000E+04
     ZETAF1        0.00000000E+00
     CB1           0.00000000E+00
     EB1           0.00000000E+00
     ZETAB1        0.00000000E+00
AM1       2    25     0     0     0     0     0     0     0     0     0     0
BM1       0     0     0    16    18     0     0     0     0     0     0     0
AE1    1.000  1.000  0.000  0.000  0.000  0.000  0.000  0.000
       0.000  0.000  0.000  0.000
BE1    0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
       0.000  0.000  0.000  0.000
     CF2           7.14000000E+13
     EF2           3.79970000E+04
     ZETAF2        0.00000000E+00
     CB2           1.50000000E+13
     EB2           0.00000000E+00
     ZETAB2        0.00000000E+00
AM2       0     0     1     0     0     0     0     1     0     0     0     0
BM2       0     0     0     0     0     0     0     0     1     0     0     1
AE2    0.000  0.000  1.000  0.000  0.000  0.000  0.000  1.000
       0.000  0.000  0.000  0.000
BE2    0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
       1.000  0.000  0.000  1.000
     CF3           1.20000000E+10
     EF3           2.76800000E+03
     ZETAF3        1.00000000E+00
     CB3           3.20000000E+09
     EB3           1.96780000E+04
     ZETAB3        1.00000000E+00
AM3       0     1     0     0     0     0     0     0     1     0     0     0
BM3       0     0     0     0     0     0     0     1     0     0     0     1
AE3    0.000  1.000  0.000  0.000  0.000  0.000  0.000  0.000
       1.000  0.000  0.000  0.000
BE3    0.000  0.000  0.000  0.000  0.000  0.000  0.000  1.000
       0.000  0.000  0.000  1.000
     AS1           0.99020700E+00
     BS1          -5.17916000E+01
     CS1           0.99307400E+00
     DS1          -0.34342800E+00
     ES1           0.01116680E+00
AN1       0     0     0     0     0     0     1     0     0     0     0     0
BN1       0     0     0     0     0     2     0     0     0     0     0     0
     AS2           0.43131000E+00
     BS2          -5.96554000E+01
     CS2           3.50335000E+00
     DS2          -0.34001600E+00
     ES2           0.01587150E+00
AN2       0     1     0     0     0     0     0     0     0     0     0     0
BN2       0     0     0     0     0     0     0     2     0     0     0     0
     AS3           0.79470900E+00
     BS3          -1.13208000E+02
     CS3           3.16837000E+00
     DS3          -0.44381400E+00
     ES3           0.02696990E+00
AN3       0     0     1     0     0     0     0     0     0     0     0     0
BN3       0     0     0     0           0     0     0     2     0     0     0
     AS4          -0.65293900E+00
     BS4          -9.82320000E+00
     CS4           3.93033000E+00
     DS4           0.16349000E+00
     ES4          -0.01428650E+00
AN4       0     1     0     0     0     0     1     0     0     0     0     0
BN4       0     0     0     0     0     0     0     0     0     2     0     0
     AS5           1.15888200E+00
     BS5          -7.68472000E+01
     CS5           8.53215500E+00
     DS5          -0.86832000E+00
     ES5           0.04634710E+00
```

```
AN5     0   1   0   0   2   0   0   0   0   0   0   0
BN5     0   0   0   0   0   0   0   0   0   4   0   0
    AS6          0.98087500E+00
    BS6          6.84453000E+01
    CS6         -1.05938000E+01
    DS6          0.57426000E+00
    ES6         -0.04145700E+00
AN6     0   1   0   0   0   0   0   0   0   0   2   0
BN6     0   0   0   2   0   0   0   0   0   0   0   0
      NCHOP    10
```

Figure 7 shows a typical velocity vector plot and species 1 mass fraction contours for this coarse test problem. The entire mass of species 1 has entered the mesh via the jet.

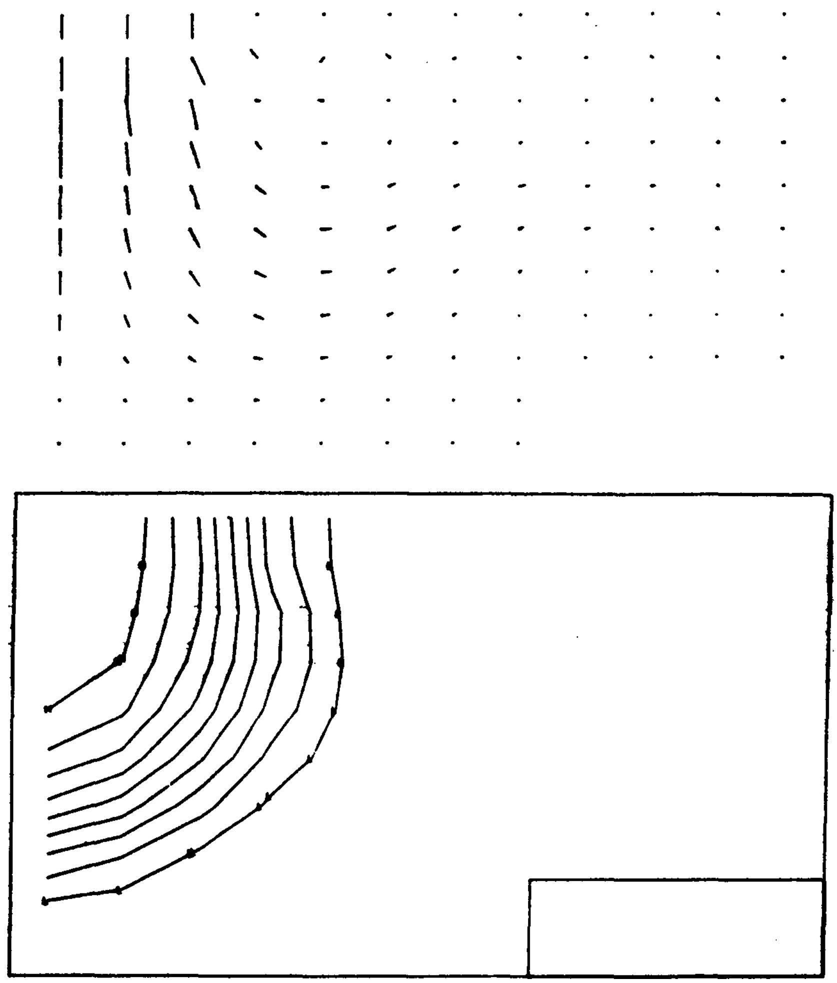

Fig. 7. Velocity vector plot and isopleths of mass fraction of species 1 on cycle 100 (t = 4.480×10^{-4} s) for the inflow boundary test problem. The maximum speed is 6.651×10^{3} cm/s, and the high and low contour values of mass fraction are 8.973×10^{-1} and 9.970×10^{-2} respectively.

Printed in the United States of America. Available from
National Technical Information Service
US Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Microfiche $3.00

001-025	4.00	126-150	7.25	251-275	10.75	376-400	13.00	501-525	15.25
026-050	4.50	151-175	8.00	276-300	11.00	401-425	13.25	526-550	15.50
051-075	5.25	176-200	9.00	301-325	11.75	426-450	14.00	551-575	16.25
076-100	6.00	201-225	9.25	326-350	12.00	451-475	14.50	576-600	16.50
101-125	6.50	226-250	9.50	351-375	12.50	476-500	15.00	601-up	

Note: Add $2.50 for each additional 100-page increment from 601 pages up.