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**YAQUI: An Arbitrary
Lagrangian-Eulerian Computer Program
for Fluid Flow at All Speeds**

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

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YAQUI: An Arbitrary Lagrangian-Eulerian Computer Program for Fluid Flow at All Speeds

by

Anthony A. Amsden

Cyril W. Hirt*

*Present address: Science Applications, Incorporated, P. O. Box 2351,
La Jolla, California 92037.

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ABSTRACT

A numerical fluid-dynamics computing technique is presented that combines the Implicit Continuous-fluid Eulerian (ICE) and the Arbitrary Lagrangian-Eulerian (ALE) methods. An implicit treatment of the pressure equation similar to that in ICE enables the calculation of flows at all speeds from supersonic to far subsonic. In addition, the vertices of the computing grid may be moved with the fluid in normal Lagrangian fashion or be held fixed in a Eulerian manner, or be moved in some arbitrary way to give a continuous rezoning capability, as in the ALE method. Greater distortions in the fluid motion can be handled than would be allowed by a purely Lagrangian method, and with more resolution than is afforded by a purely Eulerian method. The report describes the combined (ICED-ALE) technique in the framework of a computer program called YAQUI, for which the complete flow diagram and FORTRAN index listing are provided. Representative calculations illustrate some of the features of YAQUI, and include both computer-generated plots and numerical listings.

I. BASIC DESCRIPTION OF THE METHOD (ICED-ALE)

A. Introduction

Over the past decade, there has been considerable progress in development of computer techniques for solution of multidimensional problems in fluid dynamics. A number of basic techniques have become well established, and useful and practical applications are being made to an ever-increasing range of problems in many fields. Because of computer storage and time limitations, numerical methods obviously cannot afford the luxury of following the dynamics of each and every molecule of the fluid at hand, but must, instead, depend upon following the dynamics of a finite, discrete set of fluid elements. Therefore, the region of interest is usually subdivided into a finite grid or mesh of computing zones, associating with each zone or vertex the local values of the quantities of interest, such as mass, energy, and velocity. The governing differential equations are approximated by finite-

difference forms in relation to the grid, and this set of equations is then solved repeatedly over the domain to advance the solution through finite intervals of time, analogous to the frames of a motion picture.

Given this basic description, however, there are two fundamentally important considerations beyond which the various techniques differ. The first of these considerations is the flow-speed regime of interest, and the second is the interrelationship of the grid and the fluid. These two points will be discussed separately and then brought together.

The types of fluid flows that have been most amenable to calculation are generally those that can be characterized as either compressible or incompressible. Compressible, or high-speed, flows are those in which the fluid speed is comparable to or faster than the local material sound speed, and they are therefore governed only by local influences. In the incompressible or low-speed regime, however,

fluid speeds are much less than material sound speeds, and disturbances at any point must, for all practical purposes, be felt instantaneously throughout the entire domain. As a result, the numerical stability restrictions for high-speed flows produce intolerably small time steps at low flow speeds. On the other hand, low-speed methods cannot sense compressibility effects produced by increased flow speeds, as no equation of state is used. Unfortunately, many fluid-dynamics problems of interest do not fall at either of these two extremes, and they are therefore not accurately calculated by either high- or low-speed methods. Examples are flows that are initially supersonic but rapidly become subsonic, or flows that are supersonic in one region or direction and far subsonic in another. Consequently, much effort is being placed on developing techniques to calculate in this intermediate regime.

The second point concerns the relationship between the fluid and the coordinate grid. Traditionally, there have been two basic viewpoints for both high- and low-speed flows. The first is Lagrangian, in which the mesh of grid points is embedded in the fluid and moves with it. Clear delineation of fluid interfaces and well-resolved details of the flow are afforded, but the approach is limited by its inability to cope easily with strong distortions, which so often characterize flows of interest. The second basic viewpoint, known as Eulerian, treats the mesh as a fixed reference frame through which the fluid moves. Strong distortions can be handled with relative ease, but generally at the expense of precise interface definition and resolution of detail.

Because of the obvious shortcomings of purely high-speed and purely low-speed methods, coupled with the shortcomings of purely Lagrangian vs purely Eulerian approaches, increasing emphasis is being placed on development of ever more sophisticated hybrid techniques.

Presently, the most successful method for calculating flows at all speeds is the Implicit Continuous-fluid Eulerian (ICE) technique,¹ in which the flow may vary from supersonic to far subsonic. This is enabled by an implicit treatment of the pressure calculation. The method is extremely versatile and can be used for calculations in one,

two, or three space dimensions, allowing for arbitrary equation of state.

Simultaneously, techniques have been developed that succeed to a great extent in combining the best features of both the Lagrangian and Eulerian approaches. In some methods, Lagrangian particles are used to define fluid interfaces or free surfaces, or to define the fluid itself, within a Eulerian mesh. There are other approaches, however, that have no basic dependence on particles. One such is the Arbitrary Lagrangian-Eulerian (ALE) method,² a low-speed technique that allows the vertices to move with the fluid in normal Lagrangian fashion or be held fixed in a Eulerian manner, or to move in some arbitrarily specified way to give a continuous rezoning capability. Greater distortions in the fluid motion can be handled than would be allowed by a purely Lagrangian method, with more resolution than is afforded by a purely Eulerian method.

This report describes a combination of the ICE and ALE schemes (ICED-ALE) in a computer program called YAQUI. It is based on the most recent improvements available in both the ICE and ALE methods, together with other improvements made possible by the marriage of the two schemes.

Although much more work remains to be done in the development of such hybrid techniques, YAQUI has established itself as a versatile tool for studying flows at all speeds and it has the capability of continuous rezoning.

The ICE technique was originally developed by F. H. Harlow, and the ALE technique by C. W. Hirt, who originated the ICED-ALE combination as it is represented in YAQUI. The code as it stands, however, represents the efforts of a number of people who have experimented with many alternatives along the way, and who have provided valuable contributions to its development. We are grateful for the help of our colleagues F. H. Harlow, T. D. Butler, H. M. Ruppel, J. U. Brackbill, R. A. Gentry, and W. E. Pracht of Group T-3, and for that of E. M. Jones and R. C. Anderson of Group J-10.

Inasmuch as the underlying technique has been discussed in detail elsewhere,² this report will start from that point. First, the finite-difference equations will be presented as they appear in YAQUI, then the code itself will be discussed in detail.

B. The Method Layout and the Computing Mesh

The basic hydrodynamic part of each cycle of the ICED-ALE method is divided into three distinct subsections or phases. The first phase is a typical, explicit Lagrangian calculation. The second is an iteration that provides advanced pressures for the momentum equations and advanced compression for the mass equation. These ensure the stability of the method with respect to sound-signal propagation. Finally, the third phase, called the rezone section, performs all the convective-flux calculations, which must be included if the mesh is not purely Lagrangian.

The computing mesh consists of a two-dimensional network of quadrilateral cells, and it will handle calculations in either cylindrical or plane (Cartesian) coordinates. Calculations in cylindrical coordinates are scaled to unit azimuthal angle, thus allowing the equations to be written without any π factors. The radial coordinate is denoted by r or x , and the axial coordinate by z or y , with the origin located at the lower left corner of the mesh. The coordinate names in the equations in this report are x and y . The coordinate named r is used to determine the geometry: r is always set equal to x for cylindrical coordinates, but the expressions automatically reduce to Cartesian expressions if all r 's are set to unity. The vertices of the cells are labeled with the indices i and j , which increase in the radial and axial directions, respectively. Cell centers are denoted by half-integer indices $i + 1/2$ and $j + 1/2$. The mesh of cells is $\bar{I}$ cells wide by $\bar{J}$ cells high.

The mesh illustrated in Fig. 1 is in cylindrical coordinates, where the cells are sections of toroids of revolution about the cylinder.

The variables in an ICED-ALE grid are of two types: those defined at vertices, and those defined at cell centers. The principal variables are shown in Fig. 2, where coordinates (x and y), velocities (u and v), and masses (M) are defined at vertices, and the densities (ρ), pressures (p), volumes (V), and energies are defined at the cell centers. E is the specific total energy, and I is the specific internal energy.

Fig. 1. A typical ICED-ALE mesh in cylindrical coordinates.

Fig. 2. A typical ICED-ALE cell showing the locations of the principal variables. The numbers are in the shorthand vertex notation used in the equations that follow and in the YAQUI code.

In the equations that follow, the superscript n denotes the beginning-of-cycle values. The advancement of the solution through a time step, of duration δt , provides values at the beginning of the next $(n+1)$ cycle. Intermediate values are typically labeled with a tilde for the results of Phase 1, or with a subscript L for the results of Phase 2.

C. Initial Conditions and Preliminary Calculations

Input Quantities: The input data supply the initial

values of x , y , u , and v at the vertices and ρ and I for cells.

Preliminary Calculations (each cycle):

- (1) The radius of each vertex is calculated as
 $r = x$ in cylindrical coordinates, or
 $r = 1$ in plane coordinates.
- (2) Cell pressures are calculated at the beginning of each cycle using an equation of state
 $p = p(\rho, I)$,

although the equation of state may be bypassed for small Mach numbers. This is discussed further in Sec. III F, "Incompressible Flow Calculations."

- (3) Cell volumes are given by

$$V_{i+\frac{1}{2}}^{j+\frac{1}{2}} = \frac{1}{3} [(r_1 + r_2 + r_3) ATR + (r_1 + r_3 + r_4) ABL],$$

where

$$ATR = \frac{1}{2} [x_1 (y_2 - y_3) + x_2 (y_3 - y_1) + x_3 (y_1 - y_2)],$$

$$ABL = \frac{1}{2} [x_1 (y_3 - y_4) + x_3 (y_4 - y_1) + x_4 (y_1 - y_3)].$$

The subscript notation for vertex quantities has been simplified to that shown in Fig. 2. It is used throughout this report and in the YAQUI code.

- (4) With the cell volumes defined, the masses at cell centers can be computed from

$$M_{i+\frac{1}{2}}^{j+\frac{1}{2}} = \rho_{i+\frac{1}{2}}^{j+\frac{1}{2}} V_{i+\frac{1}{2}}^{j+\frac{1}{2}},$$

but because most references are to the vertex masses, it is convenient to replace the cell masses immediately by vertex masses:

$$M_i^j = \frac{1}{4} (M_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i-\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j-\frac{1}{2}} + M_{i-\frac{1}{2}}^{j-\frac{1}{2}}).$$

To maintain energy conservation throughout the entire calculational cycle, it is necessary to calculate and store Z , the total specific energy per cell. However, the pressure iteration in Phase 2 requires a set of internal energies, I . One could get by with only a computer storage matrix of internal energies, by updating I during the iteration so that the total energy was conserved. The extra calculation required to do this, however, especially within an iteration, makes it seem reasonable to keep E and I separately. Therefore, we maintain a field of E 's throughout the cycle, where

initially

$$E_{i+\frac{1}{2}}^{j+\frac{1}{2}} = I_{i+\frac{1}{2}}^{j+\frac{1}{2}} + \frac{1}{8} (u_1^2 + u_2^2 + u_3^2 + u_4^2 + v_1^2 + v_2^2 + v_3^2 + v_4^2),$$

to which we will later add the various work and dissipation terms.

D. Phase 1 of the Calculation

In this section we carry out a typical fully explicit Lagrangian calculation, with no grid motion, to obtain vertex values of the tilde velocities, $\tilde{u}$ and $\tilde{v}$, and the change in total energy per unit mass, Q .

These three quantities are calculated in several steps. The following formulas show how these values accumulate from the contributions of each step. The appropriate initial values are, for each vertex,

$$\tilde{u}_1^j = n u_1^j + \delta t A_x,$$

and

$$\tilde{v}_1^j = n v_1^j + \delta t A_y,$$

where A_x and A_y are body accelerations or accelerations from other forces applied at the vertices, and the superscript n denotes the beginning-of-cycle values. In most cases of interest, A_x and A_y are set equal to the gravity components

$$A_{x_1}^j = g_r \quad \text{and} \quad A_{y_1}^j = g_z.$$

It is also helpful to insert a small, controlled, artificial diffusive acceleration into A_x and A_y at this point. To see the reason for this, consider the integration area that will be used for updating the velocity components at vertex $\binom{j}{i}$ in Fig. 3. The region is surrounded by dashed lines connecting the vertices $\binom{j}{i+1}$, $\binom{j+1}{i}$, $\binom{j}{i-1}$, and $\binom{j-1}{i}$ that will influence the accelerations at vertex $\binom{j}{i}$, but in the equations the acceleration computed from the surface stresses is independent of the vertex's location within the integration area. Although proper rezoning will tend to keep the vertex near the center of the region, and aid in

Fig. 3. Momentum-integration areas about cells (i, j) and $(i+1, j)$, indicated by dashed lines and dotted lines, respectively.

obtaining the most accurate results, consider the integration area for the next cell $(i+1, j)$, indicated by the dotted lines in Fig. 3. This indicates that values at four different vertices, (i, j) , $(i+2, j)$, $(i, j+1)$, and $(i+1, j+1)$, will enter. Although this definition of an integration area provides flexibility, there is a definite lack of communication between neighboring vertices, which can allow slight relative oscillations to arise in the velocity field. Introduction of a small restoring acceleration at each vertex, based upon the local velocity field, can prevent any vertex from deviating too strongly from its neighbors and couple the alternate nodes more strongly. This is done in YAQUI by introducing a weighted average of the neighboring vertex velocities. We can write

$$A_{x_1}^j = g_x + \frac{1}{a_{nc} \delta t} (n_{<u>_1^j} - n_{u_1^j}) ,$$

and

$$A_{y_1}^j = g_y + \frac{1}{a_{nc} \delta t} (n_{<v>_1^j} - n_{v_1^j}) ,$$

where

$$n_{<u>_1^j} = \frac{1}{4} (n_{u_{i+1}^j} + n_{u_i^{j+1}} + n_{u_{i-1}^j} + n_{u_i^{j-1}}) ,$$

$$n_{<v>_1^j} = \frac{1}{4} (n_{v_{i+1}^j} + n_{v_i^{j+1}} + n_{v_{i-1}^j} + n_{v_i^{j-1}}) ,$$

and a_{nc} is a coefficient that governs the amount of coupling, and upon which there is a stringent stability requirement, discussed in Sec. II F. It is

possible to interpret a_{nc} as the number of cycles required for the vertex velocity to nearly equal the average of the neighboring velocities. The effect of this formulation becomes more apparent if one considers the initial tilde velocities that result from it:

$$\tilde{u}_1^j = \left(1 - \frac{1}{a_{nc}}\right) n_{u_1^j} + \left(\frac{1}{a_{nc}}\right) n_{<u>_1^j} + \delta t g_x ,$$

and

$$\tilde{v}_1^j = \left(1 - \frac{1}{a_{nc}}\right) n_{v_1^j} + \left(\frac{1}{a_{nc}}\right) n_{<v>_1^j} + \delta t g_y ,$$

which show the effective interpolation among neighbors that is added in. Note that for $a_{nc} = 1.0$, the technique becomes identical to a procedure that Lax introduced many years ago. To avoid the difficulty of that procedure as $\delta t \rightarrow 0$, it would be appropriate to take $a_{nc} = a'_{nc} / \delta t$, in which case a'_{nc} is the actual relaxation time, rather than the number of cycles for relaxation.

Next, the appropriate initial vertex energy change is calculated as

$$Q_1^j = \delta t \left[\left(A_{x_1}^j n_{u_1^j} \right) + \left(A_{y_1}^j n_{v_1^j} \right) \right] .$$

One might expect to see, instead,

$$Q_1^j = \frac{\delta t}{2} \left[A_{x_1}^j (n_{u_1^j} + \tilde{u}_1^j) + A_{y_1}^j (n_{v_1^j} + \tilde{v}_1^j) \right] ,$$

but this is inappropriate because of the way we calculate Phase 1. The initial tilde velocities we have established contain only the body accelerations, and inserting this part into the initial Q's, before the pressure forces have been calculated, can cause the Q's, and hence the E's, to depart steadily from the correct value.

This effect would be manifested, for example, in a simple hydrostatic equilibrium, in which the velocities at time n are zero. To maintain equilibrium, we know that the final tilde velocities must also equal zero, but the gravitational accelerations in the initial tilde velocities would be repeatedly added into the Q's every cycle. This condition would not arise if we were to hold off the Q calculation until the final, complete tilde velocities were available. We choose, however, to

form the Q's simultaneously in the same next step that will adjust for the various forces applied through pressure and viscous stresses over the control volumes surrounding each vertex. The changes in the initial $\tilde{u}$, $\tilde{v}$, and Q values are computed by sweeping through the cells and suitably adjusting the four vertices of each cell. Thus the net result at each vertex is the cumulative contribution from each of four surrounding cells. This technique of initializing vertices and then accumulating contributions from the cells is preferable to sweeping the vertices themselves, as it is less dependent on boundary conditions and requires calculation of auxiliary cell quantities only once per cycle.

Thus, the set of energy changes that we obtain at corner vertices is subsequently assigned to the adjacent cells in a manner that preserves total energy while updating the vertex velocities.

This second step for each vertex proceeds as follows. First, for each cell, we calculate the divergence, $D = \nabla \cdot \vec{u}$, and the components of the viscous stress tensor:

$$\pi_{xx} = 2\mu \frac{\partial u}{\partial x} + \lambda \nabla \cdot \vec{u} ,$$

$$\pi_{yy} = 2\mu \frac{\partial v}{\partial y} + \lambda \nabla \cdot \vec{u} ,$$

$$\pi_{xy} = \mu \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \right) ,$$

$$\pi_{\theta} = 2\mu \frac{u}{r} + \lambda \nabla \cdot \vec{u} .$$

Here μ is the shear stress, and $\lambda = \zeta - \frac{2}{3} \mu$, where ζ is the coefficient of dilatational viscosity.

The corresponding finite-difference equations for these quantities are:

$$\begin{aligned} D = \frac{1}{4V} \{ & (r_1 + r_2) [(u_1 + u_2) (y_2 - y_1) \\ & + (v_1 + v_2) (x_1 - x_2)] \\ & + (r_2 + r_3) [(u_2 + u_3) (y_3 - y_2) \\ & + (v_2 + v_3) (x_2 - x_3)] \\ & + (r_3 + r_4) [(u_3 + u_4) (y_4 - y_3) \\ & + (v_3 + v_4) (x_3 - x_4)] \end{aligned}$$

$$\begin{aligned} & + (r_4 + r_1) [(u_4 + u_1) (y_1 - y_4) \\ & + (v_4 + v_1) (x_4 - x_1)] \} , \end{aligned}$$

$$\begin{aligned} \pi_{xx} = \frac{\mu}{2V} \{ & (r_2 + r_1) (u_2 + u_1) (y_2 - y_1) \\ & + (r_3 + r_2) (u_3 + u_2) (y_3 - y_2) \\ & + (r_4 + r_3) (u_4 + u_3) (y_4 - y_3) \\ & + (r_1 + r_4) (u_1 + u_4) (y_1 - y_4) \\ & - \frac{CYL}{2} (u_1 + u_2 + u_3 + u_4) [(x_1 - x_3) (y_2 - y_4) \\ & + (x_2 - x_4) (y_3 - y_1)] \} + \lambda D , \end{aligned}$$

$$\begin{aligned} \pi_{yy} = \frac{\mu}{2V} \{ & (r_1 + r_2) (v_1 + v_2) (x_1 - x_2) \\ & + (r_2 + r_3) (v_2 + v_3) (x_2 - x_3) \\ & + (r_3 + r_4) (v_3 + v_4) (x_3 - x_4) \\ & + (r_4 + r_1) (v_4 + v_1) (x_4 - x_1) \} + \lambda D , \end{aligned}$$

$$\begin{aligned} \pi_{xy} = \frac{\mu}{4V} \{ & (r_1 + r_2) [(u_1 + u_2) (x_1 - x_2) \\ & + (v_1 + v_2) (y_2 - y_1)] \\ & + (r_2 + r_3) [(u_2 + u_3) (x_2 - x_3) \\ & + (v_2 + v_3) (y_3 - y_2)] \\ & + (r_3 + r_4) [(u_3 + u_4) (x_3 - x_4) \\ & + (v_3 + v_4) (y_4 - y_3)] \\ & + (r_4 + r_1) [(u_4 + u_1) (x_4 - x_1) \\ & + (v_4 + v_1) (y_1 - y_4)] \\ & - \frac{CYL}{2} (v_1 + v_2 + v_3 + v_4) [(x_1 - x_3) (y_2 - y_4) \\ & + (x_2 - x_4) (y_3 - y_1)] \} , \end{aligned}$$

$$\Pi_{\theta} = \text{CYL} \left(\frac{\mu}{4V} \left\{ (u_1 + u_2 + u_3 + u_4) [(x_1 - x_3)(y_2 - y_4) + (x_2 - x_4)(y_3 - y_1)] \right\} + \lambda D \right) .$$

In the above equations, V is the cell volume and all the velocities on the right are the beginning-of-cycle values at time n , not tilde velocities. The coefficient CYL appearing in Π_{xx} , Π_{xy} , and Π_{θ} equals 1.0 when used in cylindrical coordinates, or 0.0 when used in plane coordinates. Note also the cyclic increase in index values in each term.

Next, with the D and Π terms calculated for a cell, the resulting changes in the $\tilde{u}$ and $\tilde{v}$ velocities can be calculated at the four cell vertices as follows. Start by defining

$$\text{PTH} = \frac{1}{4} \Pi_{\theta} [(x_1 - x_3)(y_2 - y_4) + (x_2 - x_4)(y_3 - y_1)] ,$$

then

$$\begin{aligned} \tilde{u}_1 &= \tilde{u}_1 + \frac{\delta t}{2M_1} \left\{ \frac{1}{2} (r_2 + r_4) [\Pi_{xx}(y_4 - y_2) + \Pi_{xy}(x_2 - x_4)] + r_1(y_2 - y_4)p - \text{PTH} \right\} , \\ \tilde{u}_2 &= \tilde{u}_2 + \frac{\delta t}{2M_2} \left\{ \frac{1}{2} (r_3 + r_1) [\Pi_{xx}(y_1 - y_3) + \Pi_{xy}(x_3 - x_1)] + r_2(y_3 - y_1)p - \text{PTH} \right\} , \\ \tilde{u}_3 &= \tilde{u}_3 + \frac{\delta t}{2M_3} \left\{ \frac{1}{2} (r_4 + r_2) [\Pi_{xx}(y_2 - y_4) + \Pi_{xy}(x_4 - x_2)] + r_3(y_4 - y_2)p - \text{PTH} \right\} , \\ \tilde{u}_4 &= \tilde{u}_4 + \frac{\delta t}{2M_4} \left\{ \frac{1}{2} (r_1 + r_3) [\Pi_{xx}(y_3 - y_1) + \Pi_{xy}(x_1 - x_3)] + r_4(y_1 - y_3)p - \text{PTH} \right\} , \\ \tilde{v}_1 &= \tilde{v}_1 + \frac{\delta t}{2M_1} \left\{ \frac{1}{2} (r_2 + r_4) [\Pi_{xy}(y_4 - y_2) + (\Pi_{yy} - p)(x_2 - x_4)] \right\} , \\ \tilde{v}_2 &= \tilde{v}_2 + \frac{\delta t}{2M_2} \left\{ \frac{1}{2} (r_3 + r_1) [\Pi_{xy}(y_1 - y_3) + (\Pi_{yy} - p)(x_3 - x_1)] \right\} , \end{aligned}$$

$$\begin{aligned} \tilde{v}_3 &= \tilde{v}_3 + \frac{\delta t}{2M_3} \left\{ \frac{1}{2} (r_4 + r_2) [\Pi_{xy}(y_2 - y_4) + (\Pi_{yy} - p)(x_4 - x_2)] \right\} , \\ \tilde{v}_4 &= \tilde{v}_4 + \frac{\delta t}{2M_4} \left\{ \frac{1}{2} (r_1 + r_3) [\Pi_{xy}(y_3 - y_1) + (\Pi_{yy} - p)(x_1 - x_3)] \right\} , \end{aligned}$$

where p is the cell pressure previously calculated from the equation of state. The energy changes are similarly calculated for each of the four vertices, but the p 's are handled in a special mass-weighted fashion to improve accuracy when contact surfaces are present. First, calculate the Q contributions without the work terms:

$$\begin{aligned} Q_1 &= Q_1 + \frac{\delta t (r_2 + r_4)}{8M_1} \left\{ (u_2 + u_4) [\Pi_{xy}(x_2 - x_4) - \Pi_{xx}(y_2 - y_4)] - (v_2 + v_4) [\Pi_{xy}(y_2 - y_4) - \Pi_{yy}(x_2 - x_4)] \right\} , \\ Q_2 &= Q_2 + \frac{\delta t (r_3 + r_1)}{8M_2} \left\{ (u_3 + u_1) [\Pi_{xy}(x_3 - x_1) - \Pi_{xx}(y_3 - y_1)] - (v_3 + v_1) [\Pi_{xy}(y_3 - y_1) - \Pi_{yy}(x_3 - x_1)] \right\} , \\ Q_3 &= Q_3 + \frac{\delta t (r_4 + r_2)}{8M_3} \left\{ (u_4 + u_2) [\Pi_{xy}(x_4 - x_2) - \Pi_{xx}(y_4 - y_2)] - (v_4 + v_2) [\Pi_{xy}(y_4 - y_2) - \Pi_{yy}(x_4 - x_2)] \right\} , \\ Q_4 &= Q_4 + \frac{\delta t (r_1 + r_3)}{8M_4} \left\{ (u_1 + u_3) [\Pi_{xy}(x_1 - x_3) - \Pi_{xx}(y_1 - y_3)] - (v_1 + v_3) [\Pi_{xy}(y_1 - y_3) - \Pi_{yy}(x_1 - x_3)] \right\} . \end{aligned}$$

When all cells have been so treated, we can distribute the vertex energy changes, Q , into the stored cell-center energies E , to form an $\langle \tilde{E} \rangle$, which is denoted by brackets $\langle \rangle$ to identify that

the pressures were omitted from the Q terms:

$$\langle \tilde{E} \rangle_{i+\frac{1}{2}}^{j+\frac{1}{2}} = n_{i+\frac{1}{2}}^{j+\frac{1}{2}} + \frac{1}{4} (Q_1 + Q_2 + Q_3 + Q_4) .$$

Next, convert $\langle \tilde{E} \rangle$ values throughout the mesh to $\tilde{E}$'s by sweeping all cells. Define the following mass-weighted ratios for each cell:

$$P_{12} = \frac{M_{i+3/2}^{j+\frac{1}{2}} n_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}} n_{i+3/2}^{j+\frac{1}{2}}}{M_{i+3/2}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} ,$$

$$P_{23} = \frac{M_{i+\frac{1}{2}}^{j+3/2} n_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}} n_{i+3/2}^{j+3/2}}{M_{i+\frac{1}{2}}^{j+3/2} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} ,$$

$$P_{34} = \frac{M_{i-\frac{1}{2}}^{j+\frac{1}{2}} n_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}} n_{i-\frac{1}{2}}^{j+\frac{1}{2}}}{M_{i-\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} ,$$

$$P_{41} = \frac{M_{i+\frac{1}{2}}^{j-\frac{1}{2}} n_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}} n_{i+\frac{1}{2}}^{j-\frac{1}{2}}}{M_{i+\frac{1}{2}}^{j-\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} .$$

Although cell-center masses are no longer available, they can be approximated easily here by averaging four vertex masses. Finally, we can write

$$\begin{aligned} \tilde{E}_{i+\frac{1}{2}}^{j+\frac{1}{2}} = & \langle \tilde{E} \rangle_{i+\frac{1}{2}}^{j+\frac{1}{2}} - \frac{\delta t}{4M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} \left\{ (r_1+r_2) P_{12} [(\tilde{u}_1+\tilde{u}_2)(y_2-y_1) \right. \\ & + (\tilde{v}_1+\tilde{v}_2)(x_1-x_2)] + (r_2+r_3) P_{23} [(\tilde{u}_2+\tilde{u}_3)(y_3-y_2) \\ & + (\tilde{v}_2+\tilde{v}_3)(x_2-x_3)] + (r_3+r_4) P_{34} [(\tilde{u}_3+\tilde{u}_4)(y_4-y_3) \\ & + (\tilde{v}_3+\tilde{v}_4)(x_3-x_4)] + (r_4+r_1) P_{41} [(\tilde{u}_4+\tilde{u}_1)(y_1-y_4) \\ & \left. + (\tilde{v}_4+\tilde{v}_1)(x_4-x_1)] \right\} . \end{aligned}$$

We have observed that this technique of calculating $\tilde{E}$ in two steps is useful in enhancing the sharpness of shock fronts as well as contact surfaces.

The E formulation does, indeed, conserve total energy, and this can be shown as follows. If we sum over all cells

$$\sum_k M_k E_k = \sum_k M_k^{old} E_k + \sum_k \frac{M_k}{4} (Q_1+Q_2+Q_3+Q_4) ,$$

or

$$(\text{New Total Energy}) = (\text{Old Total Energy})$$

$$+ \sum_{\ell} \left(\frac{M_1 + M_2 + M_3 + M_4}{4} \right) Q_{\ell} ,$$

where the last sum has been changed from cells to vertex ℓ , and the coefficient of Q_{ℓ} is precisely the mass of vertex ℓ . Energy conservation is ensured, because the $M_{\ell} Q_{\ell}$ cancel in pairs when summed.

This completes the calculations associated with Phase 1 of the ICED-ALE cycle. If, at this point, one were to move coordinates with the $\tilde{u}$ and $\tilde{v}$ velocities and calculate new densities, the result would be a typical, explicit, Lagrangian calculation.

E. Phase 2 of the Calculation

We now need an implicit treatment to eliminate the Courant-like restriction on high sound speed that usually is required to ensure computational stability. This is accomplished by iterating the tilde quantities from Phase 1 so as to provide an advanced-time set of pressures for use in the momentum equations. These pressures, in turn, must reflect the new densities that will be calculated with the new velocities. In other words, the new densities are computed from coordinates obtained using accelerations that are functions of the new densities. Such an implicit treatment can, indeed, prevent instabilities at high sound speeds. For a completely incompressible flow, for example, the iteration tends to keep the ρ of each cell constant as the sound speed approaches infinity. The implicit coupling of p and ρ forces the cell to return to its initial ρ value, as ρ changes force corresponding pressure changes.

The implicit Phase-2 calculation proceeds as follows. First, we initialize velocities, densities, and pressures, where

$$u_L = \tilde{u} ,$$

$$v_L = \tilde{v} ,$$

$$\rho_L = n \rho ,$$

$$p_L = n p .$$

The subscript L identifies those quantities to be updated during the iteration. (In Phase 3, u_L , v_L , and ρ_L will be further changed to their final

values, $n+1_u$, $n+1_v$, and $n+1_p$.) As the tilde quantities $\tilde{u}$, $\tilde{v}$, and $\tilde{p}$ need not be saved for any other purpose, one can simply rename the tilde velocity arrays and the pressure array without any actual storage transfers. The quantity $\tilde{\rho}$, however, appears again in the Phase-3 convective flux equations, thus requiring separate storage for the ρ_L values.

In addition to the starting values of u_L , v_L , ρ_L , and p_L , one must keep the $\tilde{I}$ values available for each cell in order to compute cell pressures. The Q values are no longer needed after Phase 1.

Second, we sweep the mesh systematically in i and j and make the following calculations for each cell.

$$(1) \quad D = \frac{1}{4V} \left\{ (r_1 + r_2) \left[(u_{L1} + u_{L2})(y_2 - y_1) + (v_{L1} + v_{L2})(x_1 - x_2) \right] + (r_2 + r_3) \left[(u_{L2} + u_{L3})(y_3 - y_2) + (v_{L2} + v_{L3})(x_2 - x_3) \right] + (r_3 + r_4) \left[(u_{L3} + u_{L4})(y_4 - y_3) + (v_{L3} + v_{L4})(x_3 - x_4) \right] + (r_4 + r_1) \left[(u_{L4} + u_{L1})(y_1 - y_4) + (v_{L4} + v_{L1})(x_4 - x_1) \right] \right\} .$$

(Note that this is the same divergence equation that appeared in Phase 1, except that the velocities are at step L instead of time n .) From the mass equation, we define

$$(2) \quad S = \frac{1}{\delta t} (\rho_L - \tilde{\rho}) + \rho_L D ,$$

and

$$(3) \quad A = \frac{1}{\frac{1}{2} \left(\frac{1}{\delta t} + D \right) + 2\delta t \left(\frac{1}{\Delta x^2} + \frac{1}{\Delta z^2} \right)} .$$

This prescription for A is exact only when the cells are rectangular, but it is much simpler and quicker to calculate than the fully general value,

which may be preferable when the zoning deviates strongly from the rectangular, an errors in A alter the rate of convergence.

In the above,

$$c^2 = \left(\frac{\partial p}{\partial \rho} \right)_s$$

is the square of the adiabatic sound speed, and Δx and Δz represent the average δx and δz of the cell:

$$\Delta x = \frac{1}{2} (x_2 - x_4 + x_1 - x_3) ,$$

$$\Delta z = \frac{1}{2} (y_2 - y_4 + y_3 - y_1) .$$

If the mesh is strongly rotated or distorted, more sophisticated Δx and Δz expressions may be required.

Note that the adiabatic sound speed should be used here, because the Lagrangian representation in this phase is accomplishing the changes in pressure through simultaneous changes in ρ and I (even though the latter is not being calculated at this point). This is in contrast to the purely Eulerian calculation described in previous papers on ICE methodology,¹ in which the change of pressure through the iteration phase results from changes in density only, the full change in internal energy being calculated separately and incorporated into the pressure-change calculation as a separate step. In this purely Eulerian technique, it is the iso-thermal sound speed that is accordingly required in the implicit pressure-calculation phase.

(4) With D , S , and A defined, we can calculate the necessary pressure change for the cell,

$$\delta p = -\omega AS ,$$

where ω is a relaxation factor. Straight relaxation is given by $\omega = 1$. An optimum overrelaxation in many cases is $\omega = 1.5$ to 1.7 , whereas $\omega > 2$ will lead to an unstable iteration.

(5) The convergence test is

$$\left| \frac{\delta p}{p_{\max}} \right| < \epsilon ,$$

where $p_{\max}$ is a current maximum pressure in the system. If the test fails for any cell, a flag is set to indicate that another iteration pass through the mesh will be necessary.

(6) With δp calculated, we can update the ρ_L and p_L values for the cell.

$$\rho_L = \rho(p_L, T) \text{ or } \rho_L = \rho_L + \frac{\delta p}{c} ,$$

$$p_L = p_L + \delta p .$$

(7) Now we can adjust u_L and v_L values for the four vertices of the cell:

$$\begin{aligned} u_{L1} &= u_{L1} + \frac{\delta t}{2H_1} r_1 (y_2 - y_4) \delta p , \\ u_{L2} &= u_{L2} + \frac{\delta t}{2H_2} r_2 (y_3 - y_1) \delta p , \\ u_{L3} &= u_{L3} + \frac{\delta t}{2H_3} r_3 (y_4 - y_2) \delta p , \\ u_{L4} &= u_{L4} + \frac{\delta t}{2H_4} r_4 (y_1 - y_3) \delta p , \\ v_{L1} &= v_{L1} + \frac{\delta t}{2H_1} \left(\frac{r_2 + r_4}{2} \right) (x_4 - x_2) \delta p , \\ v_{L2} &= v_{L2} + \frac{\delta t}{2H_2} \left(\frac{r_3 + r_1}{2} \right) (x_1 - x_3) \delta p , \\ v_{L3} &= v_{L3} + \frac{\delta t}{2H_3} \left(\frac{r_4 + r_2}{2} \right) (x_2 - x_4) \delta p , \\ v_{L4} &= v_{L4} + \frac{\delta t}{2H_4} \left(\frac{r_1 + r_3}{2} \right) (x_3 - x_1) \delta p . \end{aligned}$$

When all cells satisfy the convergence test, the iteration, using the above seven steps, is terminated. At this point, the quantities u_L , v_L , ρ_L , and p_L describe the results of an implicit Lagrangian calculation that is not subject to the Courant condition. One could now move coordinates to complete the calculation if no rezoning were necessary. Note that ρ_L was calculated in terms of $n^k x$, not $n^{k+1} x$. The neglect of higher-order terms causes $n^{k+1} \rho$ to differ slightly from ρ_L , but the approximation has not caused any difficulty. The ρ_L is used only in the pressure iteration, whereas in Phase 3 $n^{k+1} \rho$ will be calculated from $n^k \rho$ by means of conservative fluxing in the mass equation.

In summary, at the end of Phase 2, we have in storage the n -time values of x , y , r , ρ , V , M , and I , as well as $\bar{E}$ and the iterated values of u_L , v_L , p_L , and ρ_L .

F. Phase 3 of the Calculation

The final phase of the ICED-ALE cycle computes

the necessary rezoning changes, i.e., convective and diffusive fluxes.

Assume at this point that a field of grid vertex velocities, u_G and v_G , have been assigned in some appropriate fashion with respect to a fixed, Eulerian reference frame. Thus, for a purely Eulerian calculation,

$$u_G = v_G = 0 .$$

At the other extreme, a purely Lagrangian calculation would use

$$u_G = u_L ,$$

$$v_G = v_L .$$

In general, the grid velocities may be any designated functions, and as such they are neither purely Eulerian nor purely Lagrangian.

There are two types of quantities to be updated in the rezoning: cell quantities M (or ρ) and E (or I), and vertex quantities u and v . The procedure is to compute the cell quantities first, then change $n^{k+1} M_{\text{cell}}$ to $n^{k+1} M_{\text{vertex}}$ and compute the vertex quantities. Finally, $n^{k+1} I$ can be calculated.

The rezoning can be accomplished using either the old $n x, n y$ coordinates or the new $n^{k+1} x, n^{k+1} y$ coordinates. The differences in rezoned quantities that result from these different coordinates are of order δt^2 , and they can be neglected for most purposes. Our procedure is to move the coordinates before the rezoning calculations, as numerical methods are usually slightly more stable when time-advanced quantities are used. The new coordinates for all vertices are given by

$$n^{k+1} x = n^k x + u_G \delta t ,$$

$$n^{k+1} y = n^k y + v_G \delta t ,$$

and

$$n^{k+1} r = n^{k+1} x \text{ for cylindrical coordinates, or } 1.0 \text{ for plane coordinates.}$$

The mass and energy are rezoned on a cell-by-cell basis. For every cell, we must first calculate flux coefficients for each of the four faces, using the new coordinates:

$$\begin{aligned}
FR &= \frac{\delta\tau(\tau_1 + \tau_2)}{8} \left[(u_{G1} - u_{L1} + u_{G2} - u_{L2})(y_2 - y_1) \right. \\
&\quad \left. + (v_{G1} - v_{L1} + v_{G2} - v_{L2})(x_1 - x_2) \right] , \\
FT &= \frac{\delta\tau(\tau_2 + \tau_3)}{8} \left[(u_{G2} - u_{L2} + u_{G3} - u_{L3})(y_3 - y_2) \right. \\
&\quad \left. + (v_{G2} - v_{L2} + v_{G3} - v_{L3})(x_2 - x_3) \right] , \\
FL &= \frac{\delta\tau(\tau_3 + \tau_4)}{8} \left[(u_{G3} - u_{L3} + u_{G4} - u_{L4})(y_4 - y_3) \right. \\
&\quad \left. + (v_{G3} - v_{L3} + v_{G4} - v_{L4})(x_3 - x_4) \right] , \\
FB &= \frac{\delta\tau(\tau_4 + \tau_1)}{8} \left[(u_{G4} - u_{L4} + u_{G1} - u_{L1})(y_1 - y_4) \right. \\
&\quad \left. + (v_{G4} - v_{L4} + v_{G1} - v_{L1})(x_4 - x_1) \right] .
\end{aligned}$$

Note that the flux coefficients are zero in Lagrangian calculations, as $u_G = u_L$ and $v_G = v_L$, and that FR for cell $(i+\frac{1}{2}, j+\frac{1}{2})$ is equal to -FL for cell $(i+\frac{3}{2}, j+\frac{1}{2})$, and FT for cell $(i+\frac{1}{2}, j+\frac{1}{2})$ is equal to -FB for cell $(i+\frac{1}{2}, j+\frac{3}{2})$.

Recall that the momentum equations in the finite calculations already contain diffusion terms, through a general stress-tensor deviator, which are used to represent true viscosity or to ensure computational stability. A slight instability results, however, if old-time values are used in the convective flux terms in the mass and energy zones, although the stability of the mass equation is enhanced by the use of the partially advanced density, ρ_L . In general, it seems preferable to prevent the instability at its source, rather than to add a separate diffusion process. (The truncation errors responsible for instability are not really

a full "diffusion form" when more than one dimension is considered.) Therefore, we will use flux expressions that can be adjusted toward a partial donor-cell treatment. It is convenient to embody the flux coefficients, FR, FT, FL, and FB, within expressions that allow various differencing forms determined from input constants, α_0 and β_0 :

$$\begin{aligned}
\alpha_R &= \alpha_0 \text{ sign FR} + 4FR \beta_0 / (v_{i+\frac{1}{2}}^{j+\frac{1}{2}} + v_{i+\frac{3}{2}}^{j+\frac{1}{2}}) , \\
\alpha_T &= \alpha_0 \text{ sign FT} + 4FT \beta_0 / (v_{i+\frac{1}{2}}^{j+\frac{3}{2}} + v_{i+\frac{1}{2}}^{j+\frac{1}{2}}) , \\
\alpha_L &= \alpha_0 \text{ sign FL} + 4FL \beta_0 / (v_{i-\frac{1}{2}}^{j+\frac{1}{2}} + v_{i+\frac{1}{2}}^{j+\frac{1}{2}}) , \\
\alpha_B &= \alpha_0 \text{ sign FB} + 4FB \beta_0 / (v_{i+\frac{1}{2}}^{j-\frac{1}{2}} + v_{i+\frac{1}{2}}^{j+\frac{1}{2}}) ,
\end{aligned}$$

where "sign FR," for example, = $\begin{cases} +1 & \text{if } FR \geq 0 \\ -1 & \text{if } FR < 0 \end{cases}$,

and the input constants allow these combinations:

$$\begin{aligned}
\alpha_0 &= 0 \text{ and } \beta_0 = 0 && \text{centered,} \\
\alpha_0 &= 1 \text{ and } \beta_0 = 0 && \text{donor cell,} \\
\alpha_0 &= 0 \text{ and } \beta_0 = 2 && \text{interpolated donor cell.}
\end{aligned}$$

Note, however, that α_0 must be sufficiently positive² for the mass equation to be stable. As full donor-cell differencing is too diffusive for most circumstances, generally $0 < \alpha_0 < 1$.

The new mass and energy for a cell $(i+\frac{1}{2}, j+\frac{1}{2})$ are given by

$$\begin{aligned}
n+1_{i+\frac{1}{2}}^{j+\frac{1}{2}} &= (\rho v)_{i+\frac{1}{2}}^{j+\frac{1}{2}} + FR \left[(1-\alpha_R) \rho_{L_{i+\frac{1}{2}}}^{j+\frac{1}{2}} + (1+\alpha_R) \rho_{L_{i+\frac{3}{2}}}^{j+\frac{1}{2}} \right] \\
&\quad + FT \left[(1-\alpha_T) \rho_{L_{i+\frac{1}{2}}}^{j+\frac{3}{2}} + (1+\alpha_T) \rho_{L_{i+\frac{1}{2}}}^{j+\frac{1}{2}} \right] \\
&\quad + FL \left[(1-\alpha_L) \rho_{L_{i-\frac{1}{2}}}^{j+\frac{1}{2}} + (1+\alpha_L) \rho_{L_{i+\frac{1}{2}}}^{j+\frac{1}{2}} \right] \\
&\quad + FB \left[(1-\alpha_B) \rho_{L_{i+\frac{1}{2}}}^{j-\frac{1}{2}} + (1+\alpha_B) \rho_{L_{i+\frac{1}{2}}}^{j+\frac{1}{2}} \right] ,
\end{aligned}$$

and

$$\begin{aligned}
n+1_{E_{1+\frac{1}{2}}}^{j+\frac{1}{2}} &= \frac{1}{n+1_{M_{1+\frac{1}{2}}}^{j+\frac{1}{2}}} \left\{ (n_{ME})_{1+\frac{1}{2}}^{j+\frac{1}{2}} \right. \\
&+ FR \left[(1-\alpha_R) (n_{\rho E})_{1+\frac{1}{2}}^{j+\frac{1}{2}} + (1+\alpha_R) (n_{\rho E})_{1+3/2}^{j+\frac{1}{2}} \right] \\
&+ FT \left[(1-\alpha_T) (n_{\rho E})_{1+\frac{1}{2}}^{j+\frac{1}{2}} + (1+\alpha_T) (n_{\rho E})_{1+3/2}^{j+\frac{1}{2}} \right] \\
&+ FL \left[(1-\alpha_L) (n_{\rho E})_{1+\frac{1}{2}}^{j+\frac{1}{2}} + (1+\alpha_L) (n_{\rho E})_{1-1/2}^{j+\frac{1}{2}} \right] \\
&\left. + FB \left[(1-\alpha_B) (n_{\rho E})_{1+\frac{1}{2}}^{j+\frac{1}{2}} + (1+\alpha_B) (n_{\rho E})_{1-1/2}^{j-\frac{1}{2}} \right] \right\}
\end{aligned}$$

Before updating the vertex quantities, we next calculate $n+1_V$ (as per the equation in Sec. I C, item (3), which in turn allows us to calculate

$$n+1_{\rho_{1+\frac{1}{2}}}^{j+\frac{1}{2}} = n+1 \left(\frac{M}{V} \right)_{1+\frac{1}{2}}^{j+\frac{1}{2}}.$$

The new volume and density replace n_V and n_ρ . The new vertex masses are then calculated using the M_1^j equation given in Sec. I C, item (4).

To adjust the vertex values of u_L and v_L for rezoning, we set initial values at all vertices, where

$$n+1_{u_1^j} = \left(\frac{n_M}{n+1_M} \right)_1^j u_{L_1}^j,$$

and

$$n+1_{v_1^j} = \left(\frac{n_M}{n+1_M} \right)_1^j v_{L_1}^j.$$

The second sweep adjusts the four corner vertex values of each cell in a manner analogous to that in the first two phases. For each cell in turn, we define several quantities:

$$\begin{aligned}
F13 &= \frac{\delta t \rho_{L_{1+\frac{1}{2}}}^{j+\frac{1}{2}} (r_1 + r_3)}{16} \left[(u_{G1} - u_{L1} + u_{G3} - u_{L3}) (y_3 - y_1) \right. \\
&\left. + (v_{G1} - v_{L1} + v_{G3} - v_{L3}) (x_1 - x_3) \right],
\end{aligned}$$

$$\begin{aligned}
F24 &= \frac{\delta t \rho_{L_{1+\frac{1}{2}}}^{j+\frac{1}{2}} (r_4 + r_2)}{16} \left[(u_{G4} - u_{L4} + u_{G2} - u_{L2}) (y_2 - y_4) \right. \\
&\left. + (v_{G4} - v_{L4} + v_{G2} - v_{L2}) (x_4 - x_2) \right],
\end{aligned}$$

$$\alpha 13 = \alpha_o \text{ sign } F13 + \beta_o \frac{4F13}{(v_{\rho_L})_{1+\frac{1}{2}}^{j+\frac{1}{2}}},$$

$$\alpha 24 = \alpha_o \text{ sign } F24 + \beta_o \frac{4F24}{(v_{\rho_L})_{1+\frac{1}{2}}^{j+\frac{1}{2}}}.$$

Here, the "sign" has the same meaning as it did in the mass- and energy-flux expressions given above, and the α_o and β_o are the same quantities as in those expressions or may be chosen independently. Because a greater proportion of donor-cell differencing is required to stabilize the mass equation than the momentum equations, it is well to use a different (smaller) α_o in the momentum equations. Given the values of F13, F24, $\alpha 13$, and $\alpha 24$ for a given cell, the vertex contributions are given by:

$$n+1_{u_1} = n+1_{u_1} - \frac{F24}{n+1_{M_1}} \left[u_{L3} (1-\alpha 24) + u_{L1} (1+\alpha 24) \right],$$

$$n+1_{u_2} = n+1_{u_2} - \frac{F13}{n+1_{M_2}} \left[u_{L4} (1-\alpha 13) + u_{L2} (1+\alpha 13) \right],$$

$$n+1_{u_3} = n+1_{u_3} + \frac{F24}{n+1_{M_3}} \left[u_{L3} (1-\alpha 24) + u_{L1} (1+\alpha 24) \right],$$

$$n+1_{u_4} = n+1_{u_4} + \frac{F13}{n+1_{M_4}} \left[u_{L4} (1-\alpha 13) + u_{L2} (1+\alpha 13) \right],$$

$$n+1_{v_1} = n+1_{v_1} - \frac{F24}{n+1_{M_1}} \left[v_{L3} (1-\alpha 24) + v_{L1} (1+\alpha 24) \right],$$

$$n+1_{v_2} = n+1_{v_2} - \frac{F13}{n+1_{M_2}} \left[v_{L4} (1-\alpha 13) + v_{L2} (1+\alpha 13) \right],$$

$$n+1_{v_3} = n+1_{v_3} + \frac{F24}{n+1_{M_3}} \left[v_{L3} (1-\alpha 24) + v_{L1} (1+\alpha 24) \right],$$

$$n+1_{v_4} = n+1_{v_4} + \frac{F13}{n+1_{M_4}} \left[v_{L4} (1-\alpha 13) + v_{L2} (1+\alpha 13) \right].$$

Finally, the new velocity field allows us to calculate the new specific internal energies for all cells:

$$n+1_{i+\frac{1}{2}}^{j+\frac{1}{2}} = n+1_{i+\frac{1}{2}}^{j+\frac{1}{2}} - \frac{1}{8} (u_1^2 + u_2^2 + u_3^2 + u_4^2 + v_1^2 + v_2^2 + v_3^2 + v_4^2),$$

where the u and v values are the $n+1$ values just calculated.

G. Boundary Conditions

Various boundary treatments can be used in an ICED-ALE program,² but we discuss here only the simple case of straight, rectangular reflective boundaries on all four sides of the mesh. (For ease of understanding, the version of the code presented in the following sections is limited to this one case.) The reflective boundaries considered are free-slip walls, the left boundary becoming the axis of symmetry for calculations in cylindrical coordinates. The criterion for any boundary condition is that velocities on boundary vertices be set in a suitable fashion. For free-slip walls, this means that normal wall velocities must be kept zero throughout the calculation. In the three phases of the calculational cycle, particular attention must therefore be given to the following:

- (1) After the Phase-1 tilde velocity calculations, normal wall velocities must be reset to zero, i.e., $\tilde{u} = 0$ on the left and right boundaries, and $\tilde{v} = 0$ on the top and bottom boundaries.
- (2) During the pressure iteration in Phase 2, the normal wall velocities must be kept zero. Therefore, the appropriate u_L and v_L component(s) must be set to zero in boundary cells before proceeding to the next cell in the iteration.
- (3) During the rezoning of cell quantities, cells adjacent to boundaries do refer to ρ and E values outside the walls, but these terms have zero coefficients, so they may be left unspecified.
- (4) After the $n+1_u$ and $n+1_v$ calculations, the normal wall velocities must be zeroed again, in a manner analogous to that used for the Phase-1 tilde velocities. As described here, the normal velocities are set assuming that the boundary is truly horizontal or vertical. Generally, however, any boundary (except the axis) may be curvilinear;

then the "normal" velocity becomes a function of both the u and v components, requiring more careful treatment.

It is important to note that no pressure boundary conditions are required in YAQUI. This is a direct benefit of the Phase-2 iteration procedure.

It is useful to surround the mesh with a band of fictitious cells (described in Sec. II B) to aid in the treatment of the boundary conditions. Generally, ρ and E should simply be set forever to zero in the fictitious cells. This allows calculation of appropriate zero fluxes at the boundaries in Phase 3. In many applications, however, it is useful to allow the rigid walls of the mesh to expand in the rezone. Then fluid is swept up, and appropriate ambient values of ρ and E must be maintained in the fictitious cells. An example of this is shown in the sample code version included in this report. Here a uniform exterior E is generated in the setup and is allowed to remain constant for all time. The rezone calculates appropriate exterior ρ_L values to maintain atmospheric equilibrium. These new exterior ρ_L values subsequently become the final exterior $n+1_\rho$ values for the cycle. Rezoning is discussed further in Sec. III B.

II. THE YAQUI COMPUTING PROGRAM

A. General Structure

Here we describe the principal structural details of the LASL ICED-ALE computing program, called YAQUI, whose flow diagram and listing appear in Appendixes A and B, respectively. YAQUI was written as a CDC-7600 production code for specific contractual purposes. As such, it embodies a number of features to make efficient use of computer storage and time. As was anticipated, however, the same basic code has been developed in several directions by a number of investigators, so it was purposely constructed in a modular form. The physical arrangement of these modules corresponds to their logical sequence in the computing cycle to the greatest degree practicable. The loss of efficiency in certain regions that results from having the entire code in FORTRAN IV, rather than machine language, is hopefully counterbalanced by increased readability for most users and the simplification of adapting it for use on computers other than the CDC-6600/7600 series.

As depicted in Fig. 4, YAQUI is built in an overlay fashion to minimize the use of small core memory (SCM), which is the "fast" memory on the CDC-7600. The main overlay, (0,0), which always resides in SCM, contains the main controlling program, YAQUI. Subserving to it are the programs in the two primary overlays, (1,0) and (2,0), which reside on disk storage. YASET is the setup program, and YAQUI1 performs the three-phase ICED-ALE calculations.

The structure within each of these three programs is further detailed in Fig. 5, which shows the UPDATE notation used in the actual code.

In addition to the main program, YAQUI, the (0,0) overlay contains the subroutines L00P and FILMC0. L00P handles the three-row buffering scheme that shuttles cell data between large core memory (LCM) and the SCM common YSC1. The details of cell-data storage and the buffering scheme are given in Secs. II C and D. FILMC0 (for film coordinates) computes the scaling for the microfilm plots. Because these two subroutines are required by both of the primary overlays, it is expedient to place them in the main overlay. Because they are thus always resident, the primary overlays can access them at will. Also in the main overlay is the common YSC2, which contains all the SCM data that must be maintained from cycle to cycle, and which is the SCM portion of the information written on tape for restarting purposes.

Two LCM blocks are initially defined in the main program: YLC1 is the storage block for cell data, and YLC2 is the storage block for the optional particles, described in Sec. II E.

To set up a calculation from initial input data, the main program calls YASET, the (1,0) overlay program, from the disk, and surrenders control to it. This overlay is placed in SCM immediately

following the (0,0) overlay. YASET itself is only a two-instruction program: it prints "YASET CALLED," so that the user can monitor his path through the overlays, and then immediately calls subroutine YASET1. YASET1 performs the actual setup, and in turn calls upon PARTGEN, to generate particles if specified, and MESHPGR, which creates the computing mesh with its initial cell and vertex quantities. When the problem setup is complete, YASET1 returns control to the (0,0) main overlay program.

To calculate after setting up, the main program calls YAQUI1, the (2,0) primary overlay, from the disk, and surrenders control to it. Because this is an overlay of the same level as (1,0), it covers the image of (1,0) in SCM, being read in also to the locations immediately following the (0,0) overlay and thus making efficient use of SCM space. Like YASET, YAQUI1 is a two-instruction program: it prints "YAQUI2 CALLED," and immediately calls subroutine YAQUI2. Should the program abort because of an unexpected error, the user can quickly ascertain which program he is in, inasmuch as the range of instruction addresses for both the (1,0) and (2,0) overlays is the same.

YAQUI2 is the largest section of code in the entire computer program. It contains the three-phase ICED-ALE, whose calculational cycles are repeated continuously under the direction of the "Control Region." This region is strategically placed immediately after the η_p calculation, at which point in the cycle all the quantities that represent the complete solution at a given instant in problem time are available. The control region provides all microfilm plots and cell data prints. Also, it updates the problem time, t , by the current δt , performs tape dumps and tape restarts, and senses problem completion or an impending operating-system time limit. In the latter two events, it returns control to the main program, which, in turn, searches the input queue for further tasks. If there are none, the job is ended.

YAQUI2 makes use of two subroutines: PARTMOV moves and plots particles, and REZONE calculates new grid vertex velocities, u_G and v_G , and new vertex coordinates, x , y , and r , for Phase 3 if the flow is neither pure Lagrangian nor pure Eulerian. If, however, the flow is pure Lagrangian or pure Eulerian, these velocities and the new coordinates

Fig. 4. The YAQUI 3 program overlay structure.

YAQUI CODE STRUCTURE

Fig. 5. Detailed breakdown of the YAQUI overlays, describing the functions of all sections and the UPDATE nomenclature.

are directly calculated in YAQUI2 in a simple, straightforward fashion. The REZONE package is really a "roll-your-own" section in which the user creates rezoning logic appropriate to his particular needs. (In the version of YAQUI presented here, the REZONE subroutine is an example of a possible way to follow the rise of debris from an atmospheric burst.)

To restart a calculation from a tape dump, the main program bypasses the (1,0) overlay and

calls (2,0) directly. The restart condition is sensed immediately by YAQUI2, and the control region reads in the tape dump, placing the data in SCM and LCM as required, and turns control over to the point in the calculational cycle that will continue the problem from where it left off when the tape dump was made.

B. The Indexing Notation

An examination of Fig. 2 shows some variables centered at vertices and some at cell centers, a common occurrence in Lagrangian computing methods. In FORTRAN, one can reference x_1^j simply as "X(I,J)," but $p_{1+\frac{1}{2}}^{j+\frac{1}{2}}$ cannot be referenced by a "half-integer" index, so the convention has evolved that "P(I,J)" refers to this pressure. Thus the indices I and J refer to a quantity lying at the lower left vertex of a cell, or at the cell center, depending upon where the quantity is defined. In YAQUI, "(I,J)" is replaced simply by "(IJ)," as only single subscripts are used for computer efficiency. In the YAQUI subscript notation, the letter "P" stands for "+," and "M" stands for "-." Thus, we write

IJ = (i,j) ,
 IPJ = (i+1,j) ,
 IJM = (i,j-1) ,
 IPJP = (i+1,j+1) ,
 etc.

Such a notation permits easy readability of programmed difference equations in the code. Figure 6 shows the single subscripts typically seen in reference to vertex quantities, and Fig. 7 shows subscripts referring to cell quantities.

As the number of vertices in either direction is one greater than the number of cells, it is apparent that the grid in computer storage must be at least $(\bar{I}+1)$ by $(\bar{J}+1)$ in size. Because our indexing refers to cell centers and lower left vertices, we must allow one extra column of storage

Fig. 6. Single subscript notation for vertex quantities.

Fig. 7. Single subscript notation for cell quantities.

on the right and one extra row along the top. YAQUI includes one extra row along the bottom in addition, giving a mesh that is $(\bar{I}+1)$ by $(\bar{J}+2)$ in extent. These exterior zones are known as fictitious cells, and having them on three sides helps in the treatment of expanding meshes and certain boundary conditions. Note that fictitious cells are not used on the left, however. The code was basically intended for calculations in cylindrical coordinates, in which the left boundary is an axis of symmetry. In plane coordinates, it becomes a rigid free-slip wall, or plane of symmetry. The omission of fictitious cells on the left implies that no fluxing will ever be desired on that side, and the code would have to be modified to allow such a feature. The actual YAQUI mesh for the conceptual mesh of Fig. 1 is shown in Fig. 8. Coordinates are not calculated for fictitious cell vertices.

Obviously, double DØ loops in FORTRAN to cover all vertices would have the limits $J = 2$ to $JP2$ and $I = 1$ to $IP1$. Similarly, loops to cover all cell centers would have the limits $J = 2$ to $JP1$ and $I = 1$ to $IBAR$.

C. The Storage of Cell Data

The YAQUI code was designed for running finely resolved calculations, implying several thousand computing cells. In addition to the basic fluid dynamics, space has been left in SCM for the later

Fig. 8. An actual YAQUI mesh, corresponding to the conceptual mesh of Fig. 1, showing vertex notation. Fictitious cells are denoted by dashed lines.

inclusion of code to deal with other physical phenomena, such as magnetohydrodynamics, turbulence, and chemistry effects. Therefore, all cell data are maintained on LCM, and the code deals with only three rows of cells at a time in SCM processing. Clearly, the optimum procedure is that which requires the minimum number of read/write references to LCM. Accordingly, the cell variables are stored in an "interleaved" fashion, in which all the variables for a given cell are stored contiguously, followed by all the variables for the next cell, etc. (Contrast this with the traditional method of storing cell variables in individual $\bar{I}$ by $\bar{J}$ blocks for each variable. This scheme is appropriate when the computing code is designed for smaller meshes that will always fit in SCM.) In the version of YAQUI presented here, the full calculational cycle, including the optional particles, requires 35 different cell variables, but we are able to get by with using only 14 storage words per cell. This is made possible by retaining quantities during a cycle only as long as they are needed, and then using their storage words for other quantities. Figure 9 shows the allocation of the 14 storage words for a YAQUI cell in the (1,0) and (2,0) overlays. The ordering from left to right corresponds to the actual order in which quantities are calculated in the code. A black dot implies that the quantity currently in the

given storage word is referenced to calculate the quantity specified at the top of the column. The open dots in the rezone imply that x , r , y , and V may be referenced, depending upon the particular rezone. Note that the vertex masses, M_v , and the cell volumes, V , are stored as reciprocals for increased computer efficiency. Because most references to M_v and V are in denominators of equations, the time-consuming divide operation is thus avoided much of the time.

The quantities $2\delta t \left(\frac{1}{\Delta r^2} + \frac{1}{\Delta z^2} \right)$, known in the code as DELSM, and $1/c^2$, known as RCSQ, are invariant through the Phase-2 iteration. It is, therefore, expedient to compute their values throughout the mesh beforehand to avoid needless and repetitive calculation within the iteration itself.

In the convective-flux part of Phase 3, the "n+1" values of M_c (the cell mass), $1/M_v$ (the vertex mass), and u and v are initially stored in vacant slots. Their "n" values are still required through the calculation of the momentum equations, after which the new masses and velocities can be transferred to their ordinary storage words. This places them in their proper locations as the "n" values going into Phase 1 of the next cycle.

The contour quantity (CQ) in the control region denotes the field of some chosen cell variable for which a contour plot is drawn on microfilm. The quantities referred to in the PART40V subroutine are described in Sec. II E.

Charts such as Fig. 9 have proven extremely useful in initially planning the storage before a code is written, but they are equally useful thereafter as an aid in visualizing what quantities are available at a given point in the calculational cycle, and where storage vacancies exist.

YLC1, the storage block for cell data on LCM, contains a single array, AAL, dimensioned at 131000₁₀ words in the version of the code presented here. Because 14 words per cell are used in this version, a maximum of 9357 cells (the product of $\bar{I}+1$ and $\bar{J}+2$) are available.

D. The Three-Row Buffering Scheme

Subroutine L00P, in the (0,0) main overlay, shuttles the cell data between the large LCM array and a small buffer in SCM where it is operated on.

Fig. 9. The storage of cell data in YAQUI, showing how the 14 words per cell are allocated.

Generally, LØØP maintains three rows of the grid in SCM at a time: the row being processed and the rows above and below. All calculations affecting cell data are actually performed directly on the current contents of the buffer. Because the cell data are interleaved in storage, all quantities pertaining to the three rows of cells are instantly available. The schematic flow diagram and sample FORTRAN double DØ-loop in Fig. 10 show how the buffering takes place.

(1) Before the "DØ" statements are entered, a CALL is made to the START entry of LØØP. START reads in the entire contents of the bottommost three rows of the grid from LCM to the SCM buffer, placing row $j = 1$ in the buffer section designated "row 1/3"; likewise row $j = 2$ is read into "row 2/3," and row $j = 3$ is read into "row 3/3." Rows 1/3, 2/3, and 3/3 are contiguous in SCM, and like their counterparts in LCM each contains $NQI = NQ * IPI$ words, where NQ is the number of quantities, or storage words, per cell. With the three rows read in, the calling program needs to know how to access data in the buffer. This information is provided by the setting of the indices IJM, IJ, and IJP to point to the first words for the $i = 1$ column of cells in each row. Thus, IJM is set to the first-word address (f.w.a.) of SCM row 1/3; similarly, IJ points to the f.w.a. of 2/3, and IJP points to the f.w.a. of 3/3. Note the indicator IBUF which is set to 1; it will control the subsequent reading and writing of individual rows and the resetting of the three indices. With the first three rows of cells read in and the basic indices set, control is returned to the calling program.

(2) The double DØ loops are initiated. Secondary indices are needed for cells not lying immediately above or below cell IJ, so IPJ ($= i+1, j$) and IPJP ($= i+1, j+1$), which initially refer to the $i=2$ column of cells, are easily obtained by applying increments of the number-of-storage-words-per-cell, NQ , to the primary indices IJ and IJP. In the example shown in Fig. 10, we are able to calculate the radius of a cell as the simple average of the radii of its four vertices. The terminal statement of the inner DØ loop, which counts columns within each row, is statement No. 89. Note how the primary indices, IJ and IJP, are first advanced to the next column in the row. The inner

loop is repeated until the row is completed, at which time control passes to the "CALL LØØP" statement.

(3) The LØØP entry immediately writes row IJM back onto LCM, and depending on the setting of IBUF, goes to statement No. 10, 20, or 30. Because IBUF was initially set to 1, control passes to statement No. 10 in our example. Now the indices IJP, IJ, and IJM are reset to point to different SCM rows -- IJP to the vacated row 1/3, IJ to 3/3, and IJM to 2/3. IBUF is reset to 2 to control the next entry to LØØP, and control passes to statement No. 40 which will read row $j = 4$, the new IJP row, into SCM row 1/3. Note that no unnecessary shuffling of data in SCM has taken place: row $j-1$ was read out and replaced by row $j+1$, and the three indices were reset to point to where the rows $j+1$, j , and $j-1$ are located. As depicted at the bottom of Fig. 10, the grid rows in SCM are in their actual logical order only every third row.

(4) LØØP returns to statement No. 99 in the sample calling program, and rows are processed similarly until all the rows specified by the J DØ-loop have been processed, at which time control passes to the "CALL DØNE" statement.

(5) The DØNE entry is really only a cleaning-up operation: because further reading is unnecessary, it merely writes the final two rows, j and $j+1$ (JP1 and JP2, respectively) back out onto LCM.

Not indicated in the flow of Fig. 10 is the incrementing of the relative address indices for reading and writing LCM. These are initially set to 0, and incremented by NQI as processing progresses up the mesh.

Given this three-row buffering subroutine, the user needs only to include the CALLs to START, LØØP, and DØNE at the appropriate points in the DØ-loops and to increment by NQ words for each cell within a row. Other than that, the logic he must know is no more complex than if the data were entirely in SCM.

The number of storage words per cell in the YAQUI version presented here is seen to be $NQ = 14$, as per Fig. 9. This may be increased very simply by adding the new variables to the EQUIVALENCE and DIMENSION statements in the Comdecks EQVREAL and DIMEN, respectively, and redefining NQ in the (0,0) main program at one place only.

«ENTRY LOOP»

WRITE ROW IJM → LCM
GO TO (10,20,30) IBUF

(10) IJP = fwa SCM $\frac{1}{3}$
IJ = fwa SCM $\frac{3}{3}$
IJM = fwa SCM $\frac{2}{3}$
IBUF = 2

(20) IJP = fwa SCM $\frac{2}{3}$
IJ = fwa SCM $\frac{1}{3}$
IJM = fwa SCM $\frac{3}{3}$
IBUF = 3

«ENTRY START»

READ INTO ROW SCM $\frac{1}{3}$
READ INTO ROW SCM $\frac{2}{3}$

(30) IJP = fwa SCM $\frac{3}{3}$
IJ = fwa SCM $\frac{2}{3}$
IJM = fwa SCM $\frac{1}{3}$
IBUF = 1

(40) READ INTO ROW (IJP)

RETURN

«ENTRY DONE»

WRITE ROW IJM → LCM
GO TO (50,60,70) IBUF

(50) IJM = fwa SCM $\frac{2}{3}$

(60) IJM = fwa SCM $\frac{3}{3}$

(70) IJM = fwa SCM $\frac{1}{3}$

(80) WRITE ROW IJM → LCM

RETURN

SCM BUFFER

ROW $\frac{3}{3}$

ROW $\frac{2}{3}$

ROW $\frac{1}{3}$

INTERLEAVED STORAGE at NQ WDS./CELL

LOOP EXAMPLE :

CALL START
DO 99 J = 2, JPI
DO 89 I = 1, IBAR
IPJ = IJ + NQ
IPJP = IJP + NQ
R = .25 * [R(IPJ) + R(IPJP) + R(IJP) + R(IJ)]

89 IJ = IPJ
IJP = IPJP
CALL LOOP
99 CONTINUE
CALL DONE

	J	J	J	J	J	J	J
ROW $\frac{3}{3}$ →	(IJP) 3	(IJ) 3	(IJM) 3	(IJP) 6	(IJ) 6	(IJM) 6	(IJP) 9
ROW $\frac{2}{3}$ →	(IJ) 2	(IJM) 2	(IJP) 5	(IJ) 5	(IJM) 5	(IJP) 8	(IJ) 8
ROW $\frac{1}{3}$ →	(IJM) 1	(IJP) 4	(IJ) 4	(IJM) 4	(IJP) 7	(IJ) 7	(IJM) 7

Fig. 10. YAQUI three-row buffer.

The SCM buffer is in common YSC1 which contains a single array, AASC, dimensioned at 4242_{10} words in this YAQUI version. Because AASC must be able to hold three complete rows at once, $NQ = 14$ means $\bar{I} < 100$.

Other entry points in the LOOP subroutine, not shown in Fig. 10, allow the user to access any cell at random easily, and to perform DO loops with the J index reversed so as to sweep from top to bottom. Examples of this flexible routine are seen in numerous places throughout YAQUI.

E. The Particle Option

The basic ICED-ALE scheme has no dependence upon particles, but deals entirely with field variables related to the computing grid. It is useful, however, to include particles in many problems of interest. These may serve either as true "markers," which are carried along by the flow but have no influence upon it, or they may act upon the surrounding fluid. In the latter case, we must store velocity components, a mass, and a drag coefficient for each particle, in addition to the usual coordinates. This permits calculation of momentum changes experienced by the particles owing to fluid forces, these changes in turn being subtracted from the fluid momentum on a cell-by-cell basis.

For simplicity, we shall first discuss the basic particle-moving scheme used in YAQUI, and then describe the inclusion of the momentum-exchange feature.

1. The Particle Mover. Our technique for moving particles in a general, quadrilateral grid is based on use of a temporary, uniform rectangular cell grid superimposed on the YAQUI grid. Given a velocity field related to a uniform grid, particles are easily moved by an ordinary interpolated area-weighting scheme. The problem, then, is to define a velocity field on the superimposed grid (hereafter called the particle grid) so that it reasonably approximates the velocity field of the current YAQUI grid. This is done as follows.

(a) First, we define the particle grid by specifying its cell-edge lengths, Δx and Δy , and its overall dimensions PXR and PYT. Because we use a vacant part of the YAQUI cell storage to store particle grid quantities, we do not allow the number

of zones in either the x or y direction to exceed that of the YAQUI grid. We generally, however, run at this maximum for the best resolution. In most calculations, the dimensions Δx and Δy are chosen so that the particle grid just encompasses the region covered by the regular rectilinear or curvilinear grid, although in some cases when particles are used solely in some specific region, the particle grid may be placed only over the region of interest.

(b) The second step, after definition and location of the particle grid, is to sweep the YAQUI vertices systematically and do the following for each.

- If the vertex lies outside the particle grid, skip to the next vertex. To be included, the vertex must have $x \leq \text{PXR}$ and $\text{PYB} \leq y \leq \text{PYT}$, where PYB is the y coordinate of the bottom of the particle grid.
- Determine (i,j) of the particle-grid cell that contains the vertex.
- Assign to each of the four corners of the particle-grid cell (i,j) x and y momenta (M_x and M_y) and mass (M_0) according to

$$\left(M_x\right)_{i+1}^j = \left(M_x\right)_{i+1}^j + mu(w)(\Delta y - h)/\Delta x \Delta y ,$$

$$\left(M_x\right)_{i+1}^{j+1} = \left(M_x\right)_{i+1}^{j+1} + mu(w)(h)/\Delta x \Delta y ,$$

$$\left(M_x\right)_i^{j+1} = \left(M_x\right)_i^{j+1} + mu(\Delta x - w)(h)/\Delta x \Delta y ,$$

$$\left(M_x\right)_i^j = \left(M_x\right)_i^j + mu(\Delta x - w)(\Delta y - h)/\Delta x \Delta y ,$$

where w and h are defined as shown in Fig. 11. Use similar expressions with the same weighting factors for M_y and M_0 .

(c) Finally, after momenta and mass have been assigned from all YAQUI vertices onto the appropriate particle-grid vertices, we calculate the u and v velocities of the particle-grid vertices as

$$PU = M_x/M_0 \quad \text{and} \quad PV = M_y/M_0 ,$$

which are the velocities to be used in moving the particles.

(d) To move a particle, we first determine in which cell (i,j) of the particle grid it is located.

Fig. 11. Assigning YAQUI vertex quantities to the surrounding particle-grid cell.

It is then moved according to an interpolated velocity based on the corner velocities of the particle-grid cell. If the particle lies at positions (w, h) as shown in Fig. 12, then

$$u_p = \left[PU_{i+1}^j(w)(\Delta y - h) + PU_{i+1}^{j+1}(w)(h) + PU_i^{j+1}(\Delta x - w)(h) + PU_i^j(\Delta x - w)(\Delta y - h) \right] / \Delta x \Delta y,$$

$$^{n+1}x_p = x_p + \delta t u_p,$$

and similarly for the v_p velocity and y_p coordinate.

2. Particle-Fluid Momentum Exchange. In particle-fluid momentum exchange, the particles do not

Fig. 12. Area weighting the particle p within the particle grid cell.

necessarily move with the fluid velocity. The basic particle mover is extended to include reaction with the surrounding fluid as follows.

(a) In addition to storing PU and PV for all particle-grid vertices, we store the quantities ΔM_x and ΔM_y , which are the x and y momentum changes caused by fluid forces suffered by the particles near each vertex. These quantities must therefore be subtracted from the fluid momentum on a cell-by-cell basis. In YAQUI, we felt that to within the accuracy of the particle mover itself, we could split the word storage used for particle-grid velocities, combine FU and ΔM_x at one-half word each, and similarly combine PV and ΔM_y .

(b) The calculation of ΔM_x and ΔM_y proceeds as follows. The velocity of each particle is governed by the equation of motion

$$^{n+1}u_p = \frac{u_p^n + \delta t \eta_p (u_{f1} + u_{rand}) + \delta t g_x}{1 + \delta t \eta_p},$$

in which u_{f1} is the u_p of the previous equation -- the area-weighted value of the particle-grid velocities at the particle location, u_{rand} is the velocity contribution from turbulent fluctuations,⁴ and η_p is a drag coefficient. The x-momentum change of the particle is

$$(\overline{\Delta M_x})_p = m_p \delta t \eta_p (u_{f1} - ^{n+1}u_p + u_{rand}),$$

where m_p is the particle mass. This momentum change is distributed to the particle-grid vertices in much the same manner that u_{f1} was calculated. Thus, if the particle is in cell (i, j) , the corresponding changes at the vertices are given by

$$(\Delta M_x)_{i+1}^j = (\Delta M_x)_{i+1}^j + \frac{w(\Delta y - h)}{\Delta x \Delta y} (\overline{\Delta M_x})_p,$$

$$(\Delta M_x)_{i+1}^{j+1} = (\Delta M_x)_{i+1}^{j+1} + \frac{wh}{\Delta x \Delta y} (\overline{\Delta M_x})_p,$$

$$(\Delta M_x)_i^{j+1} = (\Delta M_x)_i^{j+1} + \frac{(\Delta x - w)h}{\Delta x \Delta y} (\overline{\Delta M_x})_p,$$

$$(\Delta M_x)_i^j = (\Delta M_x)_i^j + \frac{(\Delta x - w)(\Delta y - h)}{\Delta x \Delta y} (\overline{\Delta M_x})_p.$$

A similar distribution is performed for ΔM_y , where

$$\left(\frac{\Delta M_y}{M_o}\right)_p = m_p \delta \eta_p \left(v_{fl} - {}^{n+1}v_p + v_{rand}\right).$$

Because ΔM_x and ΔM_y are calculated through a summation, their values must be initialized at zero each cycle.

Note that whereas the basic particle mover required that the particle coordinates (x_p, y_p) be stored from cycle to cycle, the momentum exchange requires in addition u_p, v_p, m_p , and η_p . In YAQUI, particle-storage words are split like particle-grid storage. Thus, the six quantities per particle are kept in three words, where x_p is combined with u_p , y_p is combined with v_p , and η_p is combined with m_p .

(c) After all particles have been moved and their momentum changes recorded at the particle-grid vertices, these momentum changes must be inserted into the fluid momentum field. This is done by sweeping the YAQUI vertices in the same manner as that used to set up the particle-grid velocities: Determine in which particle-grid cell (i,j) each Lagrangian vertex, is located. Because the mass, M_o , associated with each particle-grid vertex is still in storage, the change in velocity components of the Lagrangian vertices can be calculated easily. The adjusted velocity component, u , of Fig. 11 is given by

$$u = u - \left[\left(\frac{\Delta M_x}{M_o}\right)_{i+1}^j (w)(\Delta y - h) + \left(\frac{\Delta M_x}{M_o}\right)_{i+1}^{j+1} (w)(h) + \left(\frac{\Delta M_x}{M_o}\right)_1^{j+1} (\Delta x - w)(h) + \left(\frac{\Delta M_x}{M_o}\right)_1^j (\Delta x - w)(\Delta y - h) \right] / \Delta x \Delta y,$$

and v is given similarly, with ΔM_x replaced by ΔM_y . These expressions conserve momentum.

The YAQUI particle mover has been written with the momentum-exchange feature built in. To calculate with true marker particles only, however, we merely set all $m_p = 0$, $\eta_p \rightarrow \infty$, and $u_{rand} = v_{rand} = 0$, and bypass all ΔM_x and ΔM_y calculations.

Two-fluid dynamics can be performed without using particles in a purely Lagrangian manner when

the fluid distortions are not severe,² whereas for incompressible flows involving large distortions, two-fluid dynamics can be calculated by tying the particle motions strongly to the fluid in which the particles are embedded. The particle masses are chosen so as to supplement the density already contributed by the background fluid, the sum of that density and the particle density being the total density of the second fluid. (More generally, the presence of a spatially varying density in the second fluid can likewise be represented by appropriate choice of particle masses.) The masses can be negative or positive.

In the absence of a free surface, the effects of gravity are most efficiently represented by separating the pressure of the background fluid into two parts, the uniform gradient in equilibrium with gravity and the departure from this. As a result, only the departure pressure is obtained by iteration, its boundary condition being zero gradient on the top and bottom walls. The gravitational acceleration on the particles (i.e., on the difference between the densities of the fluids) then remains as the only exterior force field. To allow for this, one must accordingly supply a separate specification for the gravitational acceleration on the particles, designated by g_{zp} .

Particle storage in YAQUI is maintained in the LCM block named YLC2, which contains a single array, AA2, dimensioned at 131000₁₀ words. Because the particle data are stored using three words per particle, a maximum of 43,666 particles may be used in the version of the code presented here.

F. The Automatic Calculation of the Time Step and the Viscosity Coefficients

The automatic calculation of the time step, δt , is included as an option in YAQUI, primarily on the basis of two stability conditions, one of which is imposed by the viscous stresses, with coefficients λ and μ , and the other of which is associated with the convective fluxes for Eulerian calculations, or with the prevention of negative volumes for Lagrangian calculations.

The viscous-stress stability conditions are tested in the Phase-1 calculations in conjunction with the calculation of the viscosity coefficients for the stress-tensor terms. As described below, the code creates effective values of λ and μ on a

cell-by-cell basis, as determined by a combination of input quantities and local flow conditions. From these considerations, it then calculates a tentative δt , labeled δt_v , for use in the next cycle of calculation.

The convective-flux limitation can be imposed during the rezoning of M and E in Phase 3. From an examination of the flux coefficients FR, FT, FL, and FB, calculated for each cell as defined in Sec. I F, along with the divergence, D, and α_0 , the code obtains another competing tentative δt , labeled δt_c .

The δt actually chosen for the next calculational cycle, then, is the smaller of δt_v and δt_c , $\delta t = \min(\delta t_v, \delta t_c)$. Subsequently, the initial values of δt_v and δt_c that go into the next cycle's tests differ by some factor, δt_{fac} , which is usually slightly larger than unity, times the new δt just chosen. This permits the δt to increase when conditions become more stable. Because the δt is always chosen for the next cycle of calculation, it can be argued that it is always a cycle behind. Ideally, the δt chosen should be for use in the present cycle, as it is based upon present conditions, but this would be more difficult to accomplish. The one-cycle lag, however, presents no problems, as the δt is always small enough that significant changes in the flow field occur only over a number of cycles of calculation. Accuracy considerations alone demand this, in addition to the requirements of numerical stability.

There is a great deal of latitude in how the viscosity coefficients may be determined for Phase 1. Governing the use of the input values of λ and μ is the input quantity ξ , an integer exponent used in conjunction with ρ_1^j . Three possible forms of viscosity are allowed, depending upon the definition of ξ :

- (1) $\xi = 1$ will allow a read-in value of artificial kinematic viscosity. The input values of λ and μ must be chosen with regard to the numerical stability requirements for expected flow conditions.²
- (2) $\xi = 0$ is used when the input values of λ and μ represent the real, physical coefficients of viscosity.
- (3) $\xi = -1$ forces the code to seek its own viscosity on the basis of local numerical-stability conditions in the flow. Note that the actual numerical

values of the input λ and μ are immaterial when $\xi = -1$. Only the ratio λ/μ will be considered for dividing the total viscosity between λ and μ .

The effective λ and μ used in the viscous terms of the equations are, in all three cases, given by

$$(\lambda_{eff})_1^j = k \lambda_{input}$$

and

$$(\mu_{eff})_1^j = k \mu_{input}$$

where

$$k = (\rho_1^j)^\xi$$

when $\xi = 1$ or 0. When $\xi = -1$, k is determined directly from the numerical-stability requirement

$$\frac{\lambda + 2\mu}{\rho} > \frac{1}{2} u^2 \delta t + \frac{1}{2} u' \delta x^2$$

We define

$$k = \frac{\rho (1 + \epsilon)}{\lambda + 2\mu} \left(\frac{1}{2} u_1^2 \delta t + \frac{(u \delta x)_{max}}{n} \right)$$

where ϵ is a coefficient, u_1^2 is the square of a representative velocity at vertex $(\frac{j}{1})$ of the cell,

$$u_1^2 = (u^2 + v^2)_1^j$$

and $u' \delta x^2$ is approximated by the maximum $u \delta x$ of the cell times a factor $(1/n)$,

$$u' \delta x^2 = \frac{(u \delta x)_{max}}{n} = \frac{1}{n} \max (|u_1^j| \Delta r, |v_1^j| \Delta z)$$

in which Δr and Δz have the usual definitions of average δr and δz :

$$\Delta r = \frac{1}{2} (x_2 - x_4 + x_1 - x_3)$$

$$\Delta z = \frac{1}{2} (y_2 - y_4 + y_3 - y_1)$$

Use of ξ has removed the restriction for infinitesimal δt 's that would otherwise be required in very low-density regions, as when $\xi = 1$ or -1 , $\lambda = \rho$ times some quantity, and $\mu = \rho$ times some quantity,

so that the condition we must satisfy for stability,

$$\frac{(\lambda + 2\mu) \delta t}{\rho_{\min}} < \frac{1}{2} \left(\frac{\delta r^2 \delta z^2}{\delta r^2 + \delta z^2} \right),$$

becomes

$$\text{some quantity times } \delta t < \frac{1}{2} \left(\frac{\delta r^2 \delta z^2}{\delta r^2 + \delta z^2} \right),$$

and the dependence upon $\rho_{\min}$ has been entirely removed. Moreover, for $\xi = 1$, λ has been converted to a kinematic form more convenient for artificial viscosity in problems involving large density variations.

The λD term appearing in the Π_{xx} , Π_{yy} , and Π_{θ} equations is calculated as

$$(\lambda D)_i^j = \min(D_i^j, 0) (\lambda_{\text{eff}})_i^j,$$

as D is applied only in compressive regions, that is, when it is negative.

With the viscous effects included through the stress tensors, the crucial equation for determining δt_v is the stability condition

$$\delta t < \left[\frac{2(\lambda + 2\mu)}{\rho} \left(\frac{1}{\Delta r^2} + \frac{1}{\Delta z^2} \right) \right]^{-1},$$

which roughly states that momentum must diffuse less than one cell width per time step. Because $(\lambda + 2\mu) = \frac{4}{3} \mu + \zeta$, the right side of the above expression is always positive. Further, the alternate node coupler in Phase 1 introduces another stability condition, which can be shown to always be

$$\text{ANC} \left(\equiv \frac{1}{a_{\text{nc}}} \right) < 1.$$

Combining these two conditions, we obtain

$$\text{Quantity}_i^j = \frac{\rho_i^j (1 - \text{ANC}) \Delta r^2 \Delta z^2}{2 \left[(\lambda_{\text{eff}})^j + 2(\mu_{\text{eff}})^j \right]_i^j (\Delta r^2 + \Delta z^2)},$$

from which δt_v may be reset as

$$\delta t_v = \min(\delta t_v, \text{Quantity}_i^j),$$

thus allowing every cell a chance to participate in the selection.

As mentioned earlier, several criteria in Phase 3 influence the choice of δt_c . One requirement is that material cannot be fluxed more than one cell width per time step, as the flux approximations are based on the implicit assumption that exchanges occur only between adjacent cells. Therefore, δt_c must be based in part upon the quantity

$$\left[\max(|FR|, |FT|, |FL|, |FB|) / \text{Volume} \right]_i^j,$$

if the flow has any Eulerian features. In Lagrangian cases, $D\delta t$ can provide the same measure that flux/volume does for Eulerian cases, as both expressions have the appropriate $\frac{\delta u}{\delta x} \delta t$ dimensions.

Besides monitoring these two quantities, δt_c must take into account the differencing scheme itself. It can be shown that for stability we must require

$$\frac{U \delta t}{\delta x} < \frac{2\alpha_o}{1 + \alpha_o^2},$$

in which $U = u_{\text{fluid}} - u_{\text{grid}}$, and α_o is a measure of the donor-cell proportion in the mass equation, as described in Sec. I F. (The right side of the above condition has its maximum when $\alpha_o = 1$.) For accuracy, we restrict the limit to only a quarter of this amount:

$$\frac{\alpha_o}{2(1 + \alpha_o^2)}.$$

Combining these three conditions, then, yields the crucial quantity for determining δt_c :

$$\text{Quantity}_i^j = \frac{\delta t \left[\frac{\alpha_o}{2(1 + \alpha_o^2)} \right]}{\left(\frac{|\text{flux}|_{\text{max}}}{\text{Volume}} \right)_i^j + \delta t |D|_i^j},$$

according to which we reset δt_c , if necessary, by

$$\delta t_c = \min(\delta t_c, \text{Quantity}_i^j),$$

on a cell-to-cell basis, as we did to calculate δt_v . (For computational purposes, the denominators of both the above and the previous "Quantity_i^j" expressions should contain an added constant (on

the order of 10^{-10}) to ensure that they do not vanish.)

III. USING THE YAQUI PROGRAM

A. Mesh Generation

The generation of the initial mesh and fluid configuration in YAQUI is the responsibility of the (1,0) subroutine, MESMKR. This subroutine must provide the starting x , y , r , u , and v values for all vertices, and ρ and I values for all zones. Data punched on input cards, described fully in Sec. C below, provide MESMKR the information necessary to perform this task for a variety of circumstances.

The first consideration is to define the coordinates for all vertices. The input quantities $\bar{I}$, $\bar{J}$, δr , and δz ($=$ IBAR, JBAR, DR, and DZ in the program) are the four fundamental quantities in grid generation. They permit creation of a grid of uniform δr by δz zones whose origin, vertex (1,2), lies at coordinates (0.0, 0.0). The addition of a fifth quantity y_B ($=$ YB), the y coordinate of vertex (1,2), allows the entire mesh to be displaced upward. This is useful for calculations involving expanding meshes. The initial, basic part of MESMKR generates exactly this uniform grid.

The version of MESMKR presented here further allows the option of nonuniform zoning. As depicted in Fig. 13, the previously generated grid lines may be shifted vertically and horizontally, with zone size increasing continuously outside of some remaining inner area of uniform zones. The region of uniform zones occupies I_{uniform} ($=$ IUNF) by J_{uniform} ($=$ JUNF) zones, centered at J_{center} ($=$ JCEN) zones up from the $j = 2$ bottom boundary line. IUNF and JUNF may range from values of 1 and 2, respectively, implying variable zones throughout, up to values of IBAR and JBAR, implying uniform zones throughout. The input coefficient FREZ provides the expansion ratio for the zones lying outside the IUNF by JUNF region. A relationship of the form $x_i = x_{i-1} + \text{FREZ} (x_{i-1} - x_{i-2})$ is used to locate grid lines lying to the right of IUNF, above $J_{\text{CEN}} + \frac{J_{\text{UNF}}}{2}$, and below $J_{\text{CEN}} - \frac{J_{\text{UNF}}}{2}$. For accuracy, FREZ generally should not exceed about 1.1. The above expression will retain uniform zoning throughout if $\text{FREZ} = 1.0$. A simple program modification would allow for different expansion rates in the two directions.

Fig. 13. An initial YAQUI grid with variable zoning. The region of uniform δr and δz zones (IUNF zones by JUNF zones, centered at JCEN zones up from the bottom) is denoted by shading.

If variable zoning is employed ($\text{FREZ} > 1.0$), user calculation of YB would be inconvenient, so, instead, the input quantity REZY0, which is the y coordinate of the center of expansion, y_0 , determines the vertical placement of the mesh. REZY0 refers to the YAQUI vertex (1, $J_{\text{CEN}} + 2$), and allows YAQUI to calculate the actual value of YB.

Although the variable zoning shown in Fig. 13 for this version of MESMKR is of a simple rectangular form, we emphasize that neither the technique nor the code is by any means limited to this. MESMKR may be modified easily to create any curvilinear grid, and, indeed, simple iterative techniques⁵ have been used in MESMKR to define a variety of more complex grid shapes for special applications.

With the basic grid (x , y , and r values) defined, the second consideration is the initial u , v , ρ , and I values to define the fluid. Input data cards are read which define regions containing integral numbers of zones, and specify the initial

values of the four variables assigned to all zones lying within each region. Use of these data cards is fully described in Sec. C below.

This version of MESHMKR includes the special capability of setting up atmospheric-explosion calculations. In this case, it creates an entire background of ambient atmosphere through use of one of the fluid-region data cards. In addition, ρ and E values are initialized in the external or fictitious zones, as the grid will later be expanded in the REZONE. MESHMKR then adjusts the uniform ρ field of this ambient atmosphere to a state of gravitational equilibrium by use of an algorithm that accounts for nonuniform zoning.

When combining variable zoning with an equilibrium atmosphere, the user must consider zone height in relation to scale height. It is computationally inaccurate to allow a zone height to exceed one scale height, and for zones larger than this, a change in sign can be introduced into the ρ field. Therefore, it is wise to ensure that the condition

$$\delta z < \frac{(\gamma - 1)I_{amb}}{|g_z|},$$

is satisfied throughout the mesh. In the above expression, I_{amb} is the ambient specific internal energy. As coded in this report, I_{amb} (given by REZSIE) is a constant, but when atmospheric conditions allow it to increase with increasing altitude, larger zones may be employed in the region of increased I_{amb} . However, the above condition must still be satisfied.

Upon the ambient background, the spherical burst may be defined in any manner that the user wishes. We usually employ a special set of data cards to define the upper right quadrant of the burst. These cards are provided by a one-dimensional spherical code whose purpose is to calculate the early-time dynamics. The cards are arranged in relation to a set of uniform Eulerian zones, each data card in the set specifying a pair of relative i and j cell indices and the associated ρ , I , v , and u values. With a j index specified in YAQUI to correspond to the center of the burst, MESHMKR creates only the upper right and the mirror-image lower right quadrants, taking advantage of the cylindrical symmetry of the burst. The data are

superimposed over the previously defined ambient atmosphere, overwriting a part of it that is restricted to lie within the IUNF by JUNF area, whose uniform zones are identical in size to those of the one-dimensional code. (This restriction would be unnecessary if one were to interpolate the input data separately.) The velocity components specified on the data cards are located at cell edges, creating a minor complication, as YAQUI velocities must be centered at the vertices. As a result, MESHMKR must store these velocity values in temporary locations as they are read in. After the entire set of data cards has been processed, MESHMKR can transform the field through appropriate averaging to form a vertex-centered velocity field.

Whatever logic the user chooses to employ in grid generation, MESHMKR's work is finished when all initial x , y , r , u , v , ρ , and I values have been defined and appropriately stored. This information enables YASET1 to calculate the initial values of the remaining basic cell and vertex quantities (M_C , V , E , and M_V) in a straightforward manner.

B. Rezoning

Rezoning, which is grid motion relative to fluid motion, occurs in any flow that is not purely Lagrangian. Indeed, purely Eulerian flow is a rezone flow, and is unique only in that the grid motion is such as to maintain the grid in a fixed location. When rezoning occurs, there is a convective flux of mass, momentum, and energy from one zone to its neighbors, which must be properly accounted for. For fluxing accuracy, the grid velocities or the time step must be restricted so that fluid is fluxed less than one cell per cycle, as it is assumed in the equations that exchanges take place only between neighboring zones.

These considerations are dealt with in Phase 3, in which grid velocities, u_G and v_G , and from them the resulting new x , y , and r coordinates, are determined. For the extremes of purely Lagrangian and purely Eulerian flows, these grid velocities may be specified quite simply. In the Lagrangian limit, the grid velocities are identical to the Lagrangian velocities resulting from Phase 2, $u_G = u_L$ and $v_G = v_L$. In the Eulerian limit, the grid velocities are identically zero. In YAQUI, these two cases are treated in Phase 3 in YAQUI2 itself. The (2,0) subroutine REZONE is called to

define the grid velocities and the resulting coordinates for any flow that is neither of these two extremes. This "roll your own" subroutine allows the user to force the grid to follow one or more features of the flow continuously.

The sample REZONE included here shows just one of a variety of possible schemes for following the dynamics of an atmospheric-explosion calculation. It is a good example because it shows the three basic objectives that must be met by a rezone for such a calculation.

- (1) The mesh must be expanded so as to maintain the boundaries ahead of the strong radially expanding shock,
- (2) The mesh must rise in the atmosphere at the rate of fireball rise, and
- (3) The zoning must resolve the details of the torus in the central region finely, but may be much coarser in the outlying regions, for computer efficiency.

(The variable zoning discussed in Sec. III A and shown in Fig. 13 can provide a good beginning for this last aspect.) The following briefly explains how REZONE meets these three objectives in this version.

- (1) The mesh expansion is controlled by monitoring the largest absolute u_L or v_L fluid velocity ($u_{\max}$) along a column or ($v_{\max}$) along a row, several cells in from each rigid boundary, thereby allowing signals to be sensed before they can reach the boundaries. The normal grid velocity assigned to the boundary vertices is then calculated to be the square root of the product of this maximum velocity times the largest absolute u_L or v_L velocity ($v_{\max}$) in the entire grid:

$$(u_G)_{i=1} = 0 \text{ for all } j,$$

$$(u_G)_{i=IP1} = \left[v_{\max} (u_{\max})_{i=I-6} \right]^{1/2} \text{ for all } j,$$

$$(v_G)_{j=2} = \left[v_{\max} (v_{\max})_{j=9} \right]^{1/2} \text{ for all } i,$$

$$(v_G)_{j=JP2} = \left[v_{\max} (v_{\max})_{j=J-14} \right]^{1/2} \text{ for all } i.$$

- (2) The overall upward rise or translational velocity (v_T) of the mesh can be determined by tracking the rising maximum point of some representative feature of the flow. We have found that the

vorticity will serve this purpose if care is taken. Although the rising fireball torus will soon develop a strong vorticity field, the vorticity profile flattens with time, developing a vertically elongated plateau of the larger values. Upon this plateau, the maximum point itself may move around significantly from cycle to cycle. If the grid translation is tied to such a shifting point, the result is discontinuous up and down translation, perhaps moving the grid several zone heights all at once. A smoother and more reliable quantity to follow than the pure vorticity would be some weighted average vorticity. One possible form that we have used successfully is based upon the quantity

$$y_c = \sum_k y_k \omega_k / \sum_k \omega_k, \text{ which is summed over all cells}$$

except those near the rigid boundaries. Then v_T is calculated as

$$v_T = \text{maximum of } \left[0, \frac{\Omega_G}{\delta t} \frac{(y_c - y_{cen})}{2} \right],$$

where y_{cen} is the y coordinate about which the fireball should be kept centered, and Ω_G is an under-relaxation factor used to ensure smooth rezoning.

- (3) The technique for rezoning the interior grid lines also makes use of the center of maximum vorticity, requiring the radial center,

$$x_c = \sum_k x_k \omega_k / \sum_k \omega_k, \text{ as well as the vertical } y_c,$$

to move. The interior vertices are then made to satisfy the relations

$$\bar{x}_i = \frac{1}{2} \left({}^n x_{i+1} + {}^n x_{i-1} \right) + \beta_G \left(x_c - {}^n x_i \right) \text{ for all } j,$$

and

$$\bar{y}_j = \frac{1}{2} \left({}^n y_{j+1} + {}^n y_{j-1} \right) + \beta_G \left(y_c - {}^n y_j \right) \text{ for all } i,$$

where the coefficient β_G determines how tightly the vertices are drawn in towards the center of vorticity (x_c, y_c), and therefore governs the level of resolution in the fireball torus.

In terms of grid velocities, these results are obtained by setting

$$(u_G)_i = \frac{\Omega_G}{\delta t} (\bar{x}_i - {}^n x_i) \text{ for all } j,$$

and

$$(v_G)_j = \frac{\Omega_G}{\delta t} (\bar{y}_j - n y_j) + v_T \text{ for all } i.$$

The minimum zone size is related not only to the value of β_G , but also to the value of $\bar{I}$. For a given $\bar{I}$, it is helpful to be able to estimate a priori an appropriate value for β_G to achieve some desired level of resolution. The relationship can be shown to be

$$\delta r_{\min} \approx \frac{2\beta_F x_R}{(1 + \beta_G + \beta_F)^{\bar{I}-1} - (1 + \beta_G - \beta_F)^{\bar{I}-1}},$$

where $\delta r_{\min}$ is the minimum δr after relaxation of the grid, x_R is the x coordinate of the right boundary after all grid expansion has taken place, and $\beta_F = (2\beta_G + \beta_G^2)^{1/2}$. The procedure is to obtain solutions for various values of β_G , but the final β_G chosen as optimum for a given problem will probably differ slightly from the value suggested by the relationship, and it is generally obtained empirically.

The rest of the REZONE subroutine, from statement No. 1200 to the end, is somewhat more general than the preceding part. New values of x, y, and r are calculated for all vertices, using the values of u_G and v_G , in expressions identical to those in Phase 3 of YAQUI2. This is done in REZONE, however, to enable the following adjustments to be made before RETURNing.

- (1) The particle grid parameters are adjusted to fit the new grid.
- (2) Subroutine FILMCØ is called to adjust all the film-plot scaling parameters, and finally,
- (3) The ρ_L values in the exterior zones are recalculated using the new coordinates.

C. The Input Data

Formatted input data cards provide the information necessary to specify a problem setup. The number of cards required varies according to the problem. However, the following cards must always appear.

Card No. 1: IBAR, JBAR, IUNF, JUNF, JCEN, DR, DZ, CYL, GRDVEL, AO, AOM, BO, KXI (Format 5I4, 7F8.3, I4), where:

IBAR = $\bar{I}$, the number of real zones in the r or x direction.

JBAR = $\bar{J}$, the number of real zones in the z or y direction.

IUNF, JUNF, JCEN, and FREZ (see Card No. 4 below) allow one form of variable orthogonal zoning in the initial grid generation. Refer to Sec. III A and to Fig. 13.

DR = δr , the cell size in the r or x direction in the uniform region.

DZ = δz , the cell size in the z or y direction in the uniform region.

(Note: The user may wish to completely override the specifications of IUNF, JUNF, JCEN, DR, and DZ in MESHMKR.)

CYL = 1.0 for cylindrical geometry, or = 0.0 for plane geometry.

GRDVEL = "grid velocity," 0.0 = pure Eulerian, 1.0 = pure Lagrangian, 2.0 = REZONE.

AO = α_0 coefficient in the Phase-3 momentum equations.

AOM = α_0 coefficient in the Phase-3 mass and energy equations.

BO = β_0 coefficient in the Phase-3 mass, energy, and momentum equations.

KXI = ξ , the exponent of ρ that determines the form of viscosity in the problem. Refer to Sec. II F.

Card No. 2: NAME (Format 10A8), where columns 2-80 of this card are used for problem identification on prints and plots. Column 1 should not be used because it is treated as a carriage control. If desired, the card may be entirely blank, but it must always be included.

Card No. 3: MU, LAM, ØM, EPS, GR, GZ, ASQ, RØN, GM1 (Format 9F8.3), where:

MU = μ_{input} } Viscosity coefficients. Refer to Secs. I D and II F.

LAM = λ_{input}

ØM = ω , the Phase-2 iteration relaxation parameter. The value $\omega > 1$ provides overrelaxation, whereas $\omega > 2$ is unstable. Refer to Sec. I E.

EPS = ϵ , the Phase-2 iteration convergence criterion, typically on the order of 10^{-5} (specifying convergence to within 10^{-5} of the maximum pressure in the system at a given instant), but ϵ may be greater or smaller depending

upon the problem. Refer to Sec. I E.

- GR = g_r , gravity felt by the fluid in the r or x direction, which may be + or - to pull rightward or leftward, respectively.
- GZ = g_z , gravity felt by the fluid in the z or y direction, which may be + or - to pull upward or downward, respectively.

The quantities ASQ, RØN, and GM1 are applicable to the stiffened gas equation of state, which appears in the code version of this report.

- ASQ = a^2 , the zero-temperature sound speed.
- RØN = ρ_o , normal material density,
- GM1 = $(\gamma-1)$, where γ is a constant characteristic of the gas, becoming the ratio of specific heat at constant pressure to the specific heat at constant volume, $\gamma = c_p/c_v$, if the gas is truly polytropic.

Card No. 4: FREZ, YB, REZY0, REZUE, REZVT, REZRON, REZSIE (Format 8F8.3), where:

FREZ, YB, and REZY0 are parameters relating to the zoning and grid location in the initial grid generation. Refer to Sec. III A.

REZUE } Available for use in REZONE to specify
 REZVE } grid expansion (u_e, v_e) and translation
 REZVT } (v_T) velocities, if these velocities
 are constant.

REZRON = the ρ_o of the ambient atmosphere at altitude REZY0 at $t = t_o$.

REZSIE = the specific internal energy of the ambient atmosphere. In the code listing in this report, REZSIE is a value that remains constant in space and time.

Card No. 5: IBP, JBP, PDR, PDZ, PYB, GZP, IMØMX (Format 2I4, 4F8.3, I4). This card supplies the parameters for the optional particles described in Sec. II E.

- IBP = $\bar{I}_{\text{particles}}$ } If no particles are to be
 used, set IBP = 0. Then
 the rest of Card No. 5 is
 JBP = $\bar{J}_{\text{particles}}$ } unused, so proceed to
 Card No. 6. For particle

usage, IBP and JBP are the $\bar{I}$ and $\bar{J}$ of the particle overlay grid. $IBP \leq 1BAR$, and $JBP \leq 1BAR$.

- PDR = Δx } the (uniform) Δx and Δy of the
 particle-grid cells. See Fig. 11.
 PDZ = Δy } In variable-zoned meshes, these
 values are calculated automatically
 in the setup. Similarly, PDR and
 PDZ are recalculated by REZONE. In
 both places, the code version pre-
 sented here "stretches" the parti-
 cle grid to just cover the farthest
 points on the bottom, top, and
 right edges of the YAQUI grid.

PYB = YB_{particles}, the displacement of the particle-grid lower edge measured relative to YB. To superimpose exactly, set PYB = 0.0 and allow the code to adjust the particle grid automatically, as described above.

GZP = g_z felt by the particles, which may or may not be equal to GZ (see Card No. 3).

IMØMX = 1.0 for the momentum-exchange option, = 0.0 otherwise.

Card No. 6: T, DT, T2OMD, TLIMD, TWFIN, LPR, ICØLØR (Format 5F8.3, 2I4), where:

T = t_o , the problem starting time, usually zero.

DT = δt_o , the initial δt . The first cycle is automatically run with $\delta t = \delta t_o/10$, then the second and third cycles are run with $\delta t = \delta t_o$. From cycle 4 on, the δt is chosen automatically as described in Sec. II F.

T2OMD = 1.0 to force tape dumps every 20 min of central processor (CP) time for restarting purposes, or = 0.0 to bypass this option.

TLIMD = 1.0 to force a tape dump and RETURN to the (0,0) overlay just before reaching the CP time limit specified on the JØB card; > 1.0 to force tape dump and RETURN immediately after cycle 0 output; = 0.0 to run out to a full time limit with no tape dump.

TWFIN = problem finish time. When this is reached ($t > TWFIN$), control will RETURN to the (0,0) overlay.

(Upon RETURN to (0,0) for either the TLIMD or TWFIN condition, the (0,0) main program YAQUI searches the input queue for further tasks.)

LPR = Printing Control, where:
 0 = movie option, 1 = zone prints on microfilm only, 2 = zone prints on both film and printer, 3 = zone prints on printer only. These are described more fully in Sec. III D.

ICOLOR > 0 plots particles in red, and anything else on film in white, obviously effective only with color processing. ICOLOR ≤ 0 implies normal black-and-white processing.

Card No. 7: (DTØ(N), N=1,10) is used in conjunction with

Card No. 8: (DTØC(N), N=1,10) (both are Format 10F8.3), where DTØ_n specifies the problem-time output interval for both plots and prints. DTØC_n specifies the time at which to change to DTØ_{n+1}. As an example, assume that t is in seconds, and that output is wanted every 1/4 sec for the first second, then every 1/2 sec up to 4 sec of problem time, then every 1 sec until t = 10, then every 2 sec until t = 50, and every 10 sec until t = 200. One would use DTØ (1-10) = 0.25, 0.5, 1.0, 2.0, 10.0, DTØC (1-10) = 1.0, 4.0, 10.0, 50.0, 200.0.

To keep the output time interval fixed throughout a run, specify DTØ (1) = (interval) and DTØC (1) > TWFIN. (Note: When an output time is being approached, the automatic δt routine will choose a special δt for one cycle so that the output occurs at the precise time desired).

The above eight cards pertain to all YAQUI setups. They have defined a basic grid and provided the parameters for its use. What remains to be defined is the contents of this grid -- particle regions and fluid regions. Because these regions vary with the problem geometry, the number of cards

in the rest of the input deck varies widely. The procedure beyond Card No. 8 is to define the particle regions first, if any exist, then finally to define fluid regions.

Card No. 9: DRPAR, DZPAR, XC, YC, XD, YD, UPAR, VPAR, MTE, DRAG (Format 10F8.3).

This is a particle-region card, to be expected only if IBP > 0 on Card No.

5. One card of the above format must be provided for each discrete particle region in the mesh. In the present version of PARTGEN, a particle region may be one of two shapes -- cylindrical or spherical (rectangular or circular in plane geometry). These two general shapes are shown in Fig. 14 with the named dimensions that specify them. The four dimensions (XC, YC, XD, and YD) are input in true distance units because the particle regions are not constrained to follow zone edges. For a cylinder, XC and YC specify the coordinates of the lower left corner, and XD and YD specify those of the upper right corner. For a sphere, YD must always be identically zero to enable PARTGEN to distinguish it from a cylinder. YC specifies the position of the center, measured up the axis, and XD specifies the sphere radius. Note that the y dimensions are defined relative to y = 0, not relative to the bottom of the mesh. (This was allowed so that particles might originally be placed outside an expanding mesh, but the user should not try to move any particle while it is still outside the mesh, as the present logic in PARTMOV assumes that all particles lie within the mesh.)

DRPAR	}	Particle spacing in the r or x and z
DZPAR		or y directions, in problem units.
XC	}	Particle-region dimensions in problem units, relative to x = 0 and y = 0. See Fig. 14.
YC		
XD		
YD

CYLINDER (OR RECTANGLE)

SPHERE (OR CIRCLE)

Fig. 14. Particle-region shapes available in PARTGEN. Note that the named dimensions are measured from $x = 0$ and $y = 0$.

UPAR } Initial u and v velocity components for
VPAR } the particles in this region; will be
0.0 for true marker particles.
MTE Mass per particle = $MTE \cdot r_{\text{particle}}$. Use
 $MTE = 0.0$ for markers.
DRAG Drag coefficient, η , for these parti-
cles. Use $DRAG = 10^{10}$ for markers.

Particle-region cards are processed individually, and the number of particle regions is unlimited. If particles are used at all, the set of particle-region cards terminates with the final card having $DRPAR \leq 0.0$ and the rest of the card is unused. Therefore, the number of particle-region cards in a YAQUI deck is either zero, or two or more.

Card No. 9: if no particles are used. If particles are used, however, then this card follows the $DRPAR = 0.0$ card: NB, NR, NT, NL, UI, VI, R01, SIEI (Format 4I4, 4F8.3). This is a fluid-region card, one card of this format being provided for each discrete fluid region in the mesh. The allowed fluid region covers some specified number of zones, as shown in Fig. 15 with the named dimensions that define it. The four dimensions (NB, NR, NT, NL) are given in integer numbers of cells to emphasize that the four corners of the region must coincide with cell vertices. Thus, NL and NB specify how many cells in from the left and up to the vertex

Fig. 15. The basic fluid region available in MESHMKR, defined by the number of zones over and up to two corners.

where the lower left corner of the region is located, and NR and NT similarly locate the vertex of the upper right corner. Even if the grid is not originally orthogonal, specifying two diagonal corners uniquely specifies the zones that will be included in the region. To use a single fluid region as an entire ambient background, set $NL = NB = 0$, $NR = \bar{I}$, and $NT = \bar{J}$.

NB }
NR } numbers of zones (integers only). Refer
NT } to Fig. 15.
NL }
UI = u_I } the initial velocity components to
VI = v_I } be assigned to all vertices in the
fluid region.

$R\emptyset I = \rho_I$ } the initial density and specific
 $SIEI = SIE_I$ } internal energy to be assigned
 to all zones in the fluid region.

Fluid-region cards, like particle-region cards, are processed individually, and the number of fluid regions is also unlimited. The version of MESHMKR presented in the code listing in this report expects that at least one fluid region will be defined by this type of card. The set of fluid-region cards terminates with the final card having $NR = 0$ and the rest of the card unused. Therefore, a minimum of two fluid-region cards must be present in a YAQUI deck.

To set up an atmospheric-explosion calculation, as described in Sec. III A, the final NR card (following the ambient fluid NR card) has $NR = 1000$, instead of $NR = 0$, with $NT =$ the j index of the burst point in the full YAQUI grid. Generally, $NT = JCEN+2$, where $JCEN$ was defined on Card No. 1. The set of special data cards follows the $NR = 1000$ card, and contains $I, JJ, R\emptyset I, SIEI, VI,$ and UI (format 2I5, 4(4X,E11.5)), one card per Eulerian zone. The j index is called JJ here to emphasize that it is relative to the definition $j = 1$ at the burst point on the data cards. VI is the v velocity centered on the top edge of the Eulerian zone, and UI is the u velocity centered along the right edge. These cards are read and processed individually, the set terminating with a card having $I = 0$.

This completes the discussion of the input data cards. The final card normally placed at the end of the input deck is in reality the first card for the next problem. The first quantity on Card No. 1 is $IBAR$, and its value determines the action to be taken by YAQUI. If $IBAR > 0$, it is valid for use as $\bar{I}$, and $YASET$ is called. The value $IBAR = 0$ indicates a tape restart, and $IBAR < 0$ indicates that the end of data has been reached. Thus a negative $IBAR$ card is the appropriate way to terminate a deck, and hence, the run.

D. Output--Plots, Prints, and Motion Pictures

The YAQUI output is in the usual two forms--visual information on microfilm or motion-picture film, and printed information on microfilm or fan-fold paper. Both forms are automatically provided at cycles 0 and 1, and thereafter at intervals specified by $DT\emptyset$ and $DT\emptyset C$ in the input data. The microfilm plots are generally the most useful

output, and they are made on the III FR-80 or the S-C 4020 CQM (computer output microfilm) devices. Six plots are provided in the basic code version: particles, zones, velocity vectors and contours of density (isopycnics), internal energy (isotherms) and vorticity.

The particle plots are made by plotting the x_p and y_p coordinates of all particles, and are provided automatically when particles are used.

The zone plot is included for all Lagrangian or REZONE runs ($GRDVEL \geq 1.$). For purely Eulerian calculations ($GRDVEL = 0.$), the zone plot is provided only at cycle 0. The labels of minimum and maximum δr and δz on the zone plot are really unambiguous only for orthogonal grids. The general form used in their calculation was intended to make the labels meaningful for slightly distorted grids.

The velocity-vector plot shows the direction of fluid flow and the relative magnitude of the velocities. Vectors are plotted originating at each vertex, denoted by a "+," and have a length and direction proportional to the vertex velocity components. If (x_1, y_1) are the coordinates of vertex (i, j) , the coordinates of the vector end point (x_2, y_2) are given by

$$x_2 = x_1 + (u_1^j) (DR\emptyset U) ,$$

and

$$y_2 = y_1 + (v_1^j) (DR\emptyset U) ,$$

where $DR\emptyset U$ is a scaling coefficient defined as

$$DR\emptyset U = (0.9) (VEL_{\max}) \left(\frac{x_{i=IP1}}{\bar{I}} \right) .$$

This coefficient is recalculated whenever a velocity-vector plot is drawn, and it scales the length of a vector drawn for the largest u or v velocity in the system at that instant ($VEL_{\max}$) to be 9/10ths the length of the average zone $(x_{i=IP1}/\bar{I})$. This method ensures that the vectors are always of reasonable length, regardless of velocity magnitude. The plot is deleted if there are no significant velocities in the entire system.

The contour plots are drawn by a routine that creates plots for any cell-centered quantity stored in CQ , and they are composed of connected vector

segments joining points of equal quantity, just as the lines on a contour map join points of equal altitude. The plots may be either linear or logarithmic in contour increment. Logarithmic plots are more useful for atmospheric studies and are provided for the isopycnics and isotherms, whereas the vorticity plot is linear.

The printed information consists primarily of a listing of the principal field variables over the entire grid. One line is printed for each zone, giving the 12 quantities $i, j, x_1^j, y_1^j, u_1^j, v_1^j, I_1^j, \rho_1^j, v_1^j, D_1^j, M_{v1}^j$, and p_1^j for the zone or its lower left vertex.

A two-line short print is provided every cycle, and it contains the following 13 quantities:

T is the current problem time.

CYC is the current cycle number.

DT is the current δt .

GRINDS = $\delta CP / (\bar{I} * \bar{J})$, the elapsed central processor (CP) time for the cycle just finished, divided by the total number of zones. The CP time per cell per cycle is a useful indicator of the code's computing efficiency.

CIRC, or circulation, is a measure of fluid velocities near the rigid mesh boundaries, intended primarily for atmospheric calculations. Interaction of signals with the outer boundaries often shows up as a significant change in the value of CIRC.

ITERS is the number of iterations in the preceding Phase 2.

CPTIME is the current CP clock time.

DTV is the competing δt_v calculated during the previous cycle, in which

IDTV and JDTV are the i and j indices of the zone that limits δt_v most severely.

DTC is the competing δt_c , and, similarly,

IDTC and JDTC are the i and j indices of the zone that limits δt_c most severely.

For either δt_v or δt_c , if the printout indicates that the limiting zone is zone (1,2), the tentative next time step, $\delta t_v = \delta t_c = (\delta t) (\delta t_{fac})$, is small enough to satisfy the stability and accuracy requirements at every point in the mesh.

The short print is provided on fanfold paper regardless of the LPR setting, and on microfilm if $LPR = 1$ or $LPR = 2$. LPR primarily controls the destination of the full zone prints, where:

$LPR = 1$ gives zone prints on microfilm only,

$LPR = 2$ gives zone prints on film and paper,

$LPR = 3$ gives zone prints on paper only.

If $LPR = 0$, no information is printed on microfilm. This case is intended for motion picture use, and the only microfilm output is a particle plot. For movies, the user should hold the δt constant, and set $DT0 = \delta t$ or $2\delta t$. The code is easily altered to provide some plot other than a particle plot for the movie if desired, or to have a frame shared by several different types of plots.

E. Tape Dump and Restart

Tape dumps are staged out as Fileset 8 in the control region under influence of the quantities T2OMD and/or TLIND, as described in Sec. III C. The quantities dumped are the contents of the SCM common YSC2, the LCM block YLC1, and, if particles are used, the LCM block YLC2.

A tape restart is performed by staging in the dump tape as Fileset 7. The input deck consists of an IBAR = 0 data card, where JBAR = the dump number on the tape and is used as a check.

F. Incompressible Flow Calculations

Conceptually, the YAQUI code in this report should be able to calculate a truly incompressible flow, defined as a flow in which the sound speed is vastly greater than the fluid speed. Practically, however, the code should be slightly modified to render it suitable for handling such calculations. The equations we use are intended for flows containing compressibility effects, and they, indeed, differ from those we would choose for a fully incompressible flow technique.

In incompressible flow, variations in I can be neglected unless buoyancy effects are important, and as ρ is essentially a constant for each fluid element, the mass equation reduces to the requirement for vanishing velocity divergence. Using an equation of state is therefore unnecessary, because the changes in pressure arise as a direct consequence of the dynamics. In YAQUI, however, the equation of state is inherent: Phase 2 assumes it through the appearance of c^2 , and the equation of state is used directly to update p_L into the new p_L^{n+1} , to account for ρ changes that occurred in the Phase-3 convection. Nevertheless, the implicit treatment¹ should still enable YAQUI to handle incompressible flows. In practice, we see this to be true for Mach numbers

down to about 0.01. For lower Mach numbers, however, there are three features in YAQUI that introduce difficulties. The first difficulty occurs in the (Lagrangian) iterative phase, where we compute ρ_L from an equation that leaves δt^2 errors. The second arises in the convective flux calculation, which is treated explicitly in Phase 3. This introduces nonzero values into the velocity divergence and, consequently, allows the densities to change. The third arises in the internal energy calculation, in which the nonvanishing values of $\nabla \cdot \vec{u}$ introduce fluctuations into the internal energy field. When the overall level of internal energy is high, these fluctuations are reflected in large variations of $n^{+1}p$, which cannot be efficiently corrected in the subsequent pressure iteration. As a solution to the problem, we have bypassed the equation-of-state calculation after cycle 0, and instead used $n^{+1}p = p_L$ in incompressible flows. Yet another choice would be to iterate Phase 2 to much greater accuracy, which would not be very economical, especially in view of the vastly increased computer time requirements. We cannot run with the limit of $\epsilon = 0$ in Phase 2, but rather use a value more on the order of, say, 10^{-5} , which leaves relative errors of that order in p_L .

These considerations can be illustrated with the stiffened gas equation of state, appearing in the code version of this report. For this, n_p is given by

$$n_p = a^2 (n_\rho - \rho_o) + (\gamma - 1) n_\rho n_I .$$

The incompressible limit can be described by $a^2 \rightarrow \infty$ forcing the $(\gamma - 1)\rho I$ part of the equation to be negligible, or by $I \rightarrow \infty$. Because true ∞ cannot be used on the computer, we might choose, say, $a^2 = 10^{10}$. Even this less-than-infinite a^2 is large enough to magnify any slight ρ errors into appreciable variations in the p field.

To implement the $n^{+1}p = p_L$ logic in YAQUI, the storage requirements must be considered. Examination of Fig. 9 reveals that p_L , in storage word 11, is not saved in Phase 3. The simplest way to preserve p_L throughout the cycle is to create a 15th word of storage and store p_L in it after Phase 2. Then, at the beginning of the next cycle, $n^{+1}p$ can be set from it quite easily. Note that then one must set $NQ = 15$.

The standard Phase-2 treatment is to bypass the updating of the vertices of any cell whose δp satisfies the convergence test, the argument being that the slightly improved accuracy is generally not worth the extra computer time required to obtain it. When using $n^{+1}p = p_L$, however, it becomes more appropriate to update the vertices of all cells, whether or not the convergence test was satisfied.

G. The COMMON Block YSC2

The following list provides the names, descriptions, and sources of all quantities in the SCM COMMON YSC2 in the (0,0) overlay. This COMMON is of fundamental importance in communication between the various overlays and their subroutines. It contains all the SCM-based information that must be maintained from cycle to cycle, and it is the SCM portion of the tape-dump data.

The sources in the list are keyed to the following symbols:

- I = Supplied as part of the standard input data. The parenthetical symbol that follows I specifies where this quantity is read.
- O = (0,0) Main Overlay
- L = (0,0) Subroutine LOOP
- F = (0,0) Subroutine FILMC0
- S = (1,0) Subroutine YASET1
- P = (1,0) Subroutine PARTGEN
- 2 = (2,0) Subroutine YAQUI2
- R = (2,0) Subroutine REZONE

Multiple sources indicate that the quantity is recalculated.

NAME	DESCRIPTION	SOURCE
AA	Dummy word, always the first word in the COMMON.	--
ANC	a_{NC} , alternate node-coupler coefficient.	S
ASQ	a^2 , the zero-temperature sound speed for the stiffened gas equation of state.	I(S)
AO	α_o , determines Phase-3 momentum differencing form.	I(O)
AOFAC	$\alpha_{oM} \left[2(1 + \alpha_{oM}^2) \right]$, used in calculating δt_c .	S
ACM	α_{oM} , the α_o used in Phase-3 M and E calculation.	I(O)
BO	β_o , determines Phase-3 differencing form, used with α_o and α_{oM} .	I(O)
CØLAMU	$(1 + \epsilon)/(\lambda + 2\mu)$, used in Phase-1 viscosity-coefficient calculation.	S
CYL	= 1. if cylindrical coordinates, = 0. if plane coordinates.	I(O)
DR	δr , the cell size in the radial direction if uniformly zoned.	I(O)
DT	δt , the time step, subject to automatic recalculation.	I(S),2
DTC	δt_c , competing δt based on Phase-3 convective flux and divergence considerations.	2
DTFAC	Initial δt_v and δt_c each cycle are given by $\delta t_v = \delta t_c = (\delta t) (\delta t_{fac})$.	2
DTGR	$\delta t * g_r$.	2
DTGZ	$\delta t * g_z$.	2
DTGZP	$\delta t * g_{zp}$.	2
DTØ	Problem time interval between outputs (plots and prints).	I(S)
DTØC	Problem time at which to change to next DTØ in the set.	I(S)
DTØ16	$\delta t/16$.	2
DTØ2	$\delta t/2$.	2
DTØ4	$\delta t/4$.	2
DTØ8	$\delta t/8$.	2
DTPØS	δt possible for the cycle, but actual δt may be reduced to adjust to output time.	2
DTV	δt_v , competing δt based on Phase-1 viscous-stress considerations.	2
DT8	$\delta t * 8$.	2
DZ	δz , the cell size in the axial direction if uniformly zoned.	I(O)
EM10	10^{-10} , epsilon added to terms to ensure that they do not vanish.	S
EPS	ϵ , convergence criterion for the Phase-2 iteration.	I(S)
FIBP	Floating-point equivalent of $\bar{I}_p$.	P
FIPXL	Floating-point frame coordinate for left edge of particle plot.	F
FIPXR	Floating-point frame coordinate for right edge of particle plot.	F
FIPYB	Floating-point frame coordinate for bottom edge of particle plot.	F
FIPYT	Floating-point frame coordinate for top edge of particle plot.	F
FIXL	Floating-point frame coordinate for left edge of regular plots.	F
FIXR	Floating-point frame coordinate for right edge of regular plots.	F
FIYB	Floating-point frame coordinate for bottom edge of regular plots.	F
FIYT	Floating-point frame coordinate for top edge of regular plots.	F
FJBP	Floating-point equivalent of $\bar{J}_p$.	P
FREZ	Expansion coefficient for zoning; = 1.0 if uniform throughout.	I(S)
GGM1	$\gamma(\gamma-1)$, in which γ is the equation-of-state specific heat ratio if the gas is truly polytropic.	S
GM1	$(\gamma-1)$.	I(S)
GR	g_r , gravity component in the r direction, $\pm$.	I(S)
GRDVEL	= 0. if pure Eulerian, = 1. if Lagrangian, = 2. if REZONE.	I(O)
GZ	g_z , gravity component in the z direction, $\pm$.	I(S)
GZP	g_{zp} , g_z felt by the particles. May be equal to GZ.	I(S)

NAME	DESCRIPTION	SOURCE
I	Index i. In COMMON because of ENTRY SETIJ in LOOP.	--
IBAR	$\bar{I}$, the number of interior fluid zones in the r direction.	I(0)
IBP	$\bar{I}_p$, the number of particle-grid zones in the r direction.	I(S)
IBP1	$\bar{I}_p+1$, index of rightmost column of particle-grid vertices.	P
ICOLOR	= 1 for color movie, = 0 for black and white processing.	I(S)
IDT0	Index for DT0 and DT0C tables.	S,2
IJ	Index for cell (i,j), initialized by LOOP.	L
IJM	Index for cell (i,j-1), initialized by LOOP.	L
IJP	Index for cell (i,j+1), initialized by LOOP.	L
IJPS	Index for cell (i,j+1), saved for later reference to cell (1,j+1).	L
IMOMX3	IMOMX*1000, forces resetting of J in statement No. 2020 in PARTMOV if IMOMX = 1.	P
IMOMX	= 1 if particle-fluid momentum exchange, = 0 otherwise.	I(S)
IM1	$\bar{I}-1$, index of next-to-last zone or vertex in column.	S
IM6	$\bar{I}-6$, in usual large grids, this column is in somewhat from the right.	S
IPAR	LCF(AA2), the address of LCM block AA2, for tape dump.	P
IPXL	Integer frame coordinate for left edge of particle plot.	F
IPXR	Integer frame coordinate for right edge of particle plot.	F
IPYB	Integer frame coordinate for bottom edge of particle plot.	F
IPYT	Integer frame coordinate for top edge of particle plot.	F
IP1	$\bar{I}+1$, index of rightmost column of grid vertices.	S
IP2	$\bar{I}+2$, index used in reversed D0 loops.	S
ISCF1	ISC2-NQI, the relative first word address (f.w.a.) of $i = \bar{I} + 1$ zone in SCM buffer row 1/3.	S
ISCF2	ISCF1 + NQI, the relative f.w.a. of $i = \bar{I} + 1$ zone in SCM buffer row 2/3.	S
ISC2	NQI+1, the relative f.w.a. of $i = 1$ zone in SCM buffer row 2/3.	S
ISC3	ISC2+NQI, the relative f.w.a. of $i = 1$ zone in SCM buffer row 3/3.	S
ITV	JP1*NQI, the relative f.w.a. of the $\bar{J} + 2$ row in LCM storage.	S
IUNF	L_{UNF} , the number of zones with uniform initial δr (DR).	I(0)
IXL	Integer frame coordinate for left edge of regular plots.	F
IXR	Integer frame coordinate for right edge of regular plots.	F
IYB	Integer frame coordinate for bottom edge of regular plots.	F
IYT	Integer frame coordinate for top edge of regular plots.	F
J	Index j. In COMMON because of ENTRY RIR0W and WIR0W in LOOP.	--
JBAR	$\bar{J}$, the number of interior fluid zones in the z direction.	I(0)
JBP	$\bar{J}_p$, the number of particle-grid zones in the z direction.	I(S)
JBP2	$\bar{J}_p+2$, index of the topmost row of particle-grid vertices.	P
JCEN	Number of zones up to center of uniform-grid region.	I(0)
JM10	$\bar{J}-10$. In usual large grids, this row is down from the top.	S
JM14	$\bar{J}-14$. In usual large grids, this row is down from the top.	S
JP1	$\bar{J}+1$, index of topmost row of interior zones.	S
JP2	$\bar{J}+2$, index of topmost row of grid vertices.	S
JP4	$\bar{J}+4$, index used in reversed D0 loops and in LCM clearing.	S
JP402	$(\bar{J}+4)/2$, j index at midpoint of full YAQUI grid.	S
JUNF	J_{UNF} , the number of zones with uniform initial δz (DZ).	I(0)
JUNF02	$J_{UNF}/2$ uniform zones lie above JCEN, and $J_{UNF}/2$ lie below.	S
KXI	ξ , the ρ exponent that determines the viscosity form.	I(0)
LAM	λ_{input} viscosity coefficient. A real number.	I(S)

NAME	DESCRIPTION	SOURCE
LJP2	First word address of last zone in row JP2 when in usual SCM buffer row.	S
LPB	Number of words, truncated to a multiple of 3, that will fit in NQI-wd. SCM row.	P
LPR	Determines output options of film and printer.	I(S)
MU	μ_{input} viscosity coefficient. A real number.	I(S)
NAME	The problem identification from input card No. 2, up to 79 characters.	I(S)
NCYC	Number of calculational cycles completed.	S,2
NLC	Number of words of LCM block AA1 actually in use, for tape dump.	S
NPS	Number of words of LCM particle block AA2 actually in use, for tape dump.	P
NPT	Total number of particles generated.	P
NQ	Number of quantities, or storage words, per cell.	0
NQI	$NQ*IP1$, the number of words for a full row of zones.	S
NQIB	$NQ*IBAR$, the number of words back to zone $i = 1$ when at $i = \bar{I} + 1$ in SCM.	S
NQI2	$NQI*2$, the number of words in two full rows of zones, for PARTMØV.	P
NSC	Number of words in this SCM CØMMØN, for tape dump.	S,2
NUMIT	Number of iterations required for Phase-2 convergence.	2
NUMID	Number of the next tape dump.	S,2
ØM	ω , the Phase-2 iteration relaxation parameter.	I(S)
ØMANC	$(1-a_{NC})$, used in δt_v calculation.	S
ØMCYL	$(1-CYL)$, used in calculating r from x.	S
ØMEM10	$(1-10^{-10})$.	S
ØPEM10	$(1+10^{-10})$.	S
PDR	The uniform Δx of the particle grid.	S,P,R
PDZ	The uniform Δy of the particle grid.	S,P,R
PXCØNV	Frame-conversion coefficient for particle-plot x direction.	F
PXL	X coordinate of left edge of particle grid, in problem units.	F
PXR	X coordinate of right edge of particle grid, in problem units.	F
PXRP	$PXR*\ØPEM10$, test comparand in particle-grid mapping.	F
PYB	Y coordinate of bottom edge of particle grid, in problem units.	S,F,R
PYBM	$PYB*\ØMEM10$, test comparand in particle-grid mapping.	F
PYCØNV	Frame-conversion coefficient for particle-plot y direction.	F
PYT	Y coordinate of top edge of particle grid, in problem units.	F
PYTP	$PYT*\ØPEM10$, test comparand in particle-grid mapping.	F
RDT	$1/\delta t$.	2
REZRØN	ρ_o of the ambient atmosphere at altitude REZY0 at $t = t_o$.	I(S)
REZSIE	The (constant) specific internal energy of the ambient atmosphere.	I(S)
REZUE	Grid-expansion u velocity, available for REZØNE use.	I(S),R
REZVE	Grid-expansion v velocity, available for REZØNE use.	I(S),R
REZVT	Grid-translation velocity, available for REZØNE use.	I(S),R
REZY0	Y coordinate of center of expansion, refers to YAQUI vertex (1,JCEN+2).	I(S)
RIBAR	Reciprocal of $\bar{I}$.	S
RIBJB	Reciprocal of $\bar{I}*\bar{J}$, used in control region grind calculation.	S
RIBP	Reciprocal of $\bar{I}_p$.	P
RJBP	Reciprocal of $\bar{J}_p$.	P
RØMFR	Reciprocal of $(1.-FREZ)$.	S
RØN	ρ_o , normal density for equation-of-state use.	I(S)
RPDR	Reciprocal of Δx .	F
RPDRDZ	Reciprocal of $(\Delta x*\Delta y)$.	F

<u>NAME</u>	<u>DESCRIPTION</u>	<u>SOURCE</u>
RPDZ	Reciprocal of Δy .	F
T	t, the problem time.	I(S),2
THIRD	1./3.	S
TLIMD	= 1.0 to force a tape dump & RETURN before time limit.	I(S)
TOUT	The next output time for plots/prints.	S,2
TWFIN	Time-When-to-Finish: calculation completed when $t > TWFIN$.	I(S)
T2OMD	= 1.0 to force tape dumps every 20' CP time.	I(S)
VV	Velocity-vector plot-scaling coefficient, = 9/10 average δr .	F
XCØNV	Frame-conversion coefficient for regular plots, x direction.	F
XL	X coordinate of leftmost vertex of the grid, in problem units.	F
XR	X coordinate of rightmost vertex of the grid, in problem units.	F
YB	Y coordinate of bottommost vertex of the grid, in problem units.	F
YCØNV	Frame-conversion coefficient for regular plots, y direction.	F
YT	Y coordinate of topmost vertex of the grid, in problem units.	F
ZZ	Dummy word, always the final word in the CØMMØN.	--

IV. SOME CALCULATIONAL EXAMPLES

Here we present results from several YAQUI calculations. Emphasis is on the method's versatility in handling a given problem, rather than on presenting a wide variety of different examples.²

The flexibility of the Arbitrary Lagrangian-Eulerian approach is illustrated in the calculation of a one-dimensional shock tube, performed first in a Lagrangian fashion, and then with a full Eulerian rezone. This example is followed by sequences at very early times from three calculations of a low-altitude explosion, first Lagrangian, next Eulerian, then with the REZONE subroutine as presented in this report.

The versatility of the YAQUI particle technique is illustrated at one extreme by the marker particles carried along with the fluid in the low-altitude explosion calculations, where the particles have no influence on the flow, and at the other extreme by calculations in which the particles govern the fluid dynamics through the momentum-exchange feature.

Finally, we present listed results from a particle-fluid momentum-exchange calculation, for those readers who may find a benchmark calculation useful.

Detailed discussions of various YAQUI calculations will be presented elsewhere, and no attempt is made here to describe a variety of late-time results.

A. One-Dimensional Shock Tube

The two examples in Figs. 16 and 17 were selected from a series of one-dimensional shock-tube test cases; although they do not necessarily represent the best that YAQUI can do for this problem, they clearly demonstrate that satisfactory results can be obtained in both the Lagrangian and Eulerian limits. The figures show the profiles (heavy lines) of velocity, pressure, specific internal energy, and density from a pure Lagrangian (GRDVEL = 1.0) calculation and then a pure Eulerian (GRDVEL = 0.0) calculation of a 2:1 density-ratio shock tube, along with the theoretical solution (lighter lines) to the problem.³

The calculations were performed in a plane mesh 60 cells long by 1 cell high, allowing 30 cells for each fluid region. The initial ρ was 0.2 on the left and 0.1 on the right, and the initial specific internal energy was 0.18. The initial cell size was $\delta r = \delta z = 1/3$, the viscosity coefficients were $\lambda = 0.002$ and $\mu = 0.0$, and, in addition, the gas was polytropic with $\gamma = 5/3$. The Eulerian shock tube was run with full donor-cell differencing ($\alpha_o = \alpha_{oM} = 1.0$, $\beta_o = 0.0$). At $t = 0$, the diaphragm separating the two fluid regions was instantaneously removed, causing a shock to advance into the lower density region, and a rarefaction to propagate back from the contact surface into the higher density region. In both calculations, δt was held constant at 0.1, and the profiles shown in Figs. 16 and 17 are at $t = 10.0$. Such calculations typically require

Fig. 16. One-dimensional YAQUI Lagrangian calculation of a 2:1-density-ratio shock tube.

20 to 30 sec of CDC-7600 time to run to $t = 15.0$, producing plots and prints every unit of time.

B. A Low-Altitude Explosion

These examples demonstrate three distinct approaches to the treatment of grid motion in a typical low-altitude explosion calculation. The sets of six plots in each of Figs. 18, 19, 21, 23, and 24 represent the marker particles, computing mesh, and velocity vectors (top) and isopycnic, isotherm, and vorticity contour plots (bottom).

Figure 18 shows the various plots at time $t = 0$, immediately after superposing the explosion density, energy, and velocity data, which were provided by a one-dimensional spherical code, onto a

Fig. 17. One-dimensional YAQUI Eulerian calculation of a 2:1-density-ratio shock tube.

uniform 26 by 52 cell YAQUI computing grid that already contained an appropriate ambient background. This procedure was described in Sec. III A. In the particle plot, the explosion debris is represented by a hemisphere of particles, surrounded by more widely spaced particles in an adjacent region of the ambient atmosphere. These marker particles do not enter directly into the calculation, but are used solely as an aid to flow visualization. Note that the velocity, density, and energy fields are well developed, but that the vorticity field is not, and indeed, will not be well established for about the first two seconds of problem time.

Fig. 18. YACU low-altitude explosion calculation at $t = 0$. The six plots represent the marker particles, computing mesh, and velocity vectors (top) and isopycnic, isotherm, and vorticity contour plots (bottom).

Figure 19 shows the same six plots at $t = 1$ sec from a calculation of this problem in which the interior vertices were allowed to move in a purely Lagrangian fashion ($GRDVEL = 1.0$). The rigid walls of the computing mesh are held fixed, causing the strong radially expanding shock to reflect back into the central region shortly after $t = 2$ sec. This effect is visible in Fig. 20, which shows the appearance of the velocity vectors at $t = 2$ and $t = 3$ sec.

Figure 21 shows the six basic plots from a pure Eulerian calculation ($GRDVEL = 0.0$) of the same problem at $t = 1$ sec. More resolution is available in the central region, and less resolution is given to the shock front, than in the Lagrangian calculation. As in the Lagrangian calculation, the walls are rigid, and the $t = 2$ and $t = 3$ sec velocity-vector plots of Fig. 22 show the same strong wall reflection as did Fig. 20.

In reality, the edges of an atmospheric region are not rigid walls, so to calculate such an atmospheric explosion beyond the first two or so seconds, with this degree of resolution, would require one of several possible alternatives:

- (1) A vastly larger computing mesh could be used, but this obviously is not economical in terms of computer storage and time requirements.
- (2) Continuitive outflow boundaries would allow the strong radially expanding shock to leave the system with a minimum of upstream disturbance, but the subsequent rise of the explosion debris sucks material up behind it in the central column, causing the bottom and right walls of the mesh to become inflow boundaries. Appropriate inflow conditions are difficult to define, suggesting again a larger computing mesh to avoid this difficulty.
- (3) A third choice, which we exploit in YAQUI, is to allow the entire mesh to expand at a rate that will keep the reflective boundaries out ahead of the radial shock while it has significant strength. At the same time, we vary the sizes of the interior zones to provide high resolution in the central region and much coarser resolution in the outlying regions, which still allows the use of the same number of cells.

Figures 23 and 24 show such a calculation, using the REZONE subroutine exactly as provided in the code version of this report. The problem input

is identical to the preceding cases except that $GRDVEL = 2.0$. As the problem proceeds, the mesh is continuously enlarged at a rate that depends upon the magnitude of the velocities approaching the boundaries. This expansion leaves a region without particles around the outer regions of the mesh, which is already evident by $t = 1$ sec (Fig. 23). By $t = 5$ sec (Fig. 24), the initial mesh radius has already increased by 50%, allowing the calculation to run to much later times without boundary interference than do either the Lagrangian or pure Eulerian approaches. Note in Fig. 24 that the velocities near the rigid walls are negligible, and that the vorticity field has become well established.

Because the computer is programmed to draw pictures of a fixed size, the frame scales of Figs. 23 and 24 differ and are further quite different from the scale in the preceding figures. (Information printed on the film below each plot provides the necessary specifications to properly interpret the plot.)

Figures 23 and 24 represent only the early stages of a calculation that has been made feasible through the use of continuous rezoning and mesh expansion. These techniques, combined with an appropriate mesh translation that follows the debris rise, allow the dynamics to be followed for several hundred seconds of problem time. A wide variety of REZONE subroutines have been used with success, each tailored to provide optimum results for a particular problem.

We generally enhance this approach by combining it with an initial grid containing variable cell sizes, as described in Sec. III A. Figure 25 shows a setup configuration for the same problem, in which the cells are expanded ($FREZ = 1.1$) beyond a uniformly zoned 16 by 32 cell central region. This affords high resolution where required, at the same time allowing the continuous rezoning and expansion to take place much more gradually, as in this particular case the initial mesh encompasses a much larger volume.

The CDC-7600 CP time per cell per cycle (grinds) averages approximately 0.50 msec at two iterations per cycle, increasing by about 0.03 to 0.04 msec for each additional iteration required for convergence in Phase 2. Calculations such as

Fig. 19. A Lagrangian calculation at $t = 1$ sec of the problem setup of Fig. 18.

Fig. 20. Velocity-vector plots at $t = 2$ and $t = 3$ sec of the problem shown in Fig. 19, showing shock reflection from the boundaries.

this, with 1500- to 1600-cell meshes, can be followed to over 200 sec of problem time in well under 1h of CDC-7600 time, with generous amounts of output along the way.

C. Particle-Fluid Momentum Exchange

An example of the particle-fluid momentum-exchange feature described in Sec. II E 2 is illustrated in the particle-drag problem of Fig. 26. The first set of three frames show the initial particles, velocity vectors, and the (Eulerian) computing grid with cylindrical symmetry and rigid free-slip boundaries. In this calculation, a sphere of particles, each of which has a finite mass and drag coefficient, is immersed in a fluid of uniform density and energy, representing a two-fluid configuration in which the density of the heavier spherical part is given by the sum of the background fluid and particle densities. Initially, there are no velocities in the system; the entire dynamics of the calculation result from a gravitational force upon the particles but not upon the fluid. This causes the sphere of particles to fall and deform, producing a pronounced circulation pattern within the fluid.

The evolution of this process is shown in the remaining seven sets of plots in Fig. 26, at times of 9, 12, 15, 18, 21, 24, and 27. Each set of three frames consists of a particle plot and the velocity vectors and vorticity contours for the fluid. Note that the effects of drag soon retard the leading edge of the sphere relative to the shielded trailing edge. The sphere is deformed into a cup, with a vortex ring around the rim. At time $t = 21$, the cup collides with the bottom wall of the mesh and is seen gradually settling into place thereafter. By time $t = 27$, only the rolled rim retains any definition, but it, too, will soon collapse into the rest of the particles. The circulation pattern will persist for some time, until viscous effects gradually damp it out.

D. Input Data and Results from a Sample Calculation

The following pages are abstracted from the microfilm output of a particle-fluid momentum-exchange test calculation. They are included as an aid to the reader who uses YAQUI, allowing him to set up the same problem and compare results.

The input data are listed in their entirety, and include all information necessary to specify the

Fig. 21. An Eulerian calculation at $t = 1$ sec of the problem setup of Fig. 18.

Fig. 22. Velocity-vector plots at $t = 2$ sec and $t = 3$ sec of the problem shown in Fig. 21, showing shock reflection from the boundaries.

problem. Subsequent pages show the initial particle and zone plot configurations at time 0, along with a sample frame abstracted from the cell print. This includes a row across the mesh halfway up, cutting through the initial position of the sphere of particles. This same frame of print output is included for cycle 1, to show the initial changes in the fluid variables.

For $t = 1.0$ (cycle 7), we present six frames. These include plots of the particles, and for the fluid, the velocity vectors and contours of density, specific internal energy, and vorticity, followed by the sample listing. The normal velocities on the symmetry axis are, of course, nonphysical. They result from the momentum carried by the particles and distributed to the cell vertices. After each cycle, these velocities are reset to zero, so no buildup can occur. This will, however, act as a

sink for momentum, which would be easy to correct if it became a problem.

Finally, we present the same six frames at $t = 9.0$ (cycle 232). Note in the listing that the circulation pattern is quite evident in the wake of the particles. The u velocities at this height on the axis are now zero, as the particles are no longer present here to contribute momentum changes.

The CDC-7600 CP time for this calculation was 305 sec for 265 calculational cycles (to time $t = 9.54181$). After the first 100 cycles, the number of iterations required for convergence in each cycle stabilized at 4, for which the grinds (CP time per cell per cycle) averaged about 0.637 msec. Comparison with the grinds for the low-altitude explosion calculation (0.56 msec) indicates that slightly more time is required for the momentum-exchange option.

Fig. 23. A REZONE calculation at $t = 1$ sec of the problem setup of Fig. 18.

Fig. 24. The RFZONE calculation of the problem of Figs. 18 and 23 at $t = 5$ sec.

Fig. 25. A YAQUI setup with initial variable zoning for the problem shown in Fig. 18.

V. REFERENCES

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2. C. W. Hirt and A. A. Amsden, "An Arbitrary Lagrangian-Eulerian Computing Method for All Flow Speeds," submitted to J. Comp. Phys.
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4. R. S. Hotchkiss and C. W. Hirt, "Particle Transport in Highly Distorted Three-Dimensional Flow Fields," Vol. II, Proceedings of the 1972 Summer Computer Simulation Conference, San Diego, California, June 14-16, 1972.
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Fig. 26. YAQUI particle-fluid momentum-exchange calculation.

Fig. 26 (Contd)

YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GS 032272-3)

110872-1

```

IBAR= 26
JBAR= 52
IUNF= 26
JUNF= 52
JCEN= 26
OR= 1.00000E+00
OZ= 1.00000E+00
CYL= 1.00000E+00
GROVEL= 0.
AO= 7.50000E-01
AOM= 7.50000E-01
BO= 0.
KXI= -1
MU= 1.00000E+00
LAM= 1.00000E+01
OM= 1.00000E+00
EPS= 1.00000E-04
GR= 0.
OZ= 0.
ASQ= 1.00000E+02
RON= 1.00000E+00
GHI= 0.
FREZ= 1.00000E+00
YB= 0.
REZY0= 0.
REZUE= 0.
REZVE= 0.
REZVT= 0.
REZRON= 0.
REZSIE= 0.
ISP= 26
JSP= 52
POR= 1.00000E+00
PDZ= 1.00000E+00
PYB= 0.
GZP= -1.00000E+00
IMOMX= 1
T= 0.
DT= 1.00000E-01
T2OMD= 0.
TLIMD= 0.
TMFIN= 1.00000E+01
LPR= 1
ICOLOR= 0
DTC(1-10)= 1.00000E+00 -0. -0. -0. -0.
-0. -0. -0. -0.
DTC(1-10)= 1.00000E+02 -0. -0. -0. -0.
-0. -0. -0. -0.
DRPAR= 5.00000E-01 DZPAR= 5.00000E-01 XC= 0. YC= 2.50000E+01 XD= 0.00000E+00
TD= 0. UPAR= 0. VPAR= 0. MTE= 2.50000E-01 DRAG= 1.00000E+00
406 PARTICLES GENERATED, WITH TOTAL MASS= 3.46375E+02
NB= 0 NR= 26 NT= 32 NL= 0 U1= 0. V1= 0. R01= 1.00000E+00 SIE1= 1.00000E+00

```

PARTICLES

PDR= 1.00000E+00 PDZ= 1.00000E+00 PXR= 2.60000E+01 PYB= 0. PYT= 5.20000E+01
T3AAA 1BA YAGUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 03272-3) 110872-1 T= 0.

CYCLE= 0

ZONES
DRMIN= 1.0000E+00 DRMAX= 1.0000E+00 DZMIN= 1.0000E+00 DZMAX= 1.0000E+00 XZ= 2.6000E+01 YB= 0.
T3AAA 1BA YAOUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA108 03272-3)
110872-1 T= 0.
YT= 5.2000E+01
CYCLE= 0

13AAA 1BA YAGUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (13AAA168 032272-3)									
I	J	X	Y	U	V	SIE	RHO	YOL	D
8	26	7.0000E+00	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	7.5000E+00	0.
9	26	8.0000E+00	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	8.5000E+00	0.
10	26	9.0000E+00	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	9.5000E+00	0.
11	26	1.0000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.0500E+01	0.
12	26	1.1000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.1500E+01	0.
13	26	1.2000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.2500E+01	0.
14	26	1.3000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.3500E+01	0.
15	26	1.4000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.4500E+01	0.
16	26	1.5000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.5500E+01	0.
17	26	1.6000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.6500E+01	0.
18	26	1.7000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.7500E+01	0.
19	26	1.8000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.8500E+01	0.
20	26	1.9000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.9500E+01	0.
21	26	2.0000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.0500E+01	0.
22	26	2.1000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.1500E+01	0.
23	26	2.2000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.2500E+01	0.
24	26	2.3000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.3500E+01	0.
25	26	2.4000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.4500E+01	0.
26	26	2.5000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.5500E+01	0.
27	26	2.6000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.6500E+01	0.
1	27	0.	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	5.0000E+01	0.
2	27	1.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.5000E+01	0.
3	27	2.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.5000E+01	0.
4	27	3.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	3.5000E+01	0.
5	27	4.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	4.5000E+01	0.
6	27	5.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	5.5000E+01	0.
7	27	6.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	6.5000E+01	0.
8	27	7.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	7.5000E+01	0.
9	27	8.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	8.5000E+01	0.
10	27	9.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	9.5000E+01	0.
11	27	1.0000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.0500E+01	0.
12	27	1.1000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.1500E+01	0.
13	27	1.2000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.2500E+01	0.
14	27	1.3000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.3500E+01	0.
15	27	1.4000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.4500E+01	0.
16	27	1.5000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.5500E+01	0.
17	27	1.6000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.6500E+01	0.
18	27	1.7000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.7500E+01	0.
19	27	1.8000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.8500E+01	0.
20	27	1.9000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.9500E+01	0.
21	27	2.0000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.0500E+01	0.
22	27	2.1000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.1500E+01	0.
23	27	2.2000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.2500E+01	0.
24	27	2.3000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.3500E+01	0.
25	27	2.4000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.4500E+01	0.
26	27	2.5000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.5500E+01	0.
27	27	2.6000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.6500E+01	0.
1	28	0.	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	5.0000E+01	0.
2	28	1.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.5000E+01	0.
3	28	2.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	2.5000E+01	0.
4	28	3.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	3.5000E+01	0.
5	28	4.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	4.5000E+01	0.
6	28	5.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	5.5000E+01	0.
7	28	6.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	6.5000E+01	0.
8	28	7.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	7.5000E+01	0.
9	28	8.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	8.5000E+01	0.
10	28	9.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	9.5000E+01	0.
11	28	1.0000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.0500E+01	0.
12	28	1.1000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.1500E+01	0.
13	28	1.2000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.2500E+01	0.
14	28	1.3000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.3500E+01	0.
15	28	1.4000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.4500E+01	0.

P

0

M

CYCLE=

T3AAA 1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 03272-3)										110872-1	T= 1.00000E-02 CYCLE=	I
I	J	X	Y	U	V	SIE	RHO	VOL	D	M	P	
0.	26	7.0000E+00	2.4000E+01	0.	-9.2157E-05	1.0000E+00	1.0000E+00	7.5000E+00	-1.2418E-05	7.0000E+00	0.	
9.	26	8.0000E+00	2.4000E+01	0.	-2.9200E-05	1.0000E+00	1.0000E+00	8.5000E+00	-8.9920E-06	8.0000E+00	0.	
10.	26	9.0000E+00	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	9.5000E+00	0.	9.0000E+00	0.	
11.	26	1.0000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.0500E+01	0.	1.0000E+01	0.	
12.	26	1.1000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.1500E+01	0.	1.1000E+01	0.	
13.	26	1.2000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.2500E+01	0.	1.2000E+01	0.	
14.	26	1.3000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.3500E+01	0.	1.3000E+01	0.	
15.	26	1.4000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.4500E+01	0.	1.4000E+01	0.	
16.	26	1.5000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.5500E+01	0.	1.5000E+01	0.	
17.	26	1.6000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.6500E+01	0.	1.6000E+01	0.	
18.	26	1.7000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.7500E+01	0.	1.7000E+01	0.	
19.	26	1.8000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.8500E+01	0.	1.8000E+01	0.	
20.	26	1.9000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.9500E+01	0.	1.9000E+01	0.	
21.	26	2.0000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.0500E+01	0.	2.0000E+01	-7.1054E-13	
22.	26	2.1000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.1500E+01	0.	2.1000E+01	0.	
23.	26	2.2000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.2500E+01	0.	2.2000E+01	0.	
24.	26	2.3000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.3500E+01	0.	2.3000E+01	-7.1054E-13	
25.	26	2.4000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.4500E+01	0.	2.4000E+01	-7.1054E-13	
26.	26	2.5000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	2.5500E+01	0.	2.5000E+01	0.	
27.	26	2.6000E+01	2.4000E+01	0.	0.	0.	0.	0.	0.	1.2750E+01	7.8431E-02	
1.	27	0.	2.5000E+01	0.	-7.4257E-05	1.0000E+00	1.0000E+00	3.0000E+01	0.	2.5000E+01	0.	
2.	27	1.0000E+00	2.5000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	1.5000E+00	0.	1.0000E+00	0.	
3.	27	2.0000E+00	2.5000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	2.5000E+00	0.	2.0000E+00	0.	
4.	27	3.0000E+00	2.5000E+01	0.	-9.9007E-05	1.0000E+00	1.0000E+00	3.5000E+00	0.	3.0000E+00	0.	
5.	27	4.0000E+00	2.5000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	4.5000E+00	0.	4.0000E+00	0.	
6.	27	5.0000E+00	2.5000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	5.5000E+00	0.	5.0000E+00	0.	
7.	27	6.0000E+00	2.5000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	6.5000E+00	0.	6.0000E+00	0.	
8.	27	7.0000E+00	2.5000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	7.5000E+00	0.	7.0000E+00	0.	
9.	27	8.0000E+00	2.5000E+01	0.	-4.7184E-05	1.0000E+00	1.0000E+00	8.5000E+00	0.	8.0000E+00	0.	
10.	27	9.0000E+00	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	9.5000E+00	0.	9.0000E+00	0.	
11.	27	1.0000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.0500E+01	0.	1.0000E+01	0.	
12.	27	1.1000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.1500E+01	0.	1.1000E+01	0.	
13.	27	1.2000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.2500E+01	0.	1.2000E+01	0.	
14.	27	1.3000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.3500E+01	0.	1.3000E+01	0.	
15.	27	1.4000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.4500E+01	0.	1.4000E+01	0.	
16.	27	1.5000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.5500E+01	0.	1.5000E+01	0.	
17.	27	1.6000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.6500E+01	0.	1.6000E+01	0.	
18.	27	1.7000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.7500E+01	0.	1.7000E+01	0.	
19.	27	1.8000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.8500E+01	0.	1.8000E+01	0.	
20.	27	1.9000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	1.9500E+01	0.	1.9000E+01	0.	
21.	27	2.0000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.0500E+01	0.	2.0000E+01	-7.1054E-13	
22.	27	2.1000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.1500E+01	0.	2.1000E+01	0.	
23.	27	2.2000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.2500E+01	0.	2.2000E+01	0.	
24.	27	2.3000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.3500E+01	0.	2.3000E+01	-7.1054E-13	
25.	27	2.4000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.4500E+01	0.	2.4000E+01	-7.1054E-13	
26.	27	2.5000E+01	2.5000E+01	0.	0.	1.0000E+00	1.0000E+00	2.5500E+01	0.	2.5000E+01	0.	
27.	27	2.6000E+01	2.5000E+01	0.	0.	0.	0.	0.	0.	1.2750E+01	7.8431E-02	
1.	28	0.	2.6000E+01	0.	-7.4257E-05	1.0000E+00	1.0000E+00	3.0000E+01	0.	2.5000E+01	0.	
2.	28	1.0000E+00	2.6000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	1.5000E+00	0.	1.0000E+00	0.	
3.	28	2.0000E+00	2.6000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	2.5000E+00	0.	2.0000E+00	0.	
4.	28	3.0000E+00	2.6000E+01	0.	-9.9007E-05	1.0000E+00	1.0000E+00	3.5000E+00	0.	3.0000E+00	0.	
5.	28	4.0000E+00	2.6000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	4.5000E+00	0.	4.0000E+00	0.	
6.	28	5.0000E+00	2.6000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	5.5000E+00	0.	5.0000E+00	0.	
7.	28	6.0000E+00	2.6000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	6.5000E+00	0.	6.0000E+00	0.	
8.	28	7.0000E+00	2.6000E+01	0.	-9.9008E-05	1.0000E+00	1.0000E+00	7.5000E+00	0.	7.0000E+00	0.	
9.	28	8.0000E+00	2.6000E+01	0.	-4.7184E-05	1.0000E+00	1.0000E+00	8.5000E+00	0.	8.0000E+00	0.	
10.	28	9.0000E+00	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	9.5000E+00	0.	9.0000E+00	0.	
11.	28	1.0000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.0500E+01	0.	1.0000E+01	0.	
12.	28	1.1000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.1500E+01	0.	1.1000E+01	0.	
13.	28	1.2000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.2500E+01	0.	1.2000E+01	0.	
14.	28	1.3000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.3500E+01	0.	1.3000E+01	0.	
15.	28	1.4000E+01	2.6000E+01	0.	0.	1.0000E+00	1.0000E+00	1.4500E+01	0.	1.4000E+01	0.

PARTICLES

POR= 1.00000E+00 PDZ= 1.00000E+00 PXR= 2.60000E+01 PYB= 0. PYT= 5.20000E+01
T3AAA 1BA YAGUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 1.00000E+00 CYCLE= 7

VELOCITY VECTORS

VMAX= 2.96442E-01

T3AAA 1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA!GB 032272-3)

110872-1

T= 1.00000E+00 CYCLE=

7

ISOPYCNICS

MIN= 9.90697E-01 MAX= 1.00900E+00 L= 9.90697E-01 H= 1.00807E+00 DQ= 1.93073E-03
 T3AAA 1BA YAU1 PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 1.00000E+00 CYCLE= 7

ISOTHERMS

MIN= 9.72363E-01 MAX= 1.00004E+00 L= 9.72363E-01 H= 9.98169E-01 DQ= 2.86729E-03

T3AAA 18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA:GB 032272-3) 110872-1 T= 1.00000E+00 CYCLE= 7

VORTICITY

MIN=-7.34092E-02 MAX= 2.2235E-01 L=-7.34092E-02 H= 1.93570E-01 DQ= 2.36644E-02
T3AAA 1BA YAGU1 PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 1.00000E+00 CYCLE= 7

I	J	X	Y	U	V	S	RHO	VOL	G	M	P	CYCLE=00 1.00000E+00									
												110872-1 T=									
9	26	7.0000E+00	2.4000E+01	-2.6115E-03	-2.7685E-01	5.8534E-01	1.0013E+00	7.5000E+00	-7.4441E-03	7.0153E+00	1.6202E-01										
8	26	7.0000E+00	2.4000E+01	-2.6115E-03	-2.7685E-01	5.8534E-01	1.0013E+00	7.5000E+00	-7.4441E-03	7.0153E+00	1.6202E-01										
10	26	9.0000E+00	2.4000E+01	-2.9641E-02	-9.1458E-02	9.9983E-02	1.0003E+00	9.5000E+00	-1.7526E-03	9.0131E+00	8.9469E-02										
11	26	1.0000E+01	2.4000E+01	1.7077E-02	1.4951E-02	9.9994E-03	1.0006E+00	1.0006E+00	-1.2173E-03	1.0009E+00	5.6908E-03										
12	26	1.0000E+01	2.4000E+01	1.0472E-02	9.8134E-03	9.9997E-03	1.0003E+00	1.0003E+00	-8.1243E-04	1.0003E+00	3.7067E-02										
13	26	1.2000E+01	2.4000E+01	6.4539E-03	6.2071E-03	9.9993E-03	1.0003E+00	1.0003E+00	-5.6867E-04	1.0003E+00	2.5416E-02										
14	26	1.3000E+01	2.4000E+01	4.0581E-03	3.9648E-04	1.0000E+00	1.0000E+00	1.0000E+00	-3.8710E-04	1.0000E+00	1.7033E-02										
15	26	1.4000E+01	2.4000E+01	2.5653E-03	2.5520E-03	1.0000E+00	1.0000E+00	1.0000E+00	-2.8930E-04	1.0000E+00	1.2233E-02										
16	26	1.5000E+01	2.4000E+01	1.6663E-03	1.6012E-03	1.0000E+00	1.0000E+00	1.0000E+00	-2.0397E-04	1.0000E+00	6.4277E-03										
17	26	1.6000E+01	2.4000E+01	1.0698E-03	1.0188E-03	1.0000E+00	1.0000E+00	1.0000E+00	-1.4646E-04	1.0000E+00	6.3515E-03										
18	26	1.7000E+01	2.4000E+01	6.6491E-04	5.9648E-04	1.0000E+00	1.0000E+00	1.0000E+00	-9.4129E-05	1.0000E+00	4.4433E-03										
19	26	1.8000E+01	2.4000E+01	4.2593E-04	3.6593E-04	1.0000E+00	1.0000E+00	1.0000E+00	-6.4694E-05	1.0000E+00	3.4933E-03										
20	26	1.9000E+01	2.4000E+01	2.7631E-04	2.0612E-04	1.0000E+00	1.0000E+00	1.0000E+00	-4.8896E-05	1.0000E+00	2.8837E-03										
21	26	2.0000E+01	2.4000E+01	1.6313E-04	1.2050E-04	1.0000E+00	1.0000E+00	1.0000E+00	-4.8841E-05	1.0000E+00	1.4581E-03										
22	26	2.1000E+01	2.4000E+01	9.2403E-05	6.7997E-05	1.0000E+00	1.0000E+00	1.0000E+00	-4.9223E-05	1.0000E+00	8.3332E-04										
23	26	2.2000E+01	2.4000E+01	5.7160E-05	4.8970E-05	1.0000E+00	1.0000E+00	1.0000E+00	-4.8468E-05	1.0000E+00	6.2055E-04										
24	26	2.3000E+01	2.4000E+01	3.1064E-06	3.1064E-06	1.0000E+00	1.0000E+00	1.0000E+00	-6.1081E-06	1.0000E+00	4.1304E-04										
25	26	2.4000E+01	2.4000E+01	1.2599E-10	3.0704E-12	1.0000E+00	1.0000E+00	1.0000E+00	-3.2800E-10	1.0000E+00	4.6107E-09										
26	26	2.5000E+01	2.4000E+01	-2.0318E-10	3.6627E-25	1.0000E+00	1.0000E+00	1.0000E+00	1.9920E-10	2.5000E+01	-2.8891E-09										
27	26	2.6000E+01	2.4000E+01	0	-9.5390E-25	0	0	0	0	2.7500E+01	7.8431E-02										
1	27	0	2.5000E+01	1.4377E-05	-2.2500E-01	9.7828E-01	1.0004E+00	5.0000E+00	-7.4488E-04	1.2502E+01	3.5892E-02										
2	27	1.0000E+00	2.5000E+01	-2.9517E-04	-2.9595E-01	9.7236E-01	1.0004E+00	1.5000E+00	-7.1263E-04	1.0008E+00	3.5199E-02										
3	27	2.0000E+00	2.5000E+01	-5.9180E-04	-2.9595E-01	9.7244E-01	1.0004E+00	2.5000E+00	-7.0650E-04	2.0017E+00	3.5792E-02										
4	27	3.0000E+00	2.5000E+01	-8.3517E-04	-2.9501E-01	9.7257E-01	1.0004E+00	3.5000E+00	-7.1225E-04	3.0026E+00	3.5994E-02										
5	27	4.0000E+00	2.5000E+01	-1.2573E-03	-2.9375E-01	9.7276E-01	1.0004E+00	4.5000E+00	-7.2403E-04	4.0035E+00	3.7266E-02										
6	27	5.0000E+00	2.5000E+01	-1.3434E-03	-2.9187E-01	9.7306E-01	1.0004E+00	5.5000E+00	-7.5051E-04	5.0046E+00	3.7192E-02										
7	27	6.0000E+00	2.5000E+01	-2.7082E-03	-2.9012E-01	9.7308E-01	1.0004E+00	6.5000E+00	-8.7565E-04	6.0058E+00	4.1218E-02										
8	27	7.0000E+00	2.5000E+01	-6.0943E-04	-2.8739E-01	9.8371E-01	1.0004E+00	7.5000E+00	-1.1933E-04	7.0070E+00	3.6000E-02										
9	27	8.0000E+00	2.5000E+01	-1.2810E-02	-2.7688E-02	9.9996E-01	1.0003E+00	8.5000E+00	-3.1845E-04	8.0063E-02	3.2828E-02										
10	27	9.0000E+00	2.5000E+01	1.2810E-02	2.7688E-02	9.9996E-01	1.0003E+00	9.5000E+00	-3.1845E-04	9.0063E-02	2.5329E-02										
11	27	1.0000E+01	2.5000E+01	9.4904E-03	1.9209E-02	9.9993E-01	1.0002E+00	1.0500E+01	-3.0268E-04	1.0005E+01	1.5377E-02										
12	27	1.0000E+01	2.5000E+01	5.3329E-03	1.8666E-02	9.9997E-01	1.0001E+00	1.1500E+01	-2.0272E-04	1.1003E+01	1.0709E-02										
13	27	1.2000E+01	2.5000E+01	3.3901E-03	1.7390E-03	9.9999E-01	1.0001E+00	1.2500E+01	-1.2500E-04	1.2002E+01	7.2302E-03										
14	27	1.3000E+01	2.5000E+01	2.0988E-03	1.6773E-03	9.9997E-01	1.0000E+00	1.3500E+01	-1.1879E-04	1.3002E+01	5.7312E-03										
15	27	1.4000E+01	2.5000E+01	1.3434E-03	2.9204E-03	1.0000E+00	1.0000E+00	1.4500E+01	-7.9575E-05	1.4001E+01	4.0369E-03										
16	27	1.5000E+01	2.5000E+01	8.5733E-04	1.8475E-03	1.0000E+00	1.0000E+00	1.5500E+01	-7.3828E-05	1.5001E+01	3.5379E-03										
17	27	1.6000E+01	2.5000E+01	5.4414E-04	1.1233E-03	1.0000E+00	1.0000E+00	1.6500E+01	-1.5077E-05	1.6001E+01	2.6899E-03										
18	27	1.7000E+01	2.5000E+01	3.5296E-04	7.0730E-04	1.0000E+00	1.0000E+00	1.7500E+01	-4.7181E-05	1.7001E+01	2.6899E-03										
19	27	1.8000E+01	2.5000E+01	2.0440E-04	4.0366E-04	1.0000E+00	1.0000E+00	1.8500E+01	-5.8972E-05	1.8000E+01	7.9734E-04										
20	27	1.9000E+01	2.5000E+01	1.5145E-04	2.1652E-04	1.0000E+00	1.0000E+00	1.9500E+01	-3.5863E-05	1.9000E+01	4.9782E-04										
21	27	2.0000E+01	2.5000E+01	1.1444E-04	1.1444E-04	1.0000E+00	1.0000E+00	2.0500E+01	-2.5261E-05	2.0000E+01	6.6580E-04										
22	27	2.1000E+01	2.5000E+01	6.4717E-05	6.3802E-05	1.0000E+00	1.0000E+00	2.1500E+01	-3.4592E-05	2.1000E+01	5.9922E-04										
23	27	2.2000E+01	2.5000E+01	2.6459E-05	1.3518E-05	1.0000E+00	1.0000E+00	2.2500E+01	-1.9696E-05	2.2000E+01	3.3344E-04										
24	27	2.3000E+01	2.5000E+01	3.3286E-10	5.7813E-11	1.0000E+00	1.0000E+00	2.3500E+01	-1.8331E-10	2.3000E+01	4.6107E-09										
25	27	2.4000E+01	2.5000E+01	1.1725E-10	7.5020E-17	1.0000E+00	1.0000E+00	2.4500E+01	-3.2219E-10	2.4000E+01	4.6107E-09										
26	27	2.5000E+01	2.5000E+01	-2.0318E-10	8.2718E-25	1.0000E+00	1.0000E+00	2.5500E+01	1.9920E-10	2.5000E+01	-2.8891E-09										
27	27	2.6000E+01	2.5000E+01	0	-8.271

PARTICLES

POR= 1.00000E+00 PDZ= 1.00000E+00 PXR= 2.60000E+01 PYB= 0. PYT= 5.20000E+01
 T3AAA 1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) (10872-1 T= 9.00000E+00 C`CLE= 232

VELOCITY VECTORS

VMAX= 2.93061E+00

T3AAA 1BA YAGUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 002272-3)

110872-1

T= 9.00000E+00 CYCLE= 232

ISOPYCNICS

MIN= 9.72275E-01 MAX= 1.04901E+00 L= 9.72275E-01 H= 1.04223E+00 DD= 7.77298E-03
 T3AAA 1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 9.00000E+00 CYCLE= 232

ISOTHERMS

MIN=-7.32911E+00 MAX= 1.22158E+00 L=-7.32911E+00 H= 3.67413E-01 DQ= 8.55170E-01
T3AAA 1BA YAGUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 9.00000E+00 CYCLE= 232

VORTICITY

MIN=-2.39303E-02 MAX= 9.72045E-01 L=-2.39303E-02 H= 8.73348E-01 DD= 9.96976E-02
 T3AAA 1BA YAGI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 1:0872-1 T= 9.00000E+00 CYCLE= 232

T3AAA 1BA YAOUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. T3AAAIG8 032272-31										110872-1	T= 9.00000E+00 CYCLE= 232
I	J	K	Y	U	V	SIC	RNO	VOL	D	M	P
8.	26	7.0000E+00	2.4000E+01	-5.1537E-01	-7.8591E-01	1.0532E+00	9.9707E-01	7.5000E+00	-2.6219E-03	6.9759E+00	-2.9254E-01
9.	26	8.0000E+00	2.4000E+01	-5.3391E-01	-5.2959E-01	1.0449E+00	9.9689E-01	8.5000E+00	-2.5925E-03	7.9711E+00	-3.1083E-01
10.	26	9.0000E+00	2.4000E+01	-5.2592E-01	-2.8341E-01	1.0249E+00	9.9780E-01	9.5000E+00	-2.3934E-03	8.9668E+00	-3.1973E-01
11.	26	1.0000E+01	2.4000E+01	-4.9208E-01	-9.2084E-02	1.0145E+00	9.9800E-01	1.0500E+01	-2.1568E-03	9.9633E+00	-3.2023E-01
12.	26	1.1000E+01	2.4000E+01	-4.4172E-01	4.0406E-02	1.0114E+00	9.9680E-01	1.1500E+01	-1.8838E-03	1.0961E+01	-3.1241E-01
13.	26	1.2000E+01	2.4000E+01	-3.8491E-01	1.2368E-01	1.0081E+00	9.9700E-01	1.2500E+01	-1.8731E-03	1.1959E+01	-3.0029E-01
14.	26	1.3000E+01	2.4000E+01	-3.2845E-01	1.7166E-01	1.0077E+00	9.9717E-01	1.3500E+01	-1.3199E-03	1.2959E+01	-2.8300E-01
15.	26	1.4000E+01	2.4000E+01	-2.7833E-01	1.9782E-01	1.0040E+00	9.9735E-01	1.4500E+01	-1.0566E-03	1.3959E+01	-2.6499E-01
16.	26	1.5000E+01	2.4000E+01	-2.3353E-01	2.1086E-01	1.0020E+00	9.9755E-01	1.5500E+01	-8.1772E-04	1.4960E+01	-2.4477E-01
17.	26	1.6000E+01	2.4000E+01	-1.9098E-01	2.1659E-01	1.0019E+00	9.9774E-01	1.6500E+01	-6.0852E-04	1.5961E+01	-2.2555E-01
18.	26	1.7000E+01	2.4000E+01	-1.5721E-01	2.1866E-01	1.0014E+00	9.9794E-01	1.7500E+01	-4.6446E-04	1.6962E+01	-2.0650E-01
19.	26	1.8000E+01	2.4000E+01	-1.2884E-01	2.1852E-01	1.0010E+00	9.9810E-01	1.8500E+01	-2.9488E-04	1.7964E+01	-1.8964E-01
20.	26	1.9000E+01	2.4000E+01	-1.0426E-01	2.1746E-01	1.0006E+00	9.9826E-01	1.9500E+01	-1.8709E-04	1.8965E+01	-1.7443E-01
21.	26	2.0000E+01	2.4000E+01	-8.3362E-02	2.1595E-01	1.0006E+00	9.9833E-01	2.0500E+01	-8.9868E-05	1.9967E+01	-1.6159E-01
22.	26	2.1000E+01	2.4000E+01	-6.5270E-02	2.1434E-01	1.0005E+00	9.9843E-01	2.1500E+01	-2.2380E-05	2.0969E+01	-1.5157E-01
23.	26	2.2000E+01	2.4000E+01	-4.9414E-02	2.1286E-01	1.0004E+00	9.9857E-01	2.2500E+01	3.5902E-05	2.1969E+01	-1.4326E-01
24.	26	2.3000E+01	2.4000E+01	-3.5348E-02	2.1155E-01	1.0004E+00	9.9862E-01	2.3500E+01	6.2106E-05	2.2969E+01	-1.3776E-01
25.	26	2.4000E+01	2.4000E+01	-2.2633E-02	2.1054E-01	1.0004E+00	9.9868E-01	2.4500E+01	7.6829E-05	2.3969E+01	-1.3387E-01
26.	26	2.5000E+01	2.4000E+01	-1.0954E-02	2.0980E-01	1.0003E+00	9.9883E-01	2.5500E+01	8.7703E-05	2.4969E+01	-1.3237E-01
27.	26	2.6000E+01	2.4000E+01	0.	2.0933E-01	0.	-1.8170E-07	0.	0.	2.5972E+01	-7.8530E-02
1.	27	0.	2.5000E+01	0.	-1.4403E+00	1.1846E+00	1.0006E+00	5.0000E-01	-3.4404E-03	2.5002E+01	5.8747E-02
2.	27	1.0000E+00	2.5000E+01	-8.9913E-02	-1.4618E+00	1.0378E+00	1.0001E+00	1.5000E+00	-1.6890E-03	9.9972E+01	1.2195E-02
3.	27	2.0000E+00	2.5000E+01	-1.7724E-01	-1.4288E+00	1.0478E+00	9.9973E-01	2.5000E+00	-1.7819E-03	1.9997E+00	-2.5003E-02
4.	27	3.0000E+00	2.5000E+01	-2.6015E-01	-1.3528E+00	1.0401E+00	9.9949E-01	3.5000E+00	-1.8811E-03	2.9970E+00	-8.0391E-02
5.	27	4.0000E+00	2.5000E+01	-3.3988E-01	-1.2374E+00	1.0375E+00	9.9904E-01	4.5000E+00	-2.0103E-03	3.9946E+00	-9.6071E-02
6.	27	5.0000E+00	2.5000E+01	-4.0168E-01	-1.0853E+00	1.0398E+00	9.9868E-01	5.5000E+00	-2.1383E-03	4.9915E+00	-1.3140E-01
7.	27	6.0000E+00	2.5000E+01	-4.5440E-01	-9.0021E-01	1.0432E+00	9.9835E-01	6.5000E+00	-2.2377E-03	5.9878E+00	-1.6497E-01
8.	27	7.0000E+00	2.5000E+01	-4.9029E-01	-8.0854E-01	1.0488E+00	9.9804E-01	7.5000E+00	-2.3078E-03	6.9838E+00	-1.9560E-01
9.	27	8.0000E+00	2.5000E+01	-5.0544E-01	-6.6218E-01	1.0534E+00	9.9778E-01	8.5000E+00	-2.2432E-03	7.9798E+00	-2.2079E-01
10.	27	9.0000E+00	2.5000E+01	-4.9801E-01	-5.1177E-01	1.0589E+00	9.9761E-01	9.5000E+00	-2.1057E-03	8.9754E+00	-2.3853E-01
11.	27	1.0000E+01	2.5000E+01	-4.8399E-01	-4.2856E-02	1.0631E+00	9.9751E-01	1.0500E+01	-1.9039E-03	9.9718E+00	-2.4882E-01
12.	27	1.1000E+01	2.5000E+01	-4.1811E-01	-2.4101E-02	1.0600E+00	9.9747E-01	1.1500E+01	-1.6979E-03	1.0969E+01	-2.5274E-01
13.	27	1.2000E+01	2.5000E+01	-3.6442E-01	9.7781E-02	1.0607E+00	9.9753E-01	1.2500E+01	-1.4725E-03	1.1967E+01	-2.4494E-01
14.	27	1.3000E+01	2.5000E+01	-3.1508E-01	1.4255E-01	1.0654E+00	9.9766E-01	1.3500E+01	-1.2443E-03	1.2965E+01	-2.4377E-01
15.	27	1.4000E+01	2.5000E+01	-2.6731E-01	1.6877E-01	1.0693E+00	9.9788E-01	1.4500E+01	-1.0447E-03	1.3964E+01	-2.3362E-01
16.	27	1.5000E+01	2.5000E+01	-2.2482E-01	1.8378E-01	1.0624E+00	9.9777E-01	1.5500E+01	-8.3634E-04	1.4964E+01	-2.2262E-01
17.	27	1.6000E+01	2.5000E+01	-1.8787E-01	1.9234E-01	1.0617E+00	9.9780E-01	1.6500E+01	-6.9411E-04	1.5964E+01	-2.0992E-01
18.	27	1.7000E+01	2.5000E+01	-1.5574E-01	1.9704E-01	1.0612E+00	9.9803E-01	1.7500E+01	-5.3878E-04	1.6965E+01	-1.9740E-01
19.	27	1.8000E+01	2.5000E+01	-1.2889E-01	1.9945E-01	1.0609E+00	9.9814E-01	1.8500E+01	-4.4414E-04	1.7965E+01	-1.8562E-01
20.	27	1.9000E+01	2.5000E+01	-1.0484E-01	2.0050E-01	1.0607E+00	9.9825E-01	1.9500E+01	-3.2336E-04	1.8966E+01	-1.7473E-01
21.	27	2.0000E+01	2.5000E+01	-8.4140E-02	2.0077E-01	1.0606E+00	9.9835E-01	2.0500E+01	-2.4078E-04	1.9966E+01	-1.6526E-01
22.	27	2.1000E+01	2.5000E+01	-6.8189E-02	2.0061E-01	1.0605E+00	9.9842E-01	2.1500E+01	-1.7353E-04	2.0967E+01	-1.5751E-01
23.	27	2.2000E+01	2.5000E+01	-5.6313E-02	2.0021E-01	1.0604E+00	9.9848E-01	2.2500E+01	-1.2993E-04	2.1967E+01	-1.5175E-01
24.	27	2.3000E+01	2.5000E+01	-3.8475E-02	1.9877E-01	1.0604E+00	9.9853E-01	2.3500E+01	-1.0232E-04	2.2967E+01	-1.4723E-01
25.	27	2.4000E+01	2.5000E+01	-2.3158E-02	1.9832E-01	1.0604E+00	9.9855E-01	2.4500E+01	-6.9065E-05	2.3968E+01	-1.4468E-01
26.	27	2.5000E+01	2.5000E+01	-1.1214E-02	1.9895E-01	1.0603E+00	9.9857E-01	2.5500E+01	-8.6277E-05	2.4968E+01	-1.4349E-01
27.	27	2.6000E+01	2.5000E+01	0.	1.9868E-01	0.	-1.0315E-07	0.	0.	1.2732E+01	7.8540E-02
1.	28	0.	2.6000E+01	0.	-1.2888E+00	1.2148E+00	1.0013E+00	5.0000E-01	-2.8902E-03	2.5024E+01	1.2818E-01
2.	28	1.0000E+00	2.6000E+01	-8.5053E-02	-1.2695E+00	1.0690E+00	1.0009E+00	1.5000E+00	-1.4587E-03	1.0006E+00	8.7655E-02
3.	28	2.0000E+00	2.6000E+01	-1.6812E-01	-1.2607E+00	1.0677E+00	1.0005E+00	2.5000E+00	-1.5278E-03	2.0006E+00	5.3658E-02
4.	28	3.0000E+00	2.6000E+01	-2.4683E-01	-1.1824E+00	1.0659E+00	1.0002E+00	3.5000E+00	-1.6200E-03	2.9998E+00	1.9792E-02
5.	28	4.0000E+00	2.6000E+01	-3.1833E-01	-1.0883E+00	1.0563E+00	9.9984E-01	4.5000E+00	-1.7357E-03	3.9984E+00	-1.5583E-02
6.	28	5.0000E+00	2.6000E+01	-3.8003E-01	-9.5134E-01	1.0478E+00	9.9945E-01	5.5000E+00	-1.8330E-03	4.9962E+00	-5.1701E-02
7.	28	6.0000E+00	2.6000E+01	-4.2866E-01	-7.6571E-01	1.0430E+00	9.9913E-01	6.5000E+00	-1.9022E-03	5.9934E+00	-8.7389E-02
8.	28	7.0000E+00	2.6000E+01	-4.6876E-01	-5.9844E-01	1.0374E+00	9.9880E-01	7.5000E+00	-1.9755E-03	6.9900E+00	-1.2049E-01
9.	28	8.0000E+00	2.6000E+01	-4.7278E-01	-4.0111E-01	1.0258E+00	9.9848E-01	8.5000E+00	-1.8973E-03	7.9862E+00	-1.5130E-01
10.	28	9.0000E+00	2.6000E+01	-4.8228E-01	-2.2384E-01	1.0152E+00	9.9825E-01	9.5000E+00	-1.8032E-03	8.9823E+00	-1.7478E-01
11.	28	1.0000E+01	2.6000E+01	-4.5233E-01	-8.6894E-02	1.0118E+00	9.9800E-01	1.0500E+01	-1.6512E-03	9.9786E+00	-1.9242E-01
12.	28	1.1000E+01	2.6000E+01	-3.9808E-01	1.0781E-02	1.0086E+00	9.9787E-01	1.1500E+01	-1.5047E-03	1.0975E+01	-2.0398E-01
13.	28	1.2000E+01	2.6000E+01	-3.4428E-01	7.5636E-02	1.0060E+00	9.9781E-01	1.2500E+01	-1.3286E-03	1.1973E+01	-2.0893E-01
14.	28	1.3000E+01	2.6000E+01	-2.9790E-01	1.1898E-01	1.0042E+00	9.9790E-01	1.3500E+01	-1.1758E-03	1.2970E+01	-2.0964E-01
15.	28	1.4000E+01	2.6000E+01	-2.5471E-01	1.4292E-01	1.0029E+00	9.9793E-01	1.4500E+01	-1.0056E-03	1.3969E+01	-2.0747E-01

APPENDIX A
FLOW DIAGRAM FOR THE YAQUI PROGRAM

PROGRAM
YAQUI

0,0 OVERLAY

NQ = 14 ← No. Quantities/Cell
RESTORE PRINTER

AMSDEN
72

2

0,0 SUBROUTINES - SETUP PLOTS & PARTICLE GRID:

3

SUBROUTINE FILMCØ

PARTICLE GRID & PARTICLE PLOT SETUP:

< END SUBROUTINE FILMCØ >

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1,0 OVERLAY - THE PROBLEM SETUP:

4

«SUBROUTINE YASET1»

READ IDENTIFICATION CARD
READ NEXT 6 INPUT-DATA CDS:

1. μ } VISCOSITY COEFFICIENTS
LAM λ
OM ω RELAXATION PARAMETER
EPS ϵ CONVERGENCE CRITERION
2. g_x, g_y } GRAVITY COMPONENTS
ASQ } COEFFICIENTS FOR
RGN STIFFENED GAS
GMI EQUATION OF STATE
FREZ VARIABLE ZONING COEFF.
YB Y_0, Y of $i=2$
REZY Y_0, Y of BUBBLE CENTER
REZUE u_z } GRID EXPANSION &
REZVE v_z } TRANSLATION VELS.
REZVT v_r } FOR REZONE
REZRON $p_0 = p$ AT Y_0
REZSIE $I_{AMBIENT}$
3. I_p, J_p } PARTICLE GRID
PDR Δx } PARAMETERS
PDE Δy
PYB Y_0
GEP g_{ep}
IMMEX MOMENTUM EXCHANGE
to
T
DT
TZOMD $I = 20$ CP TAPE DUMP
TLIMD $I =$ TIME LIMIT DUMP
TWFIN TIME WHEN TO FINISH
LPR PRINT CONTROL
ICOLOR $I =$ COLOR PLOT
4. $DT\phi(1-10)$ } CONTROLS OUTPUT
6. $DT\phi C(1-10)$ } INTERVALS

NOTE:
CONSTANTS
DEPENDENT
UPON SE
WILL BE SET
IN 2,0.

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1.0 SUBROUTINES - THE PROBLEM SETUP:

5

«SUBROUTINE YASET1» CONTINUED:

219 IJP = IPJP
 CALL LOOP
 TO NEXT CELL IN ROW
 ROW COMPLETED, GO UP A ROW

229 CONTINUE
 CALL DONE
 ALL ROWS COMPLETED

1.0 SUBROUTINES - PARTICLE GENERATOR :

6

«SUBROUTINE PARTGEN»

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<<'SUBROUTINE PARTGEN>> CONTINUED:

```
<END SUBROUTINE PARTGEN>
```

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《SUBROUTINE MESHMKR》

STANDARD
CLEARING
OF LCM
CELL
STORAGE
(PLUS SOME
EXTRA):

109 AASC(I) = 0.0 ← SET TO ZERO
CALL LOOP

119 CONTINUE
CALL DONE

200 XX = 0.0
YY = YB ← YB IS INPUT
CALL START
DØ 229 J=2,JP2 } ALL
DØ 219 I=1,IP1 } VERTICES
X(IJ) = XX
Y(IJ) = YY
R(IJ) = XX * CYL + ØM CYL
XX = XX + DR

UNIFORM
ZONING:
X, Y, R
(MAY BE
RE-DONE
BELOW)

219 IJ = IJ + NQ
XX = 0.0 } ROW FINISHED, RESET
YY = YY + DZ } TO DO NEXT ROW
CALL LOOP UP

229 CONTINUE
CALL DONE

(TRULY UNIFORM MESH
MUST BYPASS THE
REMAINDER OF "200"
REGION TO AVOID
ZERO DIVIDE)
FREE = 1.0 = ABOVE LOOP
VALID

NON-
UNIFORM
ZONING:
(REFER TO
FIG. 13)
JCN = JCN + 2 = INDEX J CENTER
JTØP = JCN + JUNFO2 } INDICES
JØBT = JCN - JUNFO2 } AND
TJ = FLOAT(JUNFO2) * DZ } EXTENT
OF UNIFORM
CENTRAL REGION

CALL START
DØ 249 J=2,JP2 } ALL
DØ 239 I=1,IP1 } VERTICES
IMJ = IJ - NQ

I: IUNF+1
IN UNIFORM
X REGION
X(IJ) = X(IMJ)
+ FREE * [X(IMJ) - X(IMJ - NQ)]

R(IJ) = X(IJ) * CYL + ØM CYL
JDT = IABS(J - JTØP)
JDB = IABS(J - JØBT)

J: JØBT
ABOVE
Y(IJ) = REZYO - TJ -
DZ * FREE * RØMFR * (1 - FREE * JDB)

J: JTØP
BELOW
Y(IJ) = REZYO + TJ +
DZ * FREE * RØMFR * (1 - FREE * JDT)

J: 2
YB = Y(IJ) ← SAVE NEW YB

239 IJ = IJ + NQ
CALL LOOP ← TO NEXT ROW UP

249 CONTINUE
CALL DONE ← ALL ROWS DONE

BASIC FLUID GENERATOR:

300 READ A FLUID-REGION CARD:
NB NR } INTEGER NOS.
NT } OF CELLS
NL } DEFINING OPPOSITE
UI } INITIAL U, V,
VI } P, I FOR ALL
RØI } VERTICES OR
SIEI } CELLS IN REGION
NR } NR
NT } NT
NL } NL
UI } UI
VI } VI
RØI } RØI
SIEI } SIEI
j=2
(SEE ALSO FIG. 15)

NR: 0 = 0
ALL FLUID
REGIONS HAVE
BEEN CREATED
RETURN

NR: 1000 = 1000
SPECIAL ATMOS-
PHERIC SETUP
NEXT PAGE

PRINT CONTENTS OF ABOVE CARD

LPR: 0
WRITE CONTENTS
OF ABOVE CARD
ON FILM ALSO.
= NO FILM WRITING

NB2 = NB + 2
NR1 = NR + 1 } COMPUTE INDICES TO MATCH
NT2 = NT + 2 } THIS REGION TO APPROPRIATE
NL1 = NL + 1 } J'S & I'S IN YAQUI GRID.
DØ 329 J = NB2, NT2 } # VERTICES, BUT 1
CALL RIRØW } FEWER ROWS OF CELLS.
DØ 319 I = NL1, NR1 } # VERTICES, BUT 1
CALL SETIJ } FEWER COLS. OF CELLS.
GET ZONE

U
I > 1 AND I < IP1 YES U(IJ) = UI

V
J > 2 AND J < JP2 YES V(IJ) = VI

P, I
J = NT2 OR I = NR1 NO RØ(IJ) = RØI
SIE(IJ) = SIEI

319 CONTINUE ← TO NEXT CELL IN ROW
CALL WIRØW ← ROW DONE - WRITE IT

329 CONTINUE ← DO ALL ROWS SPEC.

SUBROUTINE CONTINUED...

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1,0 SUBROUTINES - MESH & FLUID GENERATOR (CONT'D):

9

《SUBROUTINE MESHMKR》 CONTINUED:

2,0 OVERLAY - 3-PHASE ICED-ALE:

10

《SUBSTITUTE YACI》

CONTROL Rev: 111

THE UNIVERSITY OF CHICAGO

Δ 45054.72

《SUBROUTINE YA0112》 CONTINUED:

TAPE DUMP

NOTES:

NSC = LENGTH OF SCIN COUNT YSC2, = LOGF (22) - LOGF (AA) + 1
 NLC = LENGTH OF LCM CELL STORAGE, = LOGF (AA1(24+120)) - LOGF (AA1) + 1
 NPS = LENGTH OF LCM PARTICLE STORAGE, = LOGF (AA2 (NPT+20)) - LOGF (AA2 + 1)
 LWA = FWA + 1
 THESE 3 PARAMETERS ARE STORED IN THE SCIN COMMON YSC2.
 NSC & NLC ARE CALCULATED IN YASET 1 IN STATEMENT #120.
 NPS IS CALCULATED AT THE END OF PARTICLE IN STATEMENT #290.
 USE OF JPA IN NLC ENSURES THAT CAREFULLY-CLEARED LCM WILL BE USED, TO AVOID TROUBLE ON RESTART.
 NPT IS THE TOTAL NO. OF PARTICLES IN THE SYSTEM.

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2.0 SUBROUTINES - 3-PHASE ICED-ALE (CONT'D):

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《SUBROUTINE YAQUI2》 CONTINUED:

《SUBROUTINE YAQUI2》 CONTINUED:

ZONE PLOT

VELOCITY VECTOR PLOT

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2,0 SUBROUTINES - 3-PHASE ICED-ALE (CONT'D):

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《SUBROUTINE YAQUIZ》 CONTINUED:

CONTOUR PLOTS - PAGE 1

《SUBROUTINE YAQUI2》 CONTINUED:

CONTOUR PLOTS - PAGE 2

CALL START
D0 899 J=1, JBAR
CALL LOOP
D0 889 I=1, IM1
IPJ = IJ + NQ
IPJM = IJM + NQ
N = 0
D0 879 KK=1, K
K1 = K2 = K3 = K4 = 0

← 5-1 ROWS, ACTUALLY
← SO PROPER 3 ROWS
OF X-Y COORDS WILL
BE IN SCM FOR COORD.
INTERPOLATION
← I-1 COLUMNS, ACTUALLY
← INDICATES CELL CENTER
COORDS. NOT YET
CALCULATED
← INDEX K HAS COUNT
OF NO. OF VALUES
IN "CON" TABLE

CQ(IJM): CON(KK) ← K1 = 1

CQ(IPJM): CON(KK) ← K2 = 1

CQ(IJ): CON(KK) ← K3 = 1

CQ(IPJ): CON(KK) ← K4 = 1

IF PRODUCT
≠ 0, THEN
ALL 4 ARE
= 1.
IF SUM = 0,
THEN ALL 4
ARE = 0.

K1 = K2 = K3 = K4 ≠ 0
OR
K1 + K2 + K3 + K4 = 0

YES → 879 TRY NEXT CONTOUR VALUE

N = 0

COORDS ALREADY CALCULATED FOR
A PREVIOUS CON VALUE

800 NEXT PAGE

(COORDS OF
ALL 9
VERTICES
ARE IN SCM,
BY VIRTUE
OF "CALL
LOOP"
ABOVE.)

IJB = IJM } SETUP FOR CELLS 1 & 2
IJA = IJ }
D0 799 JJ=1, 2 } COORDS. OF ALL 4 CELL
D0 889 II=1, 2 } CENTERS IN QUADRANT
IPJB = IJB + NQ
IPJA = IJA + NQ
N = N + 1 ← STORE 1-2-3-4
 $XC(N) = .25 * [X(IPJB) + X(IPJA) + X(IJA) + X(IJB)]$
 $YC(N) = .25 * [Y(IPJB) + Y(IPJA) + Y(IJA) + Y(IJB)]$
IJA = IPJA

TO NEXT COL. IN SAME ROW

789 IJB = IPJB
IJB = IJ

799 IJA = IJP
RESET UP TO ROW CONTAINING
CELLS 3 & 4

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2.0 SUBROUTINES - 3-PHASE ICED-ALE (CONT'D):

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《SUBROUTINE YAQUI2》 CONTINUED:

《SUBROUTINE YAQUI2》 CONTINUED:

PHASE-1 CALCULATION - PAGE 1

INITIALIZE VERTEX VALUES OF $\tilde{u}, \tilde{v}, Q$:Couple
Alternate
Nodes: AMSDEN
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PHASE-1 CALCULATION - PAGE 2

THIS 2ND LOOP SWEEPS CELL CENTERS & UPDATES THE 4 VERTICES OF EACH CELL

CALL START
D0 1299 J=2, JPI
D0 1199 I=1, IPAR } ALL CELL CENTERS
IPJ = JI+NQ
IPJP = IJP+NQ
X1 = X(IJP) X2 = X(IPTP) X3 = X(IJPP) X4 = X(IJ)
Y1 = Y(IJP) Y2 = Y(IPTP) Y3 = Y(IJPP) Y4 = Y(IJ)
R1 = R(IJP) R2 = R(IPTP) R3 = R(IJPP) R4 = R(IJ)
U1 = U(IJP) U2 = U(IPTP) U3 = U(IJPP) U4 = U(IJ)
V1 = V(IJP) V2 = V(IPTP) V3 = V(IJPP) V4 = V(IJ)

FORM
COMBINATIONS
THAT APPEAR
REPEATEDLY...

$$\begin{array}{ll}
X12 = X1 - X2 & R12 = R1 + R2 \\
X23 = X2 - X3 & R23 = R2 + R3 \\
X34 = X3 - X4 & R34 = R3 + R4 \\
X41 = X4 - X1 & R41 = R4 + R1 \\
X24 = X2 - X4 & R13 = .5 (R1 + R3) \\
X31 = X3 - X1 & R24 = .5 (R2 + R4) \\
X21 = X2 - Y1 & U12 = U1 + U2 \\
Y32 = Y3 - Y2 & U23 = U2 + U3 \\
Y43 = Y4 - Y3 & U34 = U3 + U4 \\
Y14 = Y1 - Y4 & U41 = U4 + U1 \\
Y24 = Y2 - Y4 & U24 = U2 + U4 \\
Y31 = Y3 - Y1 & U13 = U1 + U3
\end{array}$$

①

$$D = .25 \cdot \text{R} \cdot \text{V} \cdot \text{O} \cdot \text{L} \cdot \text{I} \cdot \text{J} \cdot \left[\begin{array}{l} \text{R12} \cdot (\text{U12} \cdot \text{V21} + \text{V12} \cdot \text{X12}) \\ + \text{R23} \cdot (\text{U23} \cdot \text{V32} + \text{V23} \cdot \text{X23}) \\ + \text{R34} \cdot (\text{U34} \cdot \text{V43} + \text{V34} \cdot \text{X34}) \\ + \text{R41} \cdot (\text{U41} \cdot \text{V14} + \text{V41} \cdot \text{X41}) \end{array} \right] \quad \left. \begin{array}{l} \text{XX} = .5 \cdot (\text{X2} - \text{X4} + \text{X1} - \text{X3}) \\ \text{YY} = .5 \cdot (\text{Y2} - \text{Y4} + \text{Y3} - \text{Y1}) \end{array} \right\} \text{AVERAGE } S^2 = \frac{8}{3} \text{ OF CELL}$$

COMPUTE EFFECTIVE
 $\lambda \in \mu$ FOR CELL:

$$\left. \begin{aligned} (\lambda_{\text{eff}})_i &= k \lambda_{\text{INPUT}} \\ (\mu_{\text{eff}})_i &= k \mu_{\text{INPUT}} \end{aligned} \right\}$$

(CYL=1.0 IF CYLINDRICAL,
=0.0 IF PLANE COORDINATES)

WHEN $\xi = -1$, BASE k UPON THE NUMERICAL STABILITY REQUIREMENTS.

```
VELIJ = U4**2 + V4**2
VELMX = G.7 * AMAX1( |U4*XX|, |V4*YY| )
AK = RØ(IJ) * CØLUMU * (DTØ2 * VELIJ + VELMX)
```

LAMD = AMINI (D,O.) * AK * LAM
MUØ2 = .5 * AK * MU
MUØ4 = .5 * MUØ2
XX = XX * XX
YY = YY * YY

```

KXI < 0
AND
YES
AK = R3(JJ) * C0LAMU * (.5 * DTFSSAVEL1 + VELMX)

```

$$DQ = \left[\frac{R\phi(IJ) \cdot \phi(MANC \cdot XX \cdot YY)}{2.4 AK \cdot (LAM + 2.4 AU) \cdot (XX + YY) + EMIO} \right]$$

$$DTV = AMINI \cdot (DTV, -5 \cdot DQ)$$

SAVE HINDIES OF LIMITING
CELL FOR NEXT SHORT PRINT,
... ALONG WITH THE MINIMUM
8cy.

$$\begin{aligned} \text{PIXX} &= \text{MU02} * \text{RV0L}(17) * [\text{R12} * \text{U12} * \text{Y21} + \text{R13} * \text{U13} * \text{Y32} \\ &\quad + \text{R34} * \text{U34} * \text{Y43} + \text{R41} * \text{U41} * \text{Y14} \\ &\quad - .5 * \text{CYL} * (\text{U12} * \text{U34} * \text{XY}) + \text{LAMD}] \\ \text{PIYY} &= \text{MU02} * \text{RV0L}(17) * [\text{R12} * \text{V12} * \text{X12} + \text{R13} * \text{V13} * \text{X13} \\ &\quad + \text{R34} * \text{V34} * \text{X34} + \text{R41} * \text{V41} * \text{X41}] + \text{LAMD}] \\ \text{PIXY} &= \text{MU04} * \text{RV0L}(17) * [\text{R12} * (\text{U12} * \text{X12} * \text{V12} * \text{Y31}) + \text{R23} * (\text{U13} * \text{X13} * \text{V13} * \text{Y32}) \\ &\quad + \text{R34} * (\text{U34} * \text{X34} * \text{V34} * \text{Y43}) + \text{R41} * (\text{U41} * \text{X41} * \text{V41} * \text{Y14}) \\ &\quad - .5 * \text{CYL} * (\text{V12} * \text{V34} * \text{XY})] \\ \text{PITH} &= .25 * \text{XY} * \text{CYL} * [\text{MU04} * \text{RV0L}(17) * (\text{U12} * \text{U34} * \text{XY}) + \text{LAMD}] \end{aligned}$$

CONTINUED ON NEXT PAGE —→

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SUBROUTINE YAQUI2 CONTINUED:

PHASE-1 CALCULATION - PAGE 3

UPDATING THE VERTICES:

$XX = HR24 * (PIXY * X24 - PIXX * Y24)$
 $YY = Y24 * P(IJ)$
 $UTIL(IPJ) = UTIL(IPJ) + DT02M1 * (XX + R1 * YY - PITH)$
 $UTIL(IJP) = UTIL(IJP) - DT02M3 * (XX + R3 * YY + PITH)$
 $XX = HR13 * (PIXY * X31 - PIXX * Y31)$
 $YY = Y31 * P(IJ)$
 $UTIL(IPJP) = UTIL(IPJP) + DT02M2 * (XX + R2 * YY - PITH)$
 $UTIL(IJ) = UTIL(IJ) - DT02M4 * (XX + R4 * YY + PITH)$
 $PYYMP = PIYY - P(IJ)$
 $XX = HR24 * (PYYMP * X24 - PIXY * Y24)$
 $VTIL(IPJ) = VTIL(IPJ) + DT02M1 * XX$
 $VTIL(IJP) = VTIL(IJP) - DT02M3 * XX$
 $XX = HR13 * (PYYMP * X31 - PIXY * Y31)$
 $VTIL(IPJP) = VTIL(IPJP) + DT02M2 * XX$
 $VTIL(IJ) = VTIL(IJ) - DT02M4 * XX$
 $XX = .5 * HR24 * [U24 * (X24 * PIXY - Y24 * PIXX) - V24 * (Y24 * PIXY - X24 * PIYY)]$
 $Q(IPJ) = Q(IPJ) + DT02M1 * XX$
 $Q(IJP) = Q(IJP) - DT02M3 * XX$
 $XX = .5 * HR13 * [U13 * (X31 * PIXY - Y31 * PIXX) - V13 * (Y31 * PIXY - X31 * PIYY)]$
 $Q(IPJP) = Q(IPJP) + DT02M2 * XX$
 $Q(IJ) = Q(IJ) - DT02M4 * XX$
 $IJ = IPJ$

TO NEXT CELL IN ROW
 $IJP = IPJP$
 ROW COMPLETED
 $UTIL(IJ) = UTIL(IJP) = UTIL(IJP - NQ1B)$
 $= UTIL(IJ - NQ1B) = 0.0$

RESET
 BOUNDARY
 VERTICES:
 $J:2$
 = RESET $\tilde{V}$'s ON BOTTOM:
 $DO 1210 IJ = ISC2, ISCF2, NQ$
 $VTIL(IJ) = 0.0$
 $\tilde{V}$'s ON BOTTOM ARE IN ROW
 $J=2$ WHICH IS ALWAYS IN
 SCM BUFFER ROW 2/3

NOTE: SINCE SUCCESSIVE CELLS WITHIN A ROW DO NOT REQUIRE THEIR NEIGHBORS' NEW TILDE VELOCITIES, IT IS REASONABLE TO RESET BOUNDARIES WHEN A ROW IS COMPLETED.

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2.0 SUBROUTINES - 3-PHASE ICED-ALE (CONT'D):

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SUBROUTINE YAQUIZ CONTINUED:

PHASE-1 CALCULATION - PAGE 4

CALCULATE $\tilde{E}$ FROM $\langle \tilde{E} \rangle$

NOTE 'PLE', THE NAME 'PL'
 IS A MESH VARIABLE.
 MR, ML, MT, MB & MC ARE
 DECLARED REAL.

IN '1300', $PL = \rho$ WAS INITIALIZED, PRESERVING ρ
 ALSO REQUIRED FOR PHASE 2. ARE:
 $UL = \tilde{U}$ BUT THESE ARE IN SAME
 $VL = \tilde{V}$ STORAGE WORDS, THUS NO
 $PL = \rho$ STORAGE TRANSFER IS
 REQUIRED. $UL = UTIL$
 $VL = VTIL$
 $PL = P$

THEREFORE, WE HAVE INITIALIZED
 UL, VL, PL, PL (SAVING ρ). (THE
 NAMES $\tilde{U}, \tilde{V}, Q$ ARE NO LONGER NEEDED.)

REFER TO
 FIG. 9 -
 STORAGE
 ALLOCATION

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《SUBROUTINE YAQUI2》 CONTINUED:

PHASE 2: ITERATION

2.0 SUBROUTINES - 3-PHASE ICED-ALE (CONT'D):

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《SUBROUTINE YAQUIZ》 CONTINUED:

PHASE-3 CALCULATION - Page 1

CALCULATE "n+1" VALUES OF $x, y, r, N_c, E, \frac{1}{V}, \rho$

《SUBROUTINE YAQUI2》 CONTINUED:

PHASE-3 CALCULATION - PAGE 2

$$M_c, E, \frac{1}{V}, P, \dots$$

IMPORTANT NOTE ON FLUX TERMS:

WITH THIS RIGID-WALL VERSION OF YAQUI, FL, FB, AL, & AB WILL AUTOMATICALLY BE CALCULATED AS 0 (INDEED: FT, FR, AT, & AR WILL ALSO BE 0 ON RIGID BOUNDARIES). ALTHOUGH FL, AL, FB, & AB COULD SIMPLY HAVE BEEN SET DIRECTLY TO 0.0 IN "3280" & "3290", THE FULL GENERAL EXPRESSIONS ARE INCLUDED HERE FOR POSSIBLE USE BY FUTURE VERSIONS OF YAQUI THAT HAVE BEEN SUITABLY MODIFIED TO ALLOW FOR BOUNDARY FLUXES. NOTE IN PARTICULAR THAT WITH NO FICTITIOUS CELLS ON THE LEFT, THE USE OF ANY NONZERO AL WILL RESULT IN ERRONEOUSLY REFERENCING P AND E VALUES FROM THE RIGHT SIDE OF THE MESH.

THE FINAL TERM IN AB (& AL) IS OF THE FORM:
 $\frac{4FB}{V_B + V_C}$ (NO BOUNDARY GRADIENT) $\rightarrow \frac{4FB}{2V_C} \rightarrow 2FB * RVOL$

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2.0 SUBROUTINES - 3-PHASE ICED-ALE (CONT'D):

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《SUBROUTINE YAQUI2》 CONTINUED:

PHASE-3 CALCULATION - PAGE 3

《SUBROUTINE YAQUI2》 CONTINUED:

PHASE-3 CALCULATION - PAGE 4

COMPLETE CALCULATION OF $n+1$ U, V. CALCULATE $n+1$ I:

$FM1 = F24 * RMP(IPJ)$
 $FM2 = F13 * RMP(IPJP)$
 $FM3 = F24 * RMP(IJP)$
 $FM4 = F13 * RMP(IJP)$
 $XX = B0 * 4. * RVOL(IJ) / ROL(IJ)$
 $AL13 = A0 * SIGN(1., F13) + XX * F13$
 $AL24 = A0 * SIGN(1., F24) + XX * F24$
 $OPAL13 = 1. + AL13$
 $OMAL13 = 1. - AL13$
 $OPAL24 = 1. + AL24$
 $OMAL24 = 1. - AL24$
 $XX = UL3 * OMAL24 + UL1 * OPAL24$
 $UP(IPJ) = UP(IPJ) - FM1 * XX$
 $UP(IJP) = UP(IJP) + FM3 * XX$
 $XX = UL4 * OMAL13 + UL2 * OPAL13$
 $UP(IPJP) = UP(IPJP) - FM2 * XX$
 $UP(IJ) = UP(IJ) + FM4 * XX$
 $XX = VL3 * OMAL24 + VL1 * OPAL24$
 $VP(IPJ) = VP(IPJ) - FM1 * XX$
 $VP(IJP) = VP(IJP) + FM3 * XX$
 $XX = VL4 * OMAL13 + VL2 * OPAL13$
 $VP(IPJP) = VP(IPJP) - FM2 * XX$
 $VP(IJ) = VP(IJ) + FM4 * XX$
 $IJ = IPJ$

 $n+1$ U $n+1$ V

TO NEXT CELL IN ROW
 3599 $IJP = IPJP$
 RESET
 BOUNDARY
 VERTICES:
 ROW COMPLETED
 $UP(IJ) = UP(IJP) = UP(IJP - NQIB)$
 $= UP(IJ - NQIB) = 0.0$
 $J = 2$
 = RESET $n+1$ U'S ON BOTTOM:
 D0 3610 $IJ = ISC2, ISC2, NQ$
 SCM. 2/3 CONTAINS J=2 VALUES
 3610 $VP(IJ) = 0.0$

NOTE: AS IN PHASE 1, SUCCESSIVE CELLS WITHIN A ROW DO NOT REQUIRE THEIR NEIGHBORS' NEW VELOCITIES; HENCE, BOUNDARIES ARE NOT RESET UNTIL ROW COMPLETION.

3620 $J = JP1$
 (SEE NOTES ON P. 20)
 = RESET $n+1$ U'S ALONG TOP:
 D0 3630 $IJP = IJPS, IJP2, NQ$
 3630 $VP(IJP) = 0.0$
 ROW DONE (ENDRY. CONDS. SET AS REQ'D)
 3640 CALL L00P
 3699 CONTINUE
 CALL DONE
 3700 CALL START
 D0 3719 $J = 2, JP2$ ALL
 D0 3709 $I = 1, IP1$ VERTICES
 MOVE
 $n+1$ U, V, MV
 TO NORMAL
 STORAGE
 WORDS:
 3709 $IJ = IJ + NQ$
 CALL L00P
 3719 CONTINUE
 CALL DONE
 MOVE $n+1$ U BEFORE
 $n+1$ $1/MV$ IS MOVED,
 AS $n+1$ U IS IN $n+1$ $1/M$
 STORAGE WORD.
 NOW THAT $n+1$ $1/MV$
 HAS BEEN MOVED,
 I STORAGE IS FREE,
 SO CALCULATE $n+1$ I

3800 CALL START
 D0 3899 $J = 2, JP1$ ALL
 D0 3889 $I = 1, IBAR$ CELLS
 $IPJ = IJ + NQ$
 $IPJP = IJP + NQ$
 $SIE(IJ) = E(IJ) - .175 * [U(IPJ) * 2 + U(IPJP) * 2 + U(IJP) * 2 + U(IJ) * 2 + V(IPJ) * 2 + V(IPJP) * 2 + V(IJP) * 2 + V(IJ) * 2]$
 $n+1$ I
 $IJP = IPJP$
 3889 $IJ = IPJ$
 CALL L00P
 3899 CONTINUE
 CALL DONE
 NPT: 0
 >
 CALL PARTMOV
 RETURN
 GO TO PRESSURE
 CALCULATION TO
 COMPLETE CYCLE

$n+1$ E HAS ALREADY
 BEEN STORED INTO
 "E" LOCATIONS
 @ "3300"

MOVE PARTICLES:

《END SUBROUTINE YAQUI2》

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2.0 SUBROUTINES — PARTICLE MOVER

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《SUBROUTINE PARTMOV》

《SUBROUTINE PARTMOV》- PAGE 2

2,0 SUBROUTINES - PARTICLE MOVER (CONT'D):

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SUBROUTINE PARTMOV - PAGE 3

MOVE PARTICLES IN RELATION TO OVERLAY GRID

《SUBROUTINE PARTMOV》- PAGE 4

2180 $XPAR(KP) = -10^3$ ← SET X_P TO AN UNREALISTIC VALUE TO INDICATE PARTICLE IS OUTSIDE; MAINLY MEANT FOR THE PARTICLE PLOT.

COMPLETE PARTICLE MOVEMENT BY WRITING FINAL BLOCK (MAY BE PARTIALLY FULL) BACK ONTO LCM:

2190 CALL ECWR (AASC, IEC, LPB, NE)

MOMENTUM TRANSFER BACK ONTO YAGUI GRID:

2500 $IMOMX = 0$ → RETURN
NO MOMENTUM TRANSFER

READ JTH ROW INTO SCM 1/3, LEAVING 2/3 & 3/3 FOR PART.GRID

IF OUTSIDE, TRY NEXT ROW:

$X(IJ) > PXR$ OR $Y(IJ) < PYB$

NEITHER TRUE

$Y(IJ) > PYT$ → YES → RETURN
ALL DONE

KI & KJ ARE INDICES OF PART.GRID CELL TO WHICH YAGUI VERTEX VALUES ARE ASSIGNED

READ PART.GRID INTO SCM 2/3 & 3/3. KIJ IS INDEX OF CELL; KIJP IS ROW ABOVE (IN 3/3).

NO → INSIDE OR ON PART.GRID
 $KI = X(IJ)$ $KJ = Y(IJ) - PYB$
 $IECP = KJ * NQI$
CALL ECWR (AASC, IEC, NQI, NE)
 $KIJ = (KI - 1) * NQI + ISC2$
 $KIJP = KI * NQI$

NOTE ON PMO USAGE (SEE ABOVE RIGHT):

PMO=0 IF VERTEX WAS NEVER SET IN "1000" LOOP, EVEN IF PU, PV WERE SET FROM NEIGHBORS IN "1200" & "1300." MOMENTUM TRANSFER CALCULATION CAN BE IMPERFECT THEREFORE, IF THERE IS MUCH DISPARITY IN SIZE BETWEEN YAGUI GRID & PARTICLE GRID. HOWEVER, REZONING IS NOT SO COMMONLY USED IN MOMENTUM TRANSFER PROBLEMS AS IT IS IN PROBLEMS IN WHICH THE PARTICLES ARE EMPLOYED SOLELY AS MARKERS.

$W = X(IJ) - FLOAT(KI - 1) * PDR$
 $H = [Y(IJ) - PYB] - FLOAT(KJ - 1) * PDZ$
 $HTE = PDZ - H$ ← BL, BR ($\Delta y - h$)
 $D0 25A9 JJ = 1, 2$
 $WTE = PDR - W$ ← BL, TL ($\Delta x - w$)
 $D0 25B9 II = 1, 2$
 $XX = RPDR2 * WTE + HTE + PMO(KIJ)$
 $U(IJ) = U(IJ) - XX * [SHIFT(PU(KIJ), 30)]$
 $V(IJ) = V(IJ) - XX * [SHIFT(PV(KIJ), 30)]$
 $WTE = W$ ← BR, TR (w)

2539 $KIJ = KIJ + NQ$ → TO BR OR TR CELL IN QUADRAINT

$HTE = H$ ← TL, TR (1.)

2549 $KIJ = KIJP$ → TO TL, TR

2589 $IJ = IJ + NQ$ → TO NEXT CELL IN YAGUI ROW

2599 CALL ECWR (AASC, IEC, NQI, NE)

STORE YAGUI ROW → LCM & GO UP A ROW

ALL ROWS DONE IN YAGUI GRID. → RETURN

《ENTRY PARPLOT》

PARTICLE PLOTTER:

CALL ADV(1) ← NEW FILM FRAME
CALL FRAME TWICE: OUTLINE REGION SURROUNDING (IPXL, IPXR, IPYT, IPYB)

NO WRITING → LPR: 0

CALL LINCNT (59) ← 59 LINES DOWN
WRITE: PDR, PDZ, PXR, PYB, PYT, JNM, NAME, T, NCYC

3000 $IECP = IPAR$ ← REL. ADDR. 1ST LCM PARTICLE

BLACK & WHITE OR COLOR?

$ICOLOR = 0$ → SET TO PLOT IN RED

$NPPT = 0$ ← COUNTS PARTICLES PLOTTED

3010 CALL ECWR (AASC, IEC, LPB, NE)
 $KP = 1$

3020 $XPAR(KP) = 0.0$

CONVERT PARTICLE TO 4020 COORDS. & PLOT:

$IXI = FIPXL + [XPAR(KP) - PXL] * PXC0NV$
 $IYI = FIFYPB + [YPAR(KP) - PYB] * PYC0NV$
CALL PLT (IXI, IYI, 42)

3050 $NPPT = NPPT + 1$

ALL ARE PLOTTED → $NPPT = NPT$

← MORE TO BE PLOTTED

$KP = KP + 3$

MORE IN BUFFER → $KP: LPB$

$IECP = IECP + LPB$

ALL PLOTTED IN BUFFER. ADVANCE REL. LCM READ ADDR.

3060 $ICOLOR = 0$ → TURN RED OFF.

《END SUBROUTINE PARTMOV》

2.0 SUBROUTINES - REZONE

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《SUBROUTINE REZONE》

SEARCH FOR
MAXIMUM
|U_L| OR |V_L|
IN FROM THE
BOUNDARIES,
TO CONTROL
MESH EXPANSION:

REZOMG = 0.15 * RDT $\leftarrow \Omega_p / \Omega$ UNDER-RELAXATION FACTOR
REZBTA = 0.002 $\leftarrow \beta$, DETERMINES HOW TIGHTLY
VERTICES WILL BE DRAWN
TOGETHER.
XX = -1.E+6
CALL START
FCR = FCT - FCB = .XX * XOMSUM - YOMSUM
DO 1049 J = 2, JPI $\leftarrow \text{XOMSUM} = 0.0$
DO 1039 I = 1, IPI
AEL = AMAX1(|UL(IJ)|, |VL(IJ)|)
XXX = AMAX1(XXX, AEL)

I : IM6 = FCR = AMAX1(FCR, AEL)

J : JMI4 = FCT = AMAX1(FCT, AEL)

J : 9 = FCB = AMAX1(FCB, AEL)

1039 IJ = IJ + NQ
CALL L3BP

1049 CONTINUE
FCR = SQRT(FCR * XXX)
FCT = SQRT(FCT * XXX)
FCB = SQRT(FCB * XXX)
CALL START
DO 1039 J = 2, JPI

SEARCH FOR
MAXIMUM
|VORTICITY|,
TO CONTROL
MESH TRANSLATION:

J : JPA42 = YCEN = Y(IJ) $\leftarrow$ SAVE HT. OF MESH CENTER,
ASSUMED HERE TO BE
SAME AS THE DESIRED
BURST CENTER.

DO 1059 I = 1, IBAR
IPJ = IJ + NQ
IPJP = IJP + NQ

J < 10 OR J > JMI0 OR I > IM6 NONE TRUE

ANY TRUE — OMIT REGIONS NEAR THE
BOUNDARIES.

X1 = X(IPJ) X2 = X(IPJP) X3 = X(IJP) X4 = X(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)

RI = 0.125 * RVOL(IJ) * [R(IPJ) + R(IPJP) + R(IJP) + R(IJ)]
YY = RI * [(U1 + U4) * (X1 - X4) + (V1 + V4) * (Y1 - Y4)
+ (U2 + U1) * (X2 - X1) + (V2 + V1) * (Y2 - Y1)
+ (U3 + U2) * (X3 - X2) + (V3 + V2) * (Y3 - Y2)
+ (U4 + U3) * (X4 - X3) + (V4 + V3) * (Y4 - Y3)]

YY : 0.0

≤ VORTICITY OF INTEREST IS THE ALGEBRAIC MINIMUM
(AND NEGATIVE)

YY = YY * YY
XOMSUM = XOMSUM + YY * X4 $\leftarrow \sum xw$
YOMSUM = YOMSUM + YY * Y4 $\leftarrow \sum yw$
OMSUM = OMSUM + YY $\leftarrow \sum w$

1055 IJ = IPJ

1059 IJP = IPJP
CALL L3BP

1069 CONTINUE $\leftarrow$ SKIP "CALL DONE" AS REF. ONLY
XC = XOMSUM / OMSUM
YC = YOMSUM / OMSUM
REZVT = AMAX1(0.0, [REZOMG * .5 * (YC - YCEN)])
 $\left\{ \begin{array}{l} XC = \sum xw / \sum w \\ YC = \sum yw / \sum w \end{array} \right.$

CALCULATE
TRANSLATION
VELOCITY
(V_T)

CONTINUED ON NEXT PAGE →

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《SUBROUTINE REZONE》 - PAGE 2

 U_q, V_q CALCULATE
 $\bar{J}_j$ SPECIFY
VELOCITIES
OF
BOTTOM
& TOP
BOUNDARIES:CALCULATE
 $\bar{Z}_j$ ARRAY
WHILE $j=2$:SPECIFY
VELOCITIES
OF
LEFT
& RIGHT
BOUNDARIES:

1080 $U_q(IJ) = U_{qTE}(I)$
 $V_q(IJ) = V_{qTE}$

1089 $IJ = IJP$
 CALL LOOP

1099 CONTINUE
 CALL DONE

CALL START
 DO 1099 J=2, Jp2 ← ALL VERTICES
 $\bar{Y}BAR = .5 * [Y(IJP) + Y(IJM)]$
 $+ REZBTA * [YC - Y(IJ)]$
 $V_{qTE} = REZOMG * [\bar{Y}BAR - Y(IJ)]$
 $+ REZVT$

J:2 ⇒ $V_{qTE} = -FCB$

J:Jp2 ⇒ $V_{qTE} = FCT$

DO 1089 I=1, IPI ← ALL VERTICES
 $IPJ = IJ + NQ$

J:2

$\bar{X}BAR = .5 * [X(IPJ) + X(IJ - NQ)]$
 $+ REZBTA * [XC - X(IJ)]$
 $U_{qTE}(I) = REZOMG * [\bar{X}BAR - X(IJ)]$

I:1 ⇒ $U_{qTE} = 0.0$

I:IPI ⇒ $U_{qTE}(I) = FCR$

1200 CALL START
 $XIP1 = YJP2 = 0.0$ } INITIALIZE
 $Y2 = 10^{20}$
 DO 1289 J=2, Jp2 } ALL VERTICES
 DO 1279 I=1, IPI
 $X(IJ) = X(IJ) + U_q(IJ) * DT$
 $Y(IJ) = Y(IJ) + V_q(IJ) * DT$
 $R(IJ) = X(IJ) * CYL + OM * CYL$

n+1
 X, Y, R

CALC.
 MAXIMUM
 EXTENT
 OF
 GRID
 IN
 ALL 3
 DIRECTIONS

J:2 ⇒ $Y2 = AMIN1[Y(IJ), Y2]$

J:Jp2 ⇒ $YJP2 = AMAX1[Y(IJ), YJP2]$

I:IPI ⇒ $XIP1 = AMAX1[X(IJ), XIP1]$

1279 $IJ = IJ + NQ$ ← DO ENTIRE ROW
 CALL LOOP ← GO UP A ROW

1289 CONTINUE ← DO ALL ROWS.
 CALL DONE

DEFINE NEW PARTICLE GRID

$PDR = XIP1 * RIBP$
 $PDZ = (YJP2 - Y2) * RJBP$
 $PYB = 0.0$
 CALL FILMCO {SET UP FOR PLOTS,
 NEW GRIDS DEFINED}

(PARTICLE GRID THIS JUST COVERS
 YAQUI GRID THROUGHOUT THE RUN.
 THIS IS THE SIMPLEST TREATMENT,
 ESP. WHEN THE CENTER OF RESOLUTION
 IS MOVING OUT RADIALY.)

UPON
RETURN

SET ρ_L IN EXTERIOR ZONES (USING THE
 NEW COORDINATES):

CALL START
 $YY = |GZ| / (GM1 * REZSIE)$
 DO 1399 J=2, JPI } ALL CELL
 DO 1389 I=1, IBAR } CENTERS
 $IPJ = IJ + NQ$
 $IPJP = IJP + NQ$
 $Y4 = REZYO + 0.25 * [Y(IJP) + Y(IPJP) + Y(IJ) + Y(IPJ)]$

J:2 ⇒ $ROL(IJM) = REZRON * EXP$
 $\{[Y4 - Y(IJ) - Y(IPJ)] * YY\}$

I:IBAR ⇒ $ROL(IPJ) = REZRON * EXP$
 $\{[Y4 - Y(IPJ) - Y(IPJP)] * YY\}$

J:JPI ⇒ $ROL(IJP) = REZRON * EXP$
 $\{[Y4 - Y(IJP) - Y(IPJP)] * YY\}$

$IJM = IJM + NQ$
 $IJP = IJP + NQ$

1389 $IJ = IJP$
 CALL LOOP

1399 CONTINUE
 CALL DONE

RETURN

《END SUBROUTINE REZONE》

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APPENDIX B

FORTRAN IV INDEX LISTING OF THE YAQUI PROGRAM

INDEX 01/12/73
1

OVERLAY (YAQUFIL,0,0)
OVERLAY (YAQUFIL,0,0)

PAGE 1
YAQUI 00002

INDEX	01/12/73	PROGRAM YAQUI (INP,OUT,FILM,FSET9=OUT,FSET12=FILM,FSET7,FSET8)	PAGE 2
1		PROGRAM YAQUI (INP,OUT,FILM,FSET9=OUT,FSET12=FILM,FSET7,FSET8)	YAQUI 00003
2		LCM /YLC1/ AA1(131000) /YLC2/ AA2(131000)	YAQUI 00004
3		COMMON /YSC1/ AASC(4242)	COMMON2 00002
4		COMMON /YSC2/ AA(1),ANC,ASO,A0,A0FAC,A0M,B0,C0LAMU,CYL,	COMMON2 00003
	1	DR,DT,D- :DTFAC,DTGR,DTGZ,DTGZP,DT0(10),DT0C(10),	COMMON2 00004
	2	DT016,DT02,DT04,DT08,DT0S,DTV,DT8,DZ,EM10,EPS,FIBP,	COMMON2 00005
	3	FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FXR,FIYB,FIYT,FJBP,	COMMON2 00006
	4	FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IRAR,IRP,IBP1,ICOLOR,	COMMON2 00007
	5	IDT0,IJ,IJM,IJP,IJPS,IMOM3,IMOMX,IM1,IM6,	COMMON2 00008
	6	IPAR,IPXL,IPXR,IPYB,IPYT,IP1,IP2,ISC1,ISC2,ISC3,	COMMON2 00009
	7	ITV,IUNF,IXL,IXR,IYB,IYT,J,JRAR,JBP,JBP2,JCEN,JM10,	COMMON2 00010
	8	JM14,JP1,JP2,JP4,JP402,JUNF,JUNF02,KXI,LAM,LJP2,LPR,	COMMON2 00011
	9	LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQ1,NQIB,NQ12,NSC,	COMMON2 00012
	1	NUMIT,NUMT0,OM,OMANC,OMCYL,OMEM10,OPEM:0,FDR,PDZ,PXCONV,	COMMON2 00013
	2	PXL,PXR,PXRP,PYB,PYRM,PYCONV,PYT,PYTP,NDT,REZRON,REZSIE,	COMMON2 00014
	3	REZUE,REZVE,REZVT,REZY0,RIAR,RIHJR,RIAP,RJBF,ROMFR,	COMMON2 00015
	4	RON,RPRD,RPRDZ,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,T20MD,	COMMON2 00016
	5	VV,XCONV,XI,XR,YB,YCONV,YT,ZZ	COMMON2 00017
	5	EQUIVALENCE (AASC(1),X,XPAR),(AASC(2),R,YPAR),(AASC(3),Y,MPAR),	EQVREAL 00002
	1	(AASC(4),U,UG,DELSM),(AASC(5),V,VG),(AASC(6),RO),	EQVREAL 00003
	2	(AASC(7),STE,MP,RMP,RCSG),(AASC(8),E,ETIL),	EQVREAL 00004
	3	(AASC(9),RVOL),(AASC(10),M,RM,VP),(AASC(11),P,PL,EP,	EQVREAL 00005
	4	UP,PM0),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL,	EQVREAL 00006
	5	VL,PHY,PV),(AASC(14),Q,ROL)	EQVREAL 00007
	6	REAL LAM,LAMD,M,MB,MC,ML,MP,MPAR,MR,MT,MTE,MU,MUO2,MUO4	EQVREAL 00008
	7	NQ = 14	YAQUI 00007
	8	PRINT 100	YAQUI 00008
	9	10 READ 110, IBAR,JBAR,IUNF,JUNF,JCEN,DR,DZ,CYL,GRDVEL,A0,A0M,B0,KXI	YAQUI 00009
	10	CALL ADV (3)	YAQUI 00010
	11	CALL LINCNT (64)	YAQUI 00011
	12	IF (IRAR) 40,30,20	YAQUI 00012
	13	20 CALL OVERLAY (7LYAQUFIL,1,0,0)	YAQUI 00013
	14	30 CALL OVERLAY (7LYAQUFIL,2,0,0)	YAQUI 00014
	15	GO TO 10	YAQUI 00015
	16	40 CALL EMPTY	YAQUI 00016
	C		YAQUI 00017
	17	100 FORMAT (1H)	YAQUI 00018
	18	110 FORMAT (5I4,/F8,3,I4)	YAQUI 00019
	19	END	YAQUI 00020

INDEX 01/12/73 PROGRAM YAQUI (INP,OUT,FILM,FSET9=OUT,FSET12=FILM,FSET7,FSET8) PAGE 3

SINGLY REFERENCED VARIABLES

AA	(1)R	4C0	EPS	-R	4C0	IJM	-I	4C0	JP1	-I	4C0	NUMTD	-I	4C0	READ	-	9F	U	-R	5EQ
AA1	(1)R	2LC	EQUIVAL	-	5F	IJP	-I	4C0	JP2	-I	4C0	OM	-R	4C0	REAL	-	6F	UG	-R	5EQ
AA2	(1)R	2LC	ETIL	-R	5EQ	IJP5	-I	4C0	JP4	-I	4C0	OMANC	-R	4C0	REZRON	-R	4C0	UL	-R	5EQ
ADV	-	10SU	FIRP	-R	4C0	IMOME3	-I	4C0	JP402	-I	4C0	OMCYL	-R	4C0	REZSIE	-R	4C0	UP	-R	5EQ
ANC	-R	4C0	FIPXL	-R	4C0	IMOMX	-I	4C0	JUNF02	-I	4C0	OMEM10	-R	4C0	REZUE	-R	4C0	UTIL	-R	5EQ
ASQ	-R	4C0	FIPXR	-R	4C0	IM1	-I	4C0	LAMD	-R	6RL	OPEM10	-R	4C0	REZVE	-R	4C0	V	-R	5EQ
AOFAC	-R	4C0	FIPYB	-R	4C0	IM6	-I	4C0	LCM	-	2F	P	-R	5EQ	REZVT	-R	4C0	VG	-R	5EQ
COLAMU	-R	4C0	FIPYT	-R	4C0	INP	-I	1AG	LINCNT	-	11SU	PDR	-R	4C0	REZY0	-R	4C0	VL	-R	5EQ
CQ	-R	5EQ	FIXL	-R	4C0	IPAR	-I	4C0	LJP2	-I	4C0	POZ	-R	4C0	R1BAR	-R	4C0	VP	-R	5EQ
DELSM	-R	5EQ	FIXR	-R	4C0	IPXL	-I	4C0	LPB	-I	4C0	PL	-R	5EQ	R1RJB	-R	4C0	VTL	-R	5EQ
OT	-R	4C0	F1YB	-R	4C0	IPXR	-I	4C0	LPR	-I	4C0	PMX	-R	5EQ	R1AP	-R	4C0	VV	-R	4C0
OTC	-R	4C0	F1YT	-R	4C0	IPYB	-I	4C0	MB	-R	6RL	PMY	-R	5EQ	RJRP	-R	4C0	X	-R	5EQ
OTFAC	-R	4C0	FJRP	-R	4C0	IPYT	-I	4C0	MC	-R	6RL	PMQ	-R	5EQ	RM	-R	5EQ	XCONV	-R	4C0
OTC2	-R	4C0	FHEZ	-R	4C0	IP1	-I	4C0	ML	-R	6RL	PRINT	-	8F	RMP	-R	5EQ	XL	-R	4C0
OTGZ	-R	4C0	FSET12	-R	1AG	IP2	-I	4C0	MR	-R	6RL	PU	-R	5EQ	RO	-R	5EQ	XPAR	-R	5EQ
OTGZP	-R	4C0	FSET7	-R	1AG	ISC1	-I	4C0	MT	-R	6RL	PV	-R	5EQ	ROL	-R	5EQ	XR	-R	4C0
OTO	(1)R	4C0	FSET8	-R	1AG	ISC2	-I	4C0	MTE	-R	6RL	PXCONV	-R	4C0	ROMFR	-R	4C0	Y	-R	5EQ
OTOC	(1)R	4C0	FSET9	-R	1AG	ISC2	-I	4C0	MU02	-R	6RL	PXL	-R	4C0	RON	-R	4C0	YAQUI	-	1SU
OTO1A	-R	4C0	GGM1	-R	4C0	ISC3	-I	4C0	MU04	-R	6RL	PXR	-R	4C0	RPDR	-R	4C0	YB	-R	4C0
OTO2	-R	4C0	GM1	-R	4C0	ITV	-I	4C0	NAME	(1)I	4C0	PXRP	-R	4C0	RPDRDZ	-R	4C0	YCONV	-R	4C0
OTO4	-R	4C0	GR	-R	4C0	IXL	-I	4C0	NCYC	-I	4C0	PYB	-R	4C0	RPDZ	-R	4C0	YLC1	-	2CN
OTO8	-R	4C0	GZ	-R	4C0	IXR	-I	4C0	NLC	-I	4C0	PYBM	-R	4C0	RVOL	-R	5EQ	YLC2	-	2CN
OTPO5	-R	4C0	GZP	-R	4C0	IYB	-I	4C0	NPS	-I	4C0	PYCCNV	-R	4C0	SIE	-R	5EQ	YPAR	-R	5EQ
OTV	-R	4C0	I	-I	4C0	IYT	-I	4C0	NPT	-I	4C0	PYT	-R	4C0	T	-R	4C0	YSC1	-	3CN
OTB	-R	4C0	IRP	-I	4C0	J	-I	4C0	NQ1	-I	4C0	PYTP	-R	4C0	THIRD	-R	4C0	YSC2	-	4CN
F	-R	5EQ	IRP1	-I	4C0	JBP	-I	4C0	NQ1B	-I	4C0	Q	-R	5EQ	TLMD	-R	4C0	YT	-R	4C0
FMPY	-	16SU	ICOLOR	-I	4C0	JBP2	-I	4C0	NQ12	-I	4C0	R	-R	5EQ	TOUT	-R	4C0	ZZ	-R	4C0
FM10	-R	4C0	INTO	-I	4C0	JM10	-I	4C0	NSC	-I	4C0	RCSQ	-R	5EQ	TWFIN	-R	4C0			
FP	-R	5EQ	IJ	-I	4C0	JM14	-I	4C0	NUMIT	-I	4C0	RDT	-R	4C0	T20MD	-R	4C0			

MULTIPLY-REFERENCED VARIABLES

10	-	9*	15																	
20	-	12	13*																	
30	-	12	14*																	
40	-	12	16*																	
100	-	8PR	17*																	
110	-	9RD	18*																	
AASC	(1)R	3C0	5EQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ	SEQ
A0	-R	4C0	9RD																	
A0M	-R	4C0	9RD																	
R0	-R	4C0	9RD																	
COMMON	-	3F	4F																	
CYL	-R	4C0	9RD																	
DR	-R	4C0	9RD																	
DZ	-R	4C0	9RD																	
FILM	-R	1AG	1AG																	
GRDVEL	-R	4C0	9RD																	
IBAR	-I	4C0	9RD	12																
JUNF	-I	4C0	9RD																	
JBAR	-I	4C0	9RD																	
JCFN	-I	4C0	9RD																	
JUNF	-I	4C0	9RD																	
KX1	-I	4C0	9RD																	
LAM	-R	4C0	6RL																	
M	-R	5EQ	6RL																	
MP	-R	5EQ	6RL																	
MPAR	-R	5EQ	6RL																	

INDEX 01/12/73 PROGRAM YAQUI (INP,OUT,FILM,FSET9=OUT,FSET12=FILM,FSET7,FSET8)

MU	-R	4C0	6RL																	
NQ	-I	4C0	7*																	
OUT	-R	1AG	1AG																	
OVERLAY	-	13SU	14SU																	

INDEX	01/12/73	SUBROUTINE LOOP	PAGE	5
1		SUBROUTINE LOOP	YAQUI	00021
2		COMMON /YSC1/ AASC(4242)	COMMON2	00002
3		COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,B0,COLAMU,CYL, DR,DT,DTFAC,DTGR,DTGZ,DTGZP,DT0(10),DT0C(10), DT016,DT02,DT04,DT08,DT0S,DTV,DTR,DZ,EM10,EPS,FIBP, FIPXL,FIPXR,FIPYB,FIPYT,FI XL,FI XR,FI YB,FI YT,FJBP, FRFZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IHAR,IRP,IBP1,ICOLDR, IDTO,IJ,IJM,IJP,IJPS,IMOME3,IMOMX,IM1,IM6, IPAR,IPXL,IPXR,IPYB,IPYT,IP1,IP2,ISC1,ISC2,ISC3, ITV,IUNF,IXL,IXR,IYB,IYT,J,JBAR,JRP,JBP2,JCEN,JM10, JM14,JP1,JP2,JP4,JP402,JUNF,JUNF02,KXI,LAM,LJP2,LPR, LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQ1,NQ1B,NQ1Z,NSC, NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV, PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE, REFZUE,REZVF,REZVT,REZY0,RIHAR,RIJB,RIBP,RJBP,ROMFR, RON,RPDR,RPDRDZ,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,TZOMD, VV,XCONV,XL,XR,YB,YCONV,YT,ZZ	COMMON2	00003
4		CALL ECWR (AASC(IJMS),IECW,NQ1,NE)	YAQUI	00023
5		IECW = IECW + NQ1	YAQUI	00024
6		GO TO (10,20,30) IRUF	YAQUI	00025
7	10	IJP = IJPS = I	YAQUI	00026
8		IJ = ISC3	YAQUI	00027
9		IJM = IJMS = ISC2	YAQUI	00028
10		IRUF = 2	YAQUI	00029
11		GO TO 40	YAQUI	00030
12	20	IJP = IJPS = ISC2	YAQUI	00031
13		IJ = 1	YAQUI	00032
14		IJM = IJMS = ISC3	YAQUI	00033
15		IRUF = 3	YAQUI	00034
16		GO TO 40	YAQUI	00035
17		ENTRY START	YAQUI	00036
18		IJPS = 1	YAQUI	00037
19		IECR = IECW = 0	YAQUI	00038
20		CALL ECRD (AASC(IJPS),IECR,NQ1,NE)	YAQUI	00039
21		IECR = IECR + NQ1	YAQUI	00040
22		IJPS = ISC2	YAQUI	00041
23		CALL ECRD (AASC(IJPS),IECR,NQ1,NE)	YAQUI	00042
24		IECR = IECR + NQ1	YAQUI	00043
25	30	IJP = IJPS = ISC3	YAQUI	00044
26		IJ = ISC2	YAQUI	00045
27		IJM = IJMS = IRUF = 1	YAQUI	00046
28	40	CALL ECRD (AASC(IJPS),IECR,NQ1,NE)	YAQUI	00047
29		IECR = IECR + NQ1	YAQUI	00048
30		RETURN	YAQUI	00049
31		ENTRY DONE	YAQUI	00050
32		CALL ECWR (AASC(IJMS),IECW,NQ1,NE)	YAQUI	00051
33		IECW = IECW + NQ1	YAQUI	00052
34		GO TO (50,60,70) IRUF	YAQUI	00053
35	50	IJMS = ISC2	YAQUI	00054
36		GO TO 80	YAQUI	00055
37	60	IJMS = ISC3	YAQUI	00056
38		GO TO 80	YAQUI	00057
39	70	IJMS = 1	YAQUI	00058
40	80	CALL FCWR (AASC(IJMS),IECW,NQ1,NE)	YAQUI	00059
41		RETURN	YAQUI	00060
42		ENTRY LOOPD	YAQUI	00061
43	100	CALL FCWR (AASC(IJMS),IECW,NQ1,NE)	YAQUI	00062
44		IECW = IECW + NQ1	YAQUI	00063

INDEX	01/12/73	SUBROUTINE LOOP	PAGE	6
45		GO TO (110,120,140) IBUF	YAQUI	00064
46	110	IBUF = 2	YAQUI	00065
47		IJ = ISCF1	YAQUI	00066
48		IJS = 1	YAQUI	00067
49		IJM = ISCF2	YAQUI	00068
50		IJMS = ISC2	YAQUI	00069
51		GO TO 130	YAQUI	00070
52		ENTRY STARTD	YAQUI	00071
53		IJMS = ISC2	YAQUI	00072
54		IECR = IECW = ITV	YAQUI	00073
55		CALL ECRD (AASC(IJMS),IECR,NQI,NE)	YAQUI	00074
56		IECR = IECR = NQI	YAQUI	00075
57	120	IJM = ISCF1	YAQUI	00076
58		IJMS = IBUF = 1	YAQUI	00077
59		IJ = ISCF2	YAQUI	00078
60		IJS = ISC2	YAQUI	00079
61	130	IF (IECR.LT.0) GO TO 150	YAQUI	00080
62		CALL ECRD (AASC(IJMS),IECR,NQI,NE)	YAQUI	00081
63		IECR = IECR = NQI	YAQUI	00082
64	140	RETURN	YAQUI	00083
65	150	IBUF = 3	YAQUI	00084
66		GO TO 100	YAQUI	00085
67		ENTRY RIROW	YAQUI	00086
68		IEC = (J-1) * NQI	YAQUI	00087
69		CALL ECRD (AASC(1),IEC,NQI,NE)	YAQUI	00088
70		RETURN	YAQUI	00089
71		ENTRY SETIJ	YAQUI	00090
72		IJ = (I-1) * NQ + 1	YAQUI	00091
73		RETURN	YAQUI	00092
74		ENTRY WIROW	YAQUI	00093
75		IEC = (J-1) * NQI	YAQUI	00094
76		CALL ECRD (AASC(1),IEC,NQI,NE)	YAQUI	00095
77		RETURN	YAQUI	00096
78		END	YAQUI	00097

MULTIPLY-REFERENCED VARIABLES

15CF? -1 300 49 5

INDEX	01/12/73	9	12	22	SUBROUTINE	LOOP	PAGE	8	
1SC2	3C0	8	14	25	26	35	50	53	60
1SC3	3C0	8	14	25	26	35	50	53	60
1TV	3C0	8	14	25	26	35	50	53	60
1	3C0	8	14	25	26	35	50	53	60
NE	4A6	20A6	23A6	28A6	32A6	40A6	43A6	55A6	62A6
NO	3C0	72	23A6	28A6	32A6	40A6	43A6	55A6	62A6
NO1	3C0	4A6	5	20A6	21	23A6	24	28A6	29
RETURN	30F	41F	64F	70F	73F	77F			

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SUBROUTINE FILMCO
COMMON /YSC1/ AASC(4242)
COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,BC,COLAMU,CYL,
1 DR,DT,DTC,DTFAC,DTGR,DYGT,DTGZP,DT0(10),DT0C(10),
2 DT016,DT02,DT04,DT08,DT0S,DTV,DTR,DZ,EM10,EPS,FIBP,
3 FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FXR,FIYB,FIYT,FJBP,
4 FREZ,GGM1,GMI,GR,GRDVEL,GZ,GZP,I,IRAR,IRP,IRP1,ICOLOR,
5 TOT0,IJ,IJM,IJP,IJPS,IMOM3,IMOMX,IP1,IM6,
6 IPAR,IPXL,IPXR,IPYB,IPYT,IP1,IP2,ISCF1,ISCF2,ISC2,ISC3,
7 IYV,IUNF,IXL,IXR,IYB,IYT,J,JRAB,JRP,JRP2,JCEN,JM10,
8 JM14,JP1,JP2,JP4,JP402,JUNF,JUNF02,KXI,LAM,LJP2,LPR,
9 LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQ1,NQIR,NQI2,NSC,
1 NUMJT,NUMTN,OM,OMANC,OMCYL,OMEM10,OMEM10,PDR,PDZ,PXCONV,
2 PXL,PXR,PXRP,PYB,PYRM,PYCONV,PYT,PYTP,ROD,REZRON,REZSIE,
3 REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJR,RIAP,RJAP,ROMFR,
4 RON,RPRD,RPRDZ,RPDZ,T,THIRD,TIMD,TOUT,TWFIN,TZOMD,
5 VV,XCONV,XL,XR,YB,YCONV,YT,ZZ
4 EQUIVALENCE (AASC(1),X,XPAR),(AASC(2),R,YPAR),(AASC(3),Y,MPAR),
1 (AASC(4),U,UG,DELMS),(AASC(5),V,VG),(AASC(6),RO),
2 (AASC(7),SIE,MP,RMP,RCSQ),(AASC(8),E,ETIL),
3 (AASC(9),RVOL),(AASC(10),M,RM,VP),(AASC(11),P,PL,EP,
4 UP,PM0),(AASC(12),UL,UL,CQ,PMX,PU),(AASC(13),VTIL,
5 VL,PMY,PV),(AASC(14),Q,ROL)
5 REAL LAM,LAMD,M,MR,MC,ML,MP,MPAR,MR,MT,MTE,MU,MUO2,MUO4
6 DIMENSION X(1),XPAR(1),R(1),YPAR(1),Y(1),MPAR(1),U(1),UG(1),
1 DELSM(1),V(1),VG(1),RO(1),SIE(1),MP(1),RMP(1),RCSQ(1),
2 E(1),ETIL(1),RVOL(1),M(1),RM(1),VP(1),P(1),PL(1),EP(1),
3 UP(1),UTIL(1),UL(1),CQ(1),PMX(1),PU(1),VTIL(1),VL(1),
4 PMY(1),PV(1),Q(1),ROL(1),PM0(1)
7 XL = 0.0
8 YB = 1.E+20
9 XR = YT = -YB
10 CALL START
11 DO 129 J=2,JP2
12 DO 119 I=1,IP1
13 XR = AMAX1(XR,X(IJ))
14 YB = AMIN1(YB,Y(IJ))
15 YT = AMAX1(YT,Y(IJ))
16 119 IJ = IJ + NQ
17 CALL LOOP
18 129 CONTINUE
19 VV = 0.9*XR*RIBAR
20 FIYB = 916.0
21 XN = XR/(YT-YB)
22 YY = 0.0
23 IF (XD.LE.1.13556) YY=1.
24 FIXL = AMAX1(0.,(511.-450.*XD)*YY)
25 FIXR = (511.-450.*XD)*YY + 1022.*(1.-YY)
26 FIYT = 16.*YY + (916.-1022.*XD)*(1.-YY)
27 XCONV = (FIXR-FIXL)/(XR-XL)
28 YCONV = (FIYT-FIYB)/(YT-YB)
29 IXL = FIXL
30 IXR = FIXR
31 IYB = FIYB
32 IYT = FIYT
33 IF (NPT.EQ.0) RETURN
34 PXL = 0.0
35 PYB = YB + PYB

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YAQUI 00098
COMMON2 00002
COMMON2 00003
COMMON2 00004
COMMON2 00005
COMMON2 00006
COMMON2 00007
COMMON2 00008
COMMON2 00009
COMMON2 00010
COMMON2 00011
COMMON2 00012
COMMON2 00013
COMMON2 00014
COMMON2 00015
COMMON2 00016
COMMON2 00017
EQVREAL 00002
EQVREAL 00003
EQVREAL 00004
EQVREAL 00005
EQVREAL 00006
EQVREAL 00007
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DIMEN 00002
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DIMEN 00004
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SUBROUTINE FILMCO

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36   PXR = PDR*FIBP
37   PYT = PYB + PDZ*FJBP
38   PXR = PXR*OPEM10
39   PYB = PYB*OPEM10
40   PYT = PYT*OPEM10
41   RPDZ = 1./PDR
42   RPDZ = 1./PDZ
43   RPDZ = RPDZ*RPDZ
44   FIPYB = 916.0
45   XD = PXR/(PYT-PYB)
46   YY = 0.0
47   IF (XN.LE.1.13556) YY=1.
48   FIPXL = AMAX1(0.,(511.-450.*XN)*YY)
49   FIPXR = (511.*450.*XD)*YY + 1022.*(1.-YY)
50   FIPYT = 16.*YY + (916.-1022./XD) *(1.-YY)
51   PXCONV = (FIPXR-FIPXL)/(PXR-PXL)
52   PYCONV = (FIPYT-FIPYB)/(PYT-PYB)
53   IPIXL = FIPXL
54   IPXR = FIPXR
55   IPYB = FIPYB
56   IPYT = FIPYT
57   RETURN
58   END

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YAQUI	00153

[illegible]

[illegible]

YT	INDEX	01/12/73					SUBROUTINE FILMCO							PAGE	13
YY	-R	3CO	9=	15=	15	21	28								
	-R	2P=	23=	24	25	25	26	26	46=	47=	48	49	49	50	50

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INDEX	01/12/73		OVERLAY(YAQUFIL,1,0)	PAGE	14
	1			YASET	00002

INDEX	01/12/73		PROGRAM YASET	PROGRAM YASET	PAGE	15
	1		PROGRAM YASET		YASET	00003
	2		PRINT 10		YASET	00004
	3		CALL YASET1		YASET	00005
	4	10	FORMAT(= YASET CALLED=)		YASET	00006
	5		END		YASET	00007

INDEX	01/12/73		PROGRAM YASET	PAGE	16	
	SINGLY REFERENCED VARIABLES					
	PRINT =	2F	YASET =	1SU	YASET1 =	3SU
	MULTIPLY-REFERENCED VARIABLES					
	10 =	2PR	4=			

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SUBROUTINE YASET1
  COMMON /YSC1/ AAL(131000)
  COMMON /YSC2/ AA(1),ANC,ASQ,AG,ADOFAC,AGM,RU,COLAMU,CYL,
  1  DRNT,DTIC,DTFAC,DTGR,DTGZ,DTGP,DTN,101,DTNC(10),
  2  DT016,DT02,DT04,DTOR,DTPOS,DTV,DTB,GZ,EM10,EP5,FIBP,
  3  FIPXL,FIPXR,FIPYR,FIPY,FIPL,FIKR,FIYB,FIYI,FJBP,
  4  FREZGG1,GH1,GR,GRDEL,GZ,GZP,I,IRAR,IRP,IRPI,ICOLOR,
  5  IDTO,IJA,IJM,IJP,IJS,IMOM3,IMOMX,IM1,IM6,
  6  IPAR,IPXL,IPXR,IPYR,IPY,IPI,IP2,ISC1,ISC2,ISC3,
  7  ITV,IUNF,IXL,IXR,IYB,IYI,IYJ,IRAR,JBP,JBP2,JCN,JM10,
  8  JM14,JPI,JP2,JP4,JP402,JINF,JUNF02,XI,LAM,LJP2,LPR,
  9  LPR,MU,NUMT0,NM,NCYC,NLC,NPL,NPT,NQ1,NQ1R,NQ12,NSC,
  1  PXL,PXR,PXP,PYR,PYBM,PYCONV,PYI,PYP,PDZ,REZRON,REZSIE,
  2  REZUE,REZVE,REZVT,REZYN,RIRAR,RIYJR,RIYR,ROMR,
  3  RDN,RPDR,RPDR2,RPN2,T,THIRD,TL,IND,TOUT,TWFIN,TZOMD,
  4  VV,XCONV,XL,XR,YB,YCONV,YT,YZ
  5  EQUIVALENCE (AASC(1),X,XPAR),AASC(2),R,YPAR),AASC(3),Y,MPAR),
  1  AASC(4),U,UUG,DELSM),AASC(5),V,VG),AASC(6),RO),
  2  AASC(7),SIE,MP,RHP,RCSQ),AASC(8),E,ETIL),
  3  AASC(9),RVOL),AASC(10),M,RM,VP),AASC(11),P,PL,EP,
  4  UP,PM0),AASC(12),UTIL,UL,CO,PIX,PU),AASC(13),VTIL,
  5  VL,PV,PV),AASC(14),Q,RQ)
  6  REAL LAM,LAND,M,MR,MC,NL,MP,MPAR,MT,MT,MT,MU,MU02,MU04
  7  DIMENSION X(1),XPAR(1),R(1),YPAR(1),Y(1),MPAR(1),U(1),UG(1),
  1  DELSM(1),V(1),VG(1),RO(1),SIE(1),MP(1),RHP(1),RCSQ(1),
  2  E(1),ETIL(1),RVOL(1),M(1),RM(1),VP(1),P(1),PL(1),EP(1),
  3  UP(1),UTIL(1),UL(1),CO(1),PIX(1),PU(1),VTIL(1),VL(1),
  4  PV(1),RV(1),Q(1),RQ(1),PM0(1)
  8  READ 500, NAME
  9  READ 510, MU,LAM,OM,EP5,GR,GZ,ASQ,RON,GH1
  10  READ 515, FREZ,YB,REZ,YO,RFZUE,REZVE,REZVT,REZRON,REZSIE
  11  READ 520, IIR,JRP,PDR,PDZ,PYR,GZP,IMOMX
  12  READ 530, I,DT,TZOMD,TLIMO,TWFIN,LPR,ICOLOR
  13  READ 540, (DTN(N),N=1,10)
  14  READ 540, (DTOC(N),N=1,10)
  15  KT = 9
  16  ASSIGN 110 TO KRET
  17  WRITE(KT,500) NAME
  18  WRITE(KT,550) IRAR,JRAR,IUNF,JUNF,JCN,DR,DZ,CYL,GRDEL,
  1  AD,ADM,RO,KXI
  19  WRITE(KT,560) MU,LAM,OM,EP5,GR,GZ,ASQ,RON,GH1
  20  WRITE(KT,565) FREZ,YB,REZ,YO,RFZUE,REZVE,REZVT,REZRON,REZSIE
  21  WRITE(KT,570) IIR,JRP,PDR,PDZ,PYR,GZP,IMOMX
  22  WRITE(KT,580) I,DT,TZOMD,TLIMO,TWFIN,LPR,ICOLOR
  23  WRITE(KT,590) (DTN(N),N=1,10)
  24  WRITE(KT,600) (DTOC(N),N=1,10)
  25  GO TO KRET
  26  IF (LPR,FO,0) GO TO 120
  27  KT = 12
  28  ASSIGN 120 TO KRET
  29  GO TO 100
  30  IM1 = IRAR - 1
  31  IM6 = IRAR - 6
  32  IP1 = IRAR - 1
  33  IP2 = IRAR + 2
  34  JM10 = JRAR - 10

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SUBROUTINE VASET1
JM14 = JBAR - 14
JP1 = JBAR + 1
JP2 = JBAR + 2
JP4 = JBAR + 4
JP402 = JP4 / 2
RIBAR = 1./FLOAT(IBAR)
RIRJB = 1./FLOAT(IBAR*JBAR)
NQIB = NQ + IBAR
OMCYL = 1.-CYL
NQ1 = NQ + IP1
ISC2 = NQ1 + 1
ISC3 = ISC2 + NOT
ITV = JP1 + NOI
ISCF1 = ISC1 + NQ1
ISCF2 = ISC2 - NQ
NSC = LOCF(ZZ) - LOCF(AA) + 1
NLC = LOCF(AA1JP*NO1) - LOCF(AA1) + 1
LJP2 = JP2 - JP2/3 + 3
IF (LJP2.FO.0) LJP2 = 3
LJP2 = LJP2*NO1 - NQ + 1
INT0 = 1
TOUT = 1 + DT0(1)
DT = DTPOS = DT*0.1
NCYC = NUHTD = 0
EM10 = 1.E-10
OMEM10 = 1.-EM10
OPEN10 = 1.-EM10
ANC = 0.05
OMANC = 1.-ANC
COLAMI = (1.0+1.67)/(LAM*NU*PM10)
AGFAC = AOM/(2.0*(1.+AOM**2))
GM1 = (GM1+1.)*.6M1
THIRD = 1./3.
TUNF = MAX0(TUNF,1)
JUNF = MAX0(JUNF+2)
JUNF02 = JUNF/2
IF (JUNF.FO.0) JSEN = JBAR/2
IF (FREQ.NE.1.) ROMPR = 1./(!.FREQ)
CALL PARTGEN
CALL WSHMR
CALL FILMCO
CALL START
DO 220 J=2,JP1
DO 210 I=1,IBAR
IPJ = 1J + NQ
IPJP = IPJ + NQ
X1 = X(IPJ)
Y1 = Y(IPJ)
R1 = R(IPJ)
X2 = X(IPJP)
Y2 = Y(IPJP)
R2 = R(IPJP)
X3 = X(IJP)
Y3 = Y(IJP)
R3 = R(IJP)
X4 = X(IJ)
Y4 = Y(IJ)
R4 = R(IJ)

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200

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VASET 00041
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SINGLY REFERENCED VARIABLES

200 = 76* DT04 -R 4C0 FIYR -R 4C0 IYR -I 4C0 MT -R 6RL PYBM -R 4C0 STARTD - 103SU
 300 = 103* DT0R -R 4C0 FIYT -R 4C0 IYT -I 4C0 MTE -R 6RL PYCONV -R 4C0 VV -R 4C0
 340 = 115* DTV -R 4C0 FJRP -R 4C0 JRP2 -I 4C0 MU02 -R 6RL PYT -R 4C0 XCONV -R 4C0
 AA2 (I)R 2LC DT8 -R 4C0 IBP1 -I 4C0 LAMD -R 6RL MU04 -R 6RL PYTP -R 4C0 XL -R 4C0
 DIMFNS1 = 7F EQUIVAL = 5F IJPS -I 4C0 LCM = 2F NPS -I 4C0 RDT -R 4C0 XR -R 4C0
 NONE = 102SU FIBP -R 4C0 IMOME3 -I 4C0 LONP = 100SU NPT -I 4C0 REAL = 6F YASET1 = 15U
 DTC -R 4C0 F1LMCO = 75SU IPAR -I 4C0 LODPD = 118SU NQ12 -I 4C0 RETURN = 120F YCONV -R 4C0
 DTFAC -R 4C0 F1PXL -R 4C0 IPXL -I 4C0 LPR -I 4C0 NUM1T -I 4C0 RIRP -R 4C0 YLC1 = 2CN
 DTGR -R 4C0 F1PXR -R 4C0 IPXR -I 4C0 MR -R 6RL PARTGEN = 735U RJBP -R 4C0 YLC2 = 2CN
 DTGZ -R 4C0 F1PYB -R 4C0 IPYB -I 4C0 MC -R 6RL PXCONV -R 4C0 RPDR -R 4C0 YSC1 = 3CN
 DTGZP -R 4C0 F1PYT -R 4C0 IPYT -I 4C0 MESHMKR = 74SU PXL -R 4C0 RPDZ -R 4C0 YSC2 = 4CN
 DT014 -R 4C0 FIXL -R 4C0 IXL -I 4C0 ML -R 6RL PXR -R 4C0 RPDZ -R 4C0 YI -R 4C0
 DT02 -R 4C0 FIXR -R 4C0 IXR -I 4C0 MR -R 6RL PXP -R 4C0 START = 76SU

MULTIPLY-REFERENCED VARIABLES

100 = 17* 29
 110 = 16A5 26*
 120 = 26 28AS 30*
 219 = 7800 99*
 229 = 7700 101*
 349 = 10600 117*
 359 = 10400 119*
 500 = 8RD 17WR 121*
 510 = 9RD 122*
 515 = 10RD 123*
 520 = 11RD 124*
 530 = 12RD 125*
 540 = 13RD 14RD 126*
 550 = 18WR 127*
 560 = 19WR 128*
 565 = 20WR 129*
 570 = 21WR 130*
 580 = 22WR 131*
 590 = 23WR 132*
 600 = 24WR 133*

AA (I)R 4C0 50
 AA5C (I)R 3C0 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ
 AA1 (I)R 2LC 51 51
 ABL -R 94= 95
 ANC -R 4C0 62= 63
 AS0 -R 4C0 9RD 19WR
 ASSIGN = 16F 28F
 ATR -R 93= 95
 A0 -R 4C0 18WR
 A0FAC -R 4C0 65= 65
 A0M -R 4C0 18WR
 R0 -R 4C0 18WR
 COLAMU -R 4C0 64= 64
 COMMON = 3F 4F
 C0 (I)R 5EQ 7DI
 CYL -R 4C0 18WR 43
 DELSM (I)R 5EQ 7DI
 OR -R 4C0 18WR
 DT -R 4C0 12RD 22WR 57= 57
 DT0 (I)R 4C0 13RD 23WR 56
 DT0C (I)R 4C0 14RD 24WR
 DTPOS -R 4C0 57=

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NZ		4CO 18WR															
F	(R	4CO	18WR	97=	61	64											
FM10	AR	5EO	701	60													
EPS	(R	5EO	701	19WR													
FTLL	AR	4CO	9RD														
FLOAT	(R	5EO	701														
FRFZ	AR	4CO	10RD	20WR	72	72											
GGM1	AR	4CC	66=	19WR	66	66											
GM1	AR	4CO	9RD	19WR													
GRVFL	AR	4CO	18WR	19WR													
GZ	AR	4CO	9RD	19WR													
GZP	AR	4CO	11RD	21WR													
I	(R	4CO	78DO	107=	111	112	113	114									
IBAR	AR	4CO	18WR	30	31	32	33	40									
IBP	AR	4CO	11RD	21WR													
ICOLOR	AR	4CO	12RD	22WR													
IODN	AR	4CO	55=														
I1	AR	106DO	107														
IJ	AR	4CO	79	90	91	92	95	95	96	96	96	97	97	97	98=	108	112
I15	AR	115	116=														
IJM	AR	4CO	109	111	117=	89	97	97	99=								
IJP	AR	4CO	80	87	88												
IMJ	AR	108=	113	116													
IMJM	AR	109=	114	117													
IMOMX	AR	4CO	11RD	21WR													
IM1	AR	4CO	30=														
IM6	AR	4CO	31=														
IPJ	AR	79=	81	82	83	97	97	98									
IPJP	AR	80=	84	85	86	97	97	99									
IP1	AR	4CO	32=	44	106DO	111	112										
IP2	AR	4CO	33=	107													
ISCF1	AR	4CO	48=	49													
ISCF2	AR	4CO	49=														
ISC2	AR	4CO	45=	46	48												
ISC3	AR	4CO	46=														
ITV	AR	4CO	47=														
IUNF	AR	4CO	18WR	68=	68	112	113	114									
J	AR	4CO	77DO	105=	111	36	37	38									
JBAR	AR	4CO	18WR	34	35												
JBP	AR	4CO	11RD	21WR													
JCEN	AR	4CO	18WR	71	71=												
JJ	AR	104DO	105														
JM10	AR	4CO	34=														
JM14	AR	4CO	35=														
JP1	AR	4CO	36=	47	7700	104DO	112	113									
JP2	AR	4CO	37=	52	52	105											
JP4	AR	4CO	38=	39	51												
JP402	AR	4CO	39=	69=	69	70											
JUNF02	AR	4CO	18WR														
JUNF02	AR	4CO	70=														
KFT	AR	16AS	25	28AS	19WR	20WR	21WR	22WR	23WR	24WR	27=						
KT	AR	15=	17WR	18WR													
KX1	AR	4CO	18WR														
LAM	AR	4CO	6RL	9RD	19WR	6A											
LJP2	AR	4CO	52=	53	53=	54=	54										
LOC	AR	50SU	50SU	51SU	51SU												

INDEX		01/12/73		22WR		26		SURROUTINE YASEYI				114	
LPR	-I	400	12RD	70I	95=	96	111	112	113	114	114	114	
M	(R)	5F0	6RL	70I	95=	96	111	112	113	114	114	114	
MAX0	-	6RSU	69SU	70I									
MP	(R)	5F0	6RL	70I									
MPAR	(R)	5F0	6RL	70I									
MU	-R	4C0	6RL	9RD	19WR	64	64						
N	-I	13RD	13RD	14RD	14RD	21WR	23WR	24WR	24WR	24WR			
NAME	(I)	4C0	8RD	17WR									
NCYC	-I	4C0	58=										
NLC	-I	4C0	51=										
ND	-I	4C0	42	44	44	54	79	80	108	109			
NOI	-I	4C0	44=	45	46	47	49	51	54				
NOIR	-I	4C0	42=										
NSC	-I	4C0	50=										
NUMTN	-I	4C0	58=										
OM	-R	4C0	9RD	19WR									
OMANC	-R	4C0	63=										
OMCYL	-R	4C0	43=										
OMEM10	-R	4C0	60=										
OPMEM10	-R	4C0	61=										
P	(R)	5EQ	70I										
PDR	-R	4C0	11RD	21WR									
PD7	-R	4C0	11RD	21WR									
PL	(R)	5EQ	70I										
PMX	(R)	5EQ	70I										
PMY	(R)	5EQ	70I										
PMN	(R)	5EQ	70I										
PU	(R)	5EQ	70I										
PV	(R)	5EQ	70I										
PR	-R	4C0	11RD	21WR									
Q	(R)	5EQ	70I										
R	(R)	5EQ	70I	83	86	89	92						
RCSQ	(R)	5EQ	70I										
REAN	-R	4C0	9F	10F	11F	12F	13F	14F					
REZRON	-R	4C0	10RD	20WR									
REZSIE	-R	4C0	10RD	20WR									
REZIF	-R	4C0	10RD	20WR									
REZVE	-R	4C0	10RD	20WR									
REZVT	-R	4C0	10RD	20WR									
REZY0	-R	4C0	10RD	20WR									
RINAR	-R	4C0	40=										
RIRJA	-R	4C0	41=										
RM	(R)	5EQ	70I	115=									
RMP	(R)	5EQ	70I		96								
RO	(R)	5EQ	70I	95									
ROL	(R)	5EQ	70I										
ROMFR	-R	4C0	72=										
RON	-R	4C0	9RD	19WR									
RVOL	(R)	5EQ	70I	96=									
R1	-R	83=	95	95									
R2	-R	86=	95	95									
R3	-R	89=	95	95									
R4	-R	92=	95	95									
SIE	(R)	5EQ	70I	97									
T	-R	4C0	12RD	22WR	56								
THIRD	-R	4C0	67=	95									
TLIM	-R	4C0	12RD	22WR									
TOUT	-R	4C0	56=										

INDEX		01/12/73		SUBROUTINE YASET1							
TWFIN	-R	4C0	12RD	22WR							
T20MD	-R	4C0	12RD	22WR							
U	()R	5EQ	7DI	97	97	97	97				
UG	()R	5EQ	7DI								
UL	()R	5EQ	7DI								
UP	()R	5EQ	7DI								
UTIL	()R	5EQ	7DI								
V	()R	5EQ	7DI	97	97	97	97				
VG	()R	5EQ	7DI								
VL	()R	5EQ	7DI								
VP	()R	5EQ	7DI								
VTIL	()R	5EQ	7DI								
WRITE	-	17F	18F	19F	20F	21F	22F	23F	24F		
X	()R	5EQ	7DI	81	84	87	90				
XPAR	()R	5EQ	7DI								
XX	-R	110=	111=	112=	112	113=	113	114=	114	115	
X1	-R	81=	93	94							
X2	-R	84=	93								
X3	-R	87=	93	94							
X4	-R	90=	94								
Y	()R	5EQ	7DI	82	85	88	91				
YB	-R	4C0	10RD	20WR							
YPAR	()R	5EQ	7DI								
Y1	-R	82=	93	93	94	94					
Y2	-R	85=	93	93							
Y3	-R	88=	93	93	94	94					
Y4	-R	91=	94	94							
ZZ	-R	4C0	50								

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INDEX	01/12/73	SUBROUTINE PARTGEN MTE,DRAG	PAGE	25
		1	YASET	00183
33		USH = SHIFT(UPAR,30).AND.777777777R	YASET	00184
34		VSH = SHIFT(VPAR,30).AND.777777777R	YASET	00185
35		DRAG = DRAG.AND..NOT.777777777R	YASET	00186
36		YTOP = YC+XD	YASET	00187
37		YBOT = YC-XD	YASET	00188
38		IF (YD.LT.EM10) GO TO 200	YASET	00189
39		YTOP = YD	YASET	00190
40		YBOT = YC	YASET	00191
41		IF (FREZ.EQ.1.0) GO TO 200	YASET	00192
42		YTOP = YMAX	YASET	00193
43		YBOT = YMIN	YASET	00194
44		XD = XMAX	YASET	00195
45	200	YTE = YBOT+.5*DZPAR	YASET	00196
46	210	XTE = XC+.5*DRPAR	YASET	00197
47	220	IF (YD.LE.0. .AND. (YTE-YC)**2+XTE**2.GT.XD**2) GO TO 240	YASET	00198
48		XPAR(KP) = (XTE.AND. .NOT. 777777777R) .OR. USH	YASET	00199
49		YPAR(KP) = (YTE.AND. .NOT. 777777777R) .OR. VSH	YASET	00200
50		MC = MTE*(XTE*CYL+OMCYL)	YASET	00201
51		MT = MT + MC	YASET	00202
52		MPAR(KP) = DRAG .OR. (SHIFT(MC,30).AND.777777777R)	YASET	00203
53		KP = KP+3	YASET	00204
54		NPT = NPT+1	YASET	00205
55		IF (KP.GT.LPB) GO TO 250	YASET	00206
56	230	XTE = XTE+DRPAR	YASET	00207
57		IF (XTE.LE.XD) GO TO 220	YASET	00208
58	240	YTE = YTE+DZPAR	YASET	00209
59		IF (YTE.LE.YTOP) GO TO 210	YASET	00210
60		GO TO 100	YASET	00211
61	250	CALL ECWF (AASC,IECP,LPB,NE)	YASET	00212
62		IECP = IECP+LPB	YASET	00213
63		KP = 1	YASET	00214
64		GO TO 230	YASET	00215
65	290	CALL ECWR (AASC,IECP,LPB,NE)	YASET	00216
66		NPS = LOCF(AA2(NPT*3)) - IPAR + 1	YASET	00217
67		PRINT 920, NPT,MT	YASET	00218
68		IF (LPR.GT.0) WRITE(12,920) NPT,MT	YASET	00219
69		RETURN	YASET	00220
70	300	PRINT 990	YASET	00221
71		RETURN	YASET	00222
	C		YASET	00223
72	900	FORMAT(10F8.3)	YASET	00224
73	910	FORMAT(10XPAR=*1PE12.5* DZPAR=*E12.5* XC=*E12.5* YC=*E12.5	YASET	00225
		1* XD=*E12.5/* YD=*E12.5* UPAR=*E12.5* VPAR=*E12.5* MTE=*E12.5	YASET	00226
		2* DRAG=*E12.5)	YASET	00227
74	920	FORMAT(4X16* PARTICLES GENERATED* WITH TOTAL MASS=*1PE12.5)	YASET	00228
75	990	FORMAT(1* PARTICLE GRID TOO LARGE FOR SCM LAYOUT.*)	YASET	00229
76		END	YASET	00230

INDEX 01/12/73		SUBROUTINE PARTGEN			
18P1	-I 4C0 15=	62=	62	65AG	
1ECP	-I 18= 61AG				
IMOMF3	-I 4C0 20=				
IMOMX	-I 4C0 18=	66			
IPAR	-I 4C0 24	24			
TUNF	-I 4C0 10	25			
JBAR	-I 4C0 12	16			
JBP	-I 4C0 16=				
JBP?	-I 4C0 25	26			
JCEN	-I 4C0 25	25			
JUMFOP	-I 4C0 25	26			
KP	-I 21= 48	49			
LAM	-R 4C0 6RL	53=	53	55	63=
LOC	- 18SU 66SU				
LOCF	-I 4C0 19=	55	61AG	62	65AG
LPR	-I 4C0 32	68			
M	(I)R 5EQ 6RL 70I				
MC	-R 6RL 50=	51	52		
MP	(I)R 5EQ 6RL 70I				
MPAR	(I)R 5EQ 6RL 70I				
MY	-R 6RL 22=	51=	52=		
MTE	-R 6RL 29RD	31PR	32WR	68WR	
MU	-R 4C0 6RL				
NE	-I 61AG 65AG				
NPS	-I 4C0 66=	54=	54	66	67PR 68WR
NPT	-I 4C0 8=	19			
NOI	-I 4C0 17				
NOI2	-I 4C0 17=				
OMCYL	-R 4C0 50				
P	(I)R 5EQ 70I				
PDF	-R 4C0 27=				
PDZ	-R 4C0 28=				
PL	(I)R 5EQ 70I				
PMX	(I)R 5EQ 70I				
PMY	(I)R 5EQ 70I				
PMO	(I)R 5EQ 70I				
PRINT	- 31F 67F	70F			
PU	(I)R 5EQ 70I				
PV	(I)R 5EQ 70I				
Q	(I)R 5EQ 70I				
R	(I)R 5EQ 70I				
RCSQ	(I)R 5EQ 70I				
RETURN	- 9F 69F	71F			
REZY0	-R 4C0 25	26			
RIAP	-R 4C0 13=	27			
RJRP	-R 4C0 14=	28			
RM	(I)R 5EQ 70I				
RMP	(I)R 5EQ 70I				
RO	(I)R 5EQ 70I				
ROL	(I)R 5EQ 70I				
ROMFR	-R 4C0 24	25	26		
RVOL	(I)R 5EQ 70I				
SHIFT	- 33SU 34SU	52SU			
SIE	(I)R 5EQ 70I				
U	(I)R 5EQ 70I				
UG	(I)R 5EQ 70I				
UL	(I)R 5EQ 70I				
UP	(I)R 5EQ 70I				

INDEX 01/12/73				SUBROUTINE PARTGEN	
UPAR	-R	29RD	31PR	32MR	33
USH	-R	33=	48		
UTIL	(R	5FQ	70I		
V	(R	5EQ	70I		
VG	(R	5EQ	70I		
VL	(R	5EQ	70I		
VP	(R	5EQ	70I		
VPAR	-R	29RD	31PR	32MR	34
VSH	-R	34=	49		
VTIL	(R	5EQ	70I		
WRITE	-	32F	68F		
X	(R	5EQ	70I		
XC	-R	29RD	31PR	32MR	46
XD	-R	29RD	31PR	32MR	36
XMAX	-R	24=	27	44	
XPAR	(R	5FQ	70I	48=	
XTE	-R	46=	47	48	
Y	(R	5EQ	70I		
YBOT	-R	37=	40=	43=	45
YC	-R	29RD	31PR	32MR	36
YD	-R	29RD	31PR	32MR	38
YMAX	-R	25=	28	42	
YMIN	-R	26=	28	43	
YPAR	(R	5EQ	70I	49=	
YTF	-R	45=	47	49	58=
YTOP	-R	36=	39=	42=	59
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INDEX 01/12/73
SUBROUTINE MESHUKR
SUBROUTINE MESHUKR
COMMON /YSC1/ AASC(4,242)
COMMON /YSC2/ AA(1),ANC,ASG,A0,A0FAC,A0M,B0,COLAMU,CYL,
1 DR,DT,DTG,DTFAC,DTGR,DTGZ,DTGP,DTN(10),DTOC(10),
2 DT016,DT02,DT04,DT08,DTPOS,DTV,DTB,NZ,EM10,EPS,FIRP,
3 FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXP,FIYB,FIYTF,JBP,
4 FREZ,GGM1,GMI,GR,GRDVEL,GZ,GZP,I,IHAR,IBP,IRPL,ICOLOR,
5 IDTO,IJ,IJM,IJP,IJS,IMOMEX3,IMOMX,IM1,IM6,
6 IPAR,IPXL,IPXR,IPYB,IPYT,IPZ,ISCF1,ISCF2,ISC2,ISC3,
7 ITV,IUNF,IXL,IXR,IYR,IYTF,IJ,JRAR,JBP,JRP2,JCEM,JM10,
8 JMI4,JPI,JP2,JP4,JP402,JUNF,JUNF02,XKI,LAH,LJP2,LPR,
9 LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NG,NQ1,NQ1B,NQ12,N5C,
1 NUNT,NUMT,NOM,OHANC,OHCYL,OWEM10,OWEM10,PDR,PDZ,PXCONV,
2 PXL,PXR,PXPB,PYB,PYBMP,PYCONV,PYT,PY/P,PDZ,REFZRON,REFZIE,
3 REFUE,REFZV,REFZV,REFZV,REFZV,REFZV,REFZV,REFZV,REFZV,REFZV,
4 ROM,RRDR,RRDRDZ,RRDZ,THIRD,THIRD,THIRD,THIRD,THIRD,THIRD,
5 VV,XCONV,XL,XX,YB,YCONV,YT,ZZ
EQUIVALENCE (AASC(1),X,XPAR),(AASC(2),R,YPAR),(AASC(3),Y,MPAR),
1 (AASC(4),H,UG,DELSM),(AASC(5),V,VG),(AASC(6),RO),
2 (AASC(7),SIE,MP,RMP,RCSQ),(AASC(8),F,ETIL),
3 (AASC(9),RVOL),(AASC(10),M,RM,VP),(AASC(11),P,PL,EP,
4 UP,PMO),(AASC(12),UTIL,VUL,CO,P,X,PU),(AASC(13),VTIL,
5 VL,PMY,PMV),(AASC(14),Q,ROL)
REAL LAH,LAM,M,NR,MC,ML,MP,MPAR,MR,MT,MTE,MU,MUO2,MUO4
1 DIMENSION X(1),XPAR(1),R(1),YPAR(1),Y(1),MPAR(1),UG(1),
2 DELSM(1),V(1),VG(1),RO(1),SIE(1),MP(1),RMP(1),RCSQ(1),
3 F(1),ETIL(1),RVOL(1),VUL(1),M(1),RM(1),VP(1),PL(1),EP(1),
4 UP(1),PMO(1),UTIL(1),VUL(1),CO(1),PMX(1),PU(1),VTIL(1),VL(1),
5 PMY(1),PMV(1),Q(1),ROL(1),PMO(1)
NQIM = NQI-1
CALL START
DO 119 J=1,JP4
1 K = IJM * NQIM
2 DO 109 I=1,IM*K
3 AASC(1) = 0.
4 CALL LOOP
5 CALL DONE
6 XX = 0.0
7 YY = YR
8 CALL START
9 DO 229 J=2,JP2
10 DO 219 I=1,IP1
11 X(IJ) = XX
12 Y(IJ) = YY
13 R(IJ) = XX*CYL*OM*CYL
14 CONTINUE
15 CALL DONE
16 XX = 0.0
17 YY = YR
18 CALL START
19 DO 229 J=2,JP2
20 DO 219 I=1,IP1
21 X(IJ) = XX
22 Y(IJ) = YY
23 R(IJ) = XX*CYL*OM*CYL
24 XX = XX * DR
25 IJ = IJ + NQ
26 XX = 0.
27 YY = YY * DZ
28 CALL LOOP
29 CONTINUE
30 CALL DONE
31 IF (FREZ*EQ,1.0) GO TO 300
32 JCEN = JCEN + 2
33 JTOP = JCEN * JUNF02
34 JBOT = JCEN * JUNF02
35 TJ = FLOAT(JUNF02) * DZ

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INDEX	01/12/73	SUBROUTINE MESMKR	PAGE	30
36		CALL START	YASET	00264
37		DO 249 J=2,JP2	YASET	00265
38		DO 239 I=1,IP1	YASET	00266
39		IMJ = IJ - NQ	YASET	00267
40		IF (I.GT.TUNF+1) X(IJ) = X(IMJ) + FREZ*(X(IMJ)-X(IMJ-NQ))	YASET	00268
41		R(IJ) = X(IJ)*CYL + DMCYL	YASET	00269
42		JNT = IARS(J-JTOP)	YASET	00270
43		JNB = IARS(J-JROT)	YASET	00271
44		IF (J.LT.JROT) Y(IJ) = REZY0 - TJ + DZ*FREZ*(1,-FREZ*JDB)*ROWFR	YASET	00272
45		IF (J.GT.JTOP) Y(IJ) = REZY0 + TJ + DZ*FREZ*(1,-FREZ*JDT)*ROWFR	YASET	00273
46		IF (J.EQ.P) YR = Y(IJ)	YASET	00274
47	239	IJ = IJ + NQ	YASET	00275
48		CALL LOOP	YASET	00276
49	249	CONTINUE	YASET	00277
50		CALL DONE	YASET	00278
51	300	READ 1000, NR,NR,NT,NL,UI,VI,ROI,SIEI	YASET	00279
52		IF (NR.EQ.0) RETURN	YASET	00280
53		IF (NR.EQ.1000) GO TO 400	YASET	00281
54		PRINT 1010, NR,NR,NT,NL,UI,VI,ROI,SIEI	YASET	00282
55		IF (LPR.GT.0) WRITE(12,1010) NR,NR,NT,NL,UI,VI,ROI,SIEI	YASET	00283
56		NR2 = NR + 2	YASET	00284
57		NR1 = NR + 1	YASET	00285
58		NT2 = NT + 2	YASET	00286
59		NL1 = NL + 1	YASET	00287
60		DO 329 J=NR2,NT2	YASET	00288
61		CALL ROW	YASET	00289
62		DO 319 I=NL1,NR1	YASET	00290
63		CALL SETIJ	YASET	00291
64		IF (I.GT.1 .AND. I.LT.IP1) U(IJ)=UI	YASET	00292
65		IF (J.GT.2 .AND. J.LT.JP2) V(IJ)=VI	YASET	00293
66		IF (J.EQ.NT2 .OR. I.EQ.NR1) GO TO 319	YASET	00294
67		RO(IJ) = ROI	YASET	00295
68		SIE(IJ) = SIEI	YASET	00296
69	319	CONTINUE	YASET	00297
70		CALL VROW	YASET	00298
71	329	CONTINUE	YASET	00299
72		GO TO 300	YASET	00300
73	400	XX = G41*REZSIE	YASET	00301
74		YY = .5*ARS(GZ)	YASET	00302
75		CALL START	YASET	00303
76		YJC2 = .5*(Y(IJP)+Y(IJ))	YASET	00304
77		RNSAV = RF2RON*EXP(-GZ*(REZY0-YJC2)/XX)	YASET	00305
78		FNUM = (Y(IJP)-Y(IJ))*YY	YASET	00306
79		FREN = FNUM*FREZ	YASET	00307
80		ROJ1 = RNSAV*(XX-FNUM)/(XX-FREN)	YASET	00308
81		DO 459 I=J,JP1	YASET	00309
82		RO(IJ) = RNSAV	YASET	00310
83		RO(IJM) = ROJ1	YASET	00311
84		E(IJ) = E(IJM) + REZSIE	YASET	00312
85		IJ = IJ + NQ	YASET	00313
86	459	IJM = IJM + NQ	YASET	00314
87		CALL LOOP	YASET	00315
88		DO 79 J=3,JP1	YASET	00316
89		FREN = (Y(IJP)-Y(IJ))*YY	YASET	00317
90		FNUM = (Y(IJ)-Y(IJM))*YY	YASET	00318
91		RNSAV = RNSAV*(XX-FNUM)/(XX-FREN)	YASET	00319
92		DO 459 I=J,JP1	YASET	00320
93		RO(IJ) = RNSAV	YASET	00321

INDEX	01/12/73	SUBROUTINE MESMKR	PAGE	31
94		E(IJ) = PEZSIE	YASET	00322
95	469	IJ = IJ + NO	YASET	00323
96		CALL LOOP	YASET	00324
97	479	CONTINUE	YASET	00325
98		FNUM = FNUMOFREZ	YASET	00326
99		FREN = FREN+PREZ	YASET	00327
100		ROJ2 = ROJAV*(IX-FNUM)/(IX+FDEN)	YASET	00328
101		DO 489 I=1,IP1	YASET	00329
102		RO(IJ) = ROJ2	YASET	00330
103		E(IJ) = PEZSIE	YASET	00331
104	489	IJ = IJ + NO	YASET	00332
105		CALL DONE	YASET	00333
106		IF (I,EO,0) GO TO 520	YASET	00334
107	500	J = JJ + N7-1	YASET	00335
108		CALL RIROW	YASET	00336
109		CALL SETIJ	YASET	00337
110		RO(IJ) = RO1	YASET	00338
111		STE(IJ) = STE1	YASET	00339
112		VL(IJ) = VI	YASET	00340
113		VL(IJ) = VI	YASET	00341
114		CALL RIROW	YASET	00342
115		J = J-2+JJ+1	YASET	00343
116		CALL RIROW	YASET	00344
117		CALL SETIJ	YASET	00345
118		RO(IJ) = RO1	YASET	00346
119		STE(IJ) = STE1	YASET	00347
120		VL(IJ) = VI	YASET	00348
121		CALL RIROW	YASET	00349
122		J = J-1	YASET	00350
123		CALL RIROW	YASET	00351
124		CALL SETIJ	YASET	00352
125		VL(IJ) = -VI	YASET	00353
126		CALL RIROW	YASET	00354
127		GO TO 520	YASET	00355
128		CALL START	YASET	00356
129	520	DO 549 J=2,JAR	YASET	00357
130		DO 539 I=1,IM1	YASET	00358
131		IPJ = IJ+NO	YASET	00359
132		IPJ = IJ+NO	YASET	00360
133		IF (I,EO,1) V(IJP) = VL(IJ)	YASET	00361
134		V(IPJP) = S*(UL(IJ)+VL(IJP))	YASET	00362
135		V(IPJP) = S*(VL(IJ)+VL(IPJ))	YASET	00363
136		IJ = IPJ	YASET	00364
137		IPJ = IPJP	YASET	00365
138	539	CALL LOOP	YASET	00366
139		CONTINUE	YASET	00367
140	549	CALL DONE	YASET	00368
141		RETURN	YASET	00369
142			YASET	00370
143	C	FORMAT(114,4F8.3)	YASET	00371
144	1000	FORMAT(114,4F8.3) NM=130 N7=130 ML=130 UT=1PE12.56 V1=	YASET	00372
145	1010	FORMAT(114,4F8.3) RO1=PE12.56 STE1=PE12.51	YASET	00373
146	1020	FORMAT(1215,4(4X,E11.5))	YASET	00374
		END	YASF	00375
				00376

SUBROUTINE MESHMKR

INDEX 01/i2/73

INDEX	(R	450	601	01/12/73
RCSO	(R	450	601	
READ	-	51F	105F	
RETURN	-	52F	12F	
REZRON	-R	300	73	
REZSIF	-R	300	73	
REZY0	-R	300	44	
PH	(R	450	601	
RHP	(R	450	601	
RO	(R	450	601	
ROI	-R	51RD	54PR	
ROJP?	-R	100=	102	
ROJ1	-R	80=	83	
ROI	(R	450	601	
ROMFR	(R	450	601	
ROSAS	-R	77=	80	
RVOL	(R	450	601	
R1P0W	-	61SU	109SU	
SETU	-	63SU	110SU	
SIF1	(R	450	601	
SIF2	(R	450	601	
SIF3	(R	450	601	
START	-R	51RD	54PR	
TJ	(R	35=	44	
U	(R	450	601	
UG	(R	450	601	
UJ	-R	51RD	54PR	
UL	(R	450	601	
UPL	(R	450	601	
UTIL	(R	450	601	
V	(R	450	601	
V1	(R	450	601	
V2	(R	51RD	54PR	
VL	(R	450	601	
VP	(R	450	601	
VTIL	(R	450	601	
W1ROW	-	70SU	115SU	
X	(R	450	601	
XPAR	(R	450	601	
XX	(R	16=	21	
Y	(R	450	601	
YB	(R	300	17	
YJC2	-R	76=	77	
YPAR	(R	450	601	
YY	-1	17=	22	

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1

OVERLAY(YAQUFIL,2,0)
OVERLAY(YAQUFIL,2,0)

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YAQUI1 00002

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1
2
3
4 10
5

PROGRAM YAQUI1 PROGRAM YAQUI1
PRINT 10
CALL YAQUI2
FORMAT(* YAQUI2 CALLED*)
END

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YAQUI1 00003
YAQUI1 00004
YAQUI1 00005
YAQUI1 00006
YAQUI1 00007

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SINGLY REFERENCED VARIABLES

PRINT = 2F YAQUI1 = 15U YAQUI2 = 35U

MULTIPLY-REFERENCED VARIABLES

10 = 2PR 4*

PROGRAM YAQUI1

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1		SUBROUTINE YAQUI2	YAQUI1 00008
2		LCM /YLC1/ AA1(I31000) /YLC2/ AA2(I31000)	YAQUI1 00009
3		COMMON /YSC1/ AASC(4242)	COMMON2 00002
4		COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,R0,COLAMU,CYL,	COMMON2 00003
	1	GH,DT,DTC,DTFAC,DTGR,DTG7,DTGZP,DTN(10),DTOC(10),	COMMON2 00004
	2	DTN16,DT02,DT04,DT08,DTP05,DTV,DT8,DZ,EM10,EPS,FIBP,	COMMON2 00005
	3	FIPXL,FIPXR,FIPYS,FIPYT,FI XL,FI XR,FI YB,FI YT,FJBP,	COMMON2 00006
	4	FREZ,GGM1,GM1,GR,GROVEL,GZ,GZP,I,IRAR,IRP,IHP1,ICOLOR,	COMMON2 00007
	5	IDTO,IJ,IJM,IJP,IJS,IMOME3,IMOMX,IM1,IM6,	COMMON2 00008
	6	IPAR,IPXL,IPXR,IPYB,IPYT,IP1,IP2,ISCF1,ISCF2,ISC2,ISC3,	COMMON2 00009
	7	ITV,IUNF,IXL,IXR,IYB,IYT,J,JBAR,JBP,JBP2,JCEN,JM10,	COMMON2 00010
	8	JM14,JP1,JP2,JP4,JP402,JUNF,JUNF02,KXI,LAM,LJP2,LPR,	COMMON2 00011
	9	LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQ1,NQ1H,NQ12,NSC,	COMMON2 00012
	1	NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV,	COMMON2 00013
	2	PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYT2,ROD,REZRON,REZSIE,	COMMON2 00014
	3	REZUE,REZVF,REZVT,REZY0,RIBAR,RIBJR,RI RP,PJBP,ROMFR,	COMMON2 00015
	4	RON,RPDR,RPDZ,RPDZ2,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,T20MD,	COMMON2 00016
	5	VV,XCONV,XL,XR,YB,YCONV,YT,ZZ	COMMON2 00017
5		EQUIVALENCE (AASC(1),X,XFAR),(AASC(2),R,YPAR),(AASC(3),Y,HPAR),	EQVREAL 00002
	1	(AASC(4),U,UG,DELSM),(AASC(5),V,VG),(AASC(6),RO),	EQVREAL 00003
	2	(AASC(7),SIE,MP,RMP,RCSQ),(AASC(8),E,ETIL),	EQVREAL 00004
	3	(AASC(9),RVOL),(AASC(10),M,RM,V2),(AASC(11),P,PL,EP,	EQVREAL 00005
	4	UP,PM0),(AASC(12),UTIL,UL,CQ,PMY,PU),(AASC(13),VTIL,	EQVREAL 00006
	5	VL,PHY,PV),(AASC(14),Q,ROL)	EQVREAL 00007
6		REAL LAM,LAMD,M,MR,MC,ML,MP,MFR,MR,MT,MTE,MU,MU02,MU04	EQVREAL 00008
7		DIMENSION X(1),XPAR(1),R(1),YPAR(1),Y(1),MPAR(1),U(1),UG(1),	DIMEN 00002
	1	DELSM(1),V(1),VG(1),RO(1),SIE(1),MP(1),RMP(1),RCSQ(1),	DIMEN 00003
	2	E(1),ETIL(1),RVOL(1),M(1),RM(1),V2(1),P(1),PL(1),EP(1),	DIMEN 00004
	3	UP(1),UTIL(1),UL(1),CQ(1),PMX(1),PU(1),VTIL(1),VL(1),	DIMEN 00005
	4	PHY(1),PV(1),Q(1),ROL(1),PM0(1)	DIMEN 00006
8		DIMENSION AT(100),FT(100),IX1(1),IX2(1),IY1(1),IY2(1),XCO(4),YCO(4)	YAQUI1 00013
	1	,CON(100)	YAQUI1 00014
9		EQUIVALENCE (AT,IX1),(AT(2),IX2),(AT(3),IY1),(AT(4),IY2),(AT(5),	YAQUI1 00015
	1	XCO),(AT(9),YCO),(FT,CON)	YAQUI1 00016
10		COMMON /YSC3/ JNM	YAQUI1 00017
11		CALL SECONDD (TBASE)	YAQUI1 00018
12		T1 = TBASE	YAQUI1 00019
13		CALL GETO (4LKJRN,JNM)	YAQUI1 00020
14		CALL M4020	YAQUI1 00021
15		CALL GETO (4LKTLH,I1)	YAQUI1 00022
16		TLIM = I1	YAQUI1 00023
17		DTVSAV = DTCSAV = 0.0	YAQUI1 00024
18		IF (IRAR.EQ.0) GO TO 370	YAQUI1 00025
19		TLIM = TLIM*27.5E-9 = 40. * (1.-TLIMD)*1.E+10	YAQUI1 00026
20	100	CALL START	YAQUI1 00027
21		CIRC = 0.	YAQUI1 00028
22		DO 190 J=2,JP1	YAQUI1 00029
23		DO 189 I=1,IRAR	YAQUI1 00030
24		IPJ = IJ + NQ	YAQUI1 00031
25		IPJP = IJP + NQ	YAQUI1 00032
26		IF (I.EQ.1) CIRC = CIRC + 0.5*(V(IJ)+V(IJP))* (Y(IJP)-Y(IJ))	YAQUI1 00033
27		IF (I.EQ.IM1) CIRC = CIRC + 0.5*(V(IJ)+V(IJP))* (Y(IJP)-Y(IJ))	YAQUI1 00034
28		IF (J.EQ.3) CIRC = CIRC + 0.5*(U(IJ)+U(IPJ))* (X(IPJ)-X(IJ))	YAQUI1 00035
29		IF (J.EQ.JBAR) CIRC = CIRC + 0.5*(U(IJ)+U(IPJ))* (X(IPJ)-X(IJ))	YAQUI1 00036
30		SJET = AMAX1(SIE(IJ),0.)	YAQUI1 00037
31		P(IJ) = ASQ*(RO(IJ)-RON) + GM1*RO(IJ)*SIET	YAQUI1 00038
32		IF (ASQ.LT.1.E+6) GO TO 180	YAQUI1 00039
33		P(IJ) = ASQ*(ROL(IJ)-RON) + GM1*RO(IJ)*SIET	YAQUI1 00040

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35	180	IF (NCYC.EQ.0) P(IJ) = -RON*GZ*(V1-VB-(F*LOAT*(J-1.5)*OZ)	YAGUI1 00041	
36	189	IJP = IPRJ	YAGUI1 00042	
37		IJ = IPRJ	YAGUI1 00043	
38	:99	CALL LOOP	YAGUI1 00044	
39		CONTINUE	YAGUI1 00045	
40	200	CALL NONE	YAGUI1 00046	
41		TOLD = T2	YAGUI1 00047	
42	40	CALL SECOND (T2)	YAGUI1 00048	
43	42	XX = (T2-TOLD)*SIGJR	YAGUI1 00049	
44	43	IF (LPR,GT.0) WRITE(12,4000) T,NCYC,DT,XX,CIRC,DTV,DTV,JDTV,NUMIT,12,DTC,INTC,JNTC	YAGUI1 00050	
45		1 CALL EMPTY	YAGUI1 00051	
46		PRINT 4000,	YAGUI1 00052	
47		IF (T+EM10,GE,TOUT) GO TO 290	YAGUI1 00053	
48		IF (NCYC,LE,1) OR, NUMIT,GT,499) GO TO 300	YAGUI1 00054	
49	210	IF (T2-T1,GE,1200.,.AND, T2040,GT,EM10) GO TO 320	YAGUI1 00055	
50	220	IF (T2-TBASE,GE,TFILM) GO TO 330	YAGUI1 00056	
51		IF (T-.6E+WFILN) GO TO 340	YAGUI1 00057	
52		NCYC = NCYC + 1	YAGUI1 00058	
53		IF (NCYC,EQ,2) DT = DTPOS = DT*10.	YAGUI1 00059	
54		IF (NCYC,GE,3) DT = DTPOS = AMIN1(DTV,DTC)	YAGUI1 00060	
55		DTV = DTC = DT*DTFAC	YAGUI1 00061	
56		IF (T+DT,GT,TOUT) DT = TOUT-T	YAGUI1 00062	
57		T = T + DT	YAGUI1 00063	
58		RNT = 1./DT	YAGUI1 00064	
59		DT02 = .5*DT	YAGUI1 00065	
60		DT04 = .25*DT	YAGUI1 00066	
61		DT08 = .125*DT	YAGUI1 00067	
62		DT016 = .0625*DT	YAGUI1 00068	
63		DT4 = DT*4.	YAGUI1 00069	
64		DT8 = DT*8.	YAGUI1 00070	
65		DT16 = DT*16.	YAGUI1 00071	
66		DT6Z = DT*6Z	YAGUI1 00072	
67		DT6ZP = DT*6ZP	YAGUI1 00073	
68	290	GO TO 1000	YAGUI1 00074	
69		TOUT = TOUT + DT*(1-DT0)	YAGUI1 00075	
70		IF (T+EM10,LY,DTOC(INTO)) GO TO 300	YAGUI1 00076	
71		TOUT = DTOC(INTO) + DT*(1-DT0+1)	YAGUI1 00077	
72		INTO = INTO + 1	YAGUI1 00078	
73	300	ASSIGN 310 TO KRET	YAGUI1 00079	
74		GO TO 500	YAGUI1 00080	
75	310	ASSIGN 210 TO KRET	YAGUI1 00081	
76		GO TO 400	YAGUI1 00082	
77	320	T1 = T2	YAGUI1 00083	
78		ASSIGN 220 TO KRET	YAGUI1 00084	
79		GO TO 350	YAGUI1 00085	
80	330	ASSIGN 340 TO KRET	YAGUI1 00086	
81		GO TO 350	YAGUI1 00087	
82	340	RETURN	YAGUI1 00088	
83	350	PRINT 4010, NUMTO,T,NCYC	YAGUI1 00089	
84		IF (LPR,GT,0) WRITE(12,4010) NUMTO,T,NCYC	YAGUI1 00090	
85		WRITE(8) (AAIN(I),I=1,NSC)	YAGUI1 00091	
86		WRITE(8) (AAI(N),I=1,NLC)	YAGUI1 00092	
87		IF (NPT,GT,0) WRITE(8) (AAZ(N),N=1,NPS)	YAGUI1 00093	
88		CALL DATAREFL (5LPSET8)	YAGUI1 00094	
89		CALL AFSREL (3LOUT)	YAGUI1 00095	
90		CALL AFSREL (4LFILM)	YAGUI1 00096	
91			YAGUI1 00097	
92			YAGUI1 00098	
93			YAGUI1 00099	
94			YAGUI1 00100	
95			YAGUI1 00101	
96			YAGUI1 00102	
97			YAGUI1 00103	
98			YAGUI1 00104	
99			YAGUI1 00105	
100			YAGUI1 00106	
101			YAGUI1 00107	
102			YAGUI1 00108	
103			YAGUI1 00109	
104			YAGUI1 00110	
105			YAGUI1 00111	
106			YAGUI1 00112	
107			YAGUI1 00113	
108			YAGUI1 00114	
109			YAGUI1 00115	
110			YAGUI1 00116	
111			YAGUI1 00117	
112			YAGUI1 00118	
113			YAGUI1 00119	
114			YAGUI1 00120	
115			YAGUI1 00121	
116			YAGUI1 00122	
117			YAGUI1 00123	
118			YAGUI1 00124	
119			YAGUI1 00125	
120			YAGUI1 00126	
121			YAGUI1 00127	
122			YAGUI1 00128	
123			YAGUI1 00129	
124			YAGUI1 00130	

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90			NUMTD = NUMTD + 1	YAQUI1	00099
91			GO TO KRET	YAQUI1	00100
92			RFWDNG 7	YAQUI1	00101
93	370		JTD = JRAR	YAQUI1	00102
94			JNSC = LOCF(ZZ) = LOCF(AA) * 1	YAQUI1	00103
95			PRAD(7) (AA(N),N=1,JNSC)	YAQUI1	00104
96			IF (JTD.NF.NUMTD) GO TO 380	YAQUI1	00105
97			READ(7) (AA1(N),N=1,NLC)	YAQUI1	00106
98			IF (NPTGT+0) READ(7) (AA2(N),N=1,NPS)	YAQUI1	00107
99			CALL AFSPEL (SLFSET7)	YAQUI1	00108
100			NUMTD = NUMTD + 1	YAQUI1	00109
101			TLIM = TLIM*27.5E-9 = 40. * (1.-TLIMD)*1.E+10	YAQUI1	00110
102			PRINT 4020, JTD	YAQUI1	00111
103			PRINT 4030, NAME,T,NCYC	YAQUI1	00112
104			IF (LPR.EQ.0) GO TO 220	YAQUI1	00113
105			WRITE(12,4020) JTD	YAQUI1	00114
106			WRITE(12,4030) NAME,T,NCYC	YAQUI1	00115
107			GO TO 250	YAQUI1	00116
108		380	PRINT 4040	YAQUI1	00117
109			WRITE(12,4040)	YAQUI1	00118
110			CALL AFSPEL (SLFSET7)	YAQUI1	00119
111			RETURN	YAQUI1	00120
112		400	IF (LPR.EQ.0) GO TO KRET	YAQUI1	00121
113			ASSIGN 440 TO KRF	YAQUI1	00122
114			ASSIGN 440 TO KRP	YAQUI1	00123
115			ASSIGN 460 TO KRF	YAQUI1	00124
116			GO TO (420,410,458) LPR	YAQUI1	00125
117		410	ASSIGN 458 TO KRF	YAQUI1	00126
118			ASSIGN 456 TO KRF	YAQUI1	00127
119		420	CALL LINCNT (64)	YAQUI1	00128
120			CALL ADV (1)	YAQUI1	00129
121			GO TO 454	YAQUI1	00130
122		440	KRF = KRF	YAQUI1	00131
123			ASSIGN 460 TO KRP	YAQUI1	00132
124			CALL START	YAQUI1	00133
125			DO 449 J=1,JP2	YAQUI1	00134
126			DO 479 I=1,IP1	YAQUI1	00135
127			IPJM = IJM + NG	YAQUI1	00136
128			IPJ = IJ + NQ	YAQUI1	00137
129			D = PRM = PRV = PRSIE = 0.	YAQUI1	00138
130			IF (J.EQ.1) GO TO 450	YAQUI1	00139
131			IF (RM(IJM,NE,0)) PRM=1/RM(IJM)	YAQUI1	00140
132			IF (I.EQ.IPI *OR. J.EQ.JP2) GO TO 450	YAQUI1	00141
133			PRSIE = SIF(IJM)	YAQUI1	00142
134			IF (RVOL(IJM),NE,0.) PRV=1./RVOL(IJM)	YAQUI1	00143
135			X1 = X(IPJM)	YAQUI1	00144
136			Y1 = Y(IPJM)	YAQUI1	00145
137			R1 = R(IPJM)	YAQUI1	00146
138			U1 = U(IPJM)	YAQUI1	00147
139			V1 = V(IPJM)	YAQUI1	00148
140			X2 = X(ITJ)	YAQUI1	00149
141			Y2 = Y(ITJ)	YAQUI1	00150
142			R2 = R(ITJ)	YAQUI1	00151
143			U2 = U(ITJ)	YAQUI1	00152
144			V2 = V(ITJ)	YAQUI1	00153
145			X3 = X(IJ)	YAQUI1	00154
146			Y3 = Y(IJ)	YAQUI1	00155
147			R3 = R(IJ)	YAQUI1	00156

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148		U3 = U(IJ)	YAQUI1 00157
149		V3 = V(IJ)	YAQUI1 00158
150		X4 = X(IJM)	YAQUI1 00159
151		Y4 = Y(IJM)	YAQUI1 00160
152		R4 = R(IJM)	YAQUI1 00161
153		U4 = U(IJM)	YAQUI1 00162
154		V4 = V(IJM)	YAQUI1 00163
155		D = .25*RVOL(IJM)*((R1+R2)*((U1+U2)*(Y2-Y1)+(V1+V2)*(X1-X2))	YAQUI1 00164
		1 + (R2+R3)*((U2+U3)*(Y3-Y2)+(V2+V3)*(X2-X3))	YAQUI1 00165
		2 + (R3+R4)*((U3+U4)*(Y4-Y3)+(V3+V4)*(X3-X4))	YAQUI1 00166
		3 + (R4+R1)*((U4+U1)*(Y1-Y4)+(V4+V1)*(X4-X1))	YAQUI1 00167
156	450	GO TO (452,452,456) LPR	YAQUI1 00168
157	452	WRITE(12,4070) I,J,X(IJM),Y(IJM),U(IJM),V(IJM),PR\$IE,R0(IJM),PRV,	YAQUI1 00169
		D,PRM,P(IJM)	YAQUI1 00170
158		LINESF = LINESF + 1	YAQUI1 00171
159		IF (LINESF.LT.62) GO TO KRF	YAQUI1 00172
160	454	LINESF = 0	YAQUI1 00173
161		WRITE(12,4080) JNM,NAME,T,NCYC	YAQUI1 00174
162		WRITE(12,4060)	YAQUI1 00175
163		GO TO KRF	YAQUI1 00176
164	456	PRINT 4070, I,J,X(IJM),Y(IJM),U(IJM),V(IJM),PR\$IE,R0(IJM),PRV,	YAQUI1 00177
		D,PRM,P(IJM)	YAQUI1 00178
165		LINESP = LINESP + 1	YAQUI1 00179
166		IF (LINESP.LT.57) GO TO KRP	YAQUI1 00180
167	458	LINESP = 0	YAQUI1 00181
168		PRINT 4050	YAQUI1 00182
169		PRINT 4080, JNM,NAME,T,NCYC	YAQUI1 00183
170		PRINT 4060	YAQUI1 00184
171		GO TO KRP	YAQUI1 00185
172	460	IJ = IPJ	YAQUI1 00186
173	479	IJM = IPJM	YAQUI1 00187
174		CALL LOOP	YAQUI1 00188
175	489	CONTINUE	YAQUI1 00189
176		IF (LPR.GT.2) GO TO KRET	YAQUI1 00190
177	490	CALL EMPTY	YAQUI1 00191
178		GO TO KRET	YAQUI1 00192
179	500	IF (NPT.GT.0) CALL PARPLOT	YAQUI1 00193
180		IF (LPR.EQ.0) GO TO 490	YAQUI1 00194
181		IF (GRDVEL.GT.EM10 .OR. NCYC.EQ.0) CALL ADV(1)	YAQUI1 00195
182		OPMIN = OZMIN = 1.E+20	YAQUI1 00196
183		DRMAX = DZMAX = VMAX = 0.	YAQUI1 00197
184		CALL START	YAQUI1 00198
185		DO 549 J=2,JP1	YAQUI1 00199
186		DO 539 I=1,IRAR	YAQUI1 00200
187		IPJ = IJ + NQ	YAQUI1 00201
188		IPJP = IJP + NQ	YAQUI1 00202
189		VMAX = AMAX1 (VMAX,ARS(U(IJ)),ARS(V(IJ)))	YAQUI1 00203
190		IF (NCYC.GT.0 .AND. GRDVEL.LT.EM10) GO TO 530	YAQUI1 00204
191		X1 = X(IPJ)	YAQUI1 00205
192		X2 = X(IPJP)	YAQUI1 00206
193		X3 = X(IPJP)	YAQUI1 00207
194		X4 = X(IJ)	YAQUI1 00208
195		Y1 = Y(IPJ)	YAQUI1 00209
196		Y2 = Y(IPJP)	YAQUI1 00210
197		Y3 = Y(IPJP)	YAQUI1 00211
198		Y4 = Y(IJ)	YAQUI1 00212
199		XY14 = SQRT((X1-X4)**2 + (Y1-Y4)**2)	YAQUI1 00213
200		XY23 = SQRT((X2-X3)**2 + (Y2-Y3)**2)	YAQUI1 00214

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201		DRMIN = AMIN1(DRMIN,XY14,XY23)	YAQUI1 00215
202		DRMAX = AMAX1(DRMAX,XY14,XY23)	YAQUI1 00216
203		XY21 = SQRT((X2-X1)**2 + (Y2-Y1)**2)	YAQUI1 00217
204		XY34 = SQRT((X3-X4)**2 + (Y3-Y4)**2)	YAQUI1 00218
205		DZMIN = AMIN1(DZMIN,XY21,XY34)	YAQUI1 00219
206		DZMAX = AMAX1(DZMAX,XY21,XY34)	YAQUI1 00220
207		IX1 = FIXL + (X1-XL)*XCONV	YAQUI1 00221
208		IY1 = FIYR + (Y1-YB)*YCONV	YAQUI1 00222
209		IX2 = FIXL + (X2-XL)*XCONV	YAQUI1 00223
210		IY2 = FIYR + (Y2-YB)*YCONV	YAQUI1 00224
211		IX3 = FIXL + (X3-XL)*XCONV	YAQUI1 00225
212		IY3 = FIYR + (Y3-YB)*YCONV	YAQUI1 00226
213		IX4 = FIXL + (X4-XL)*XCONV	YAQUI1 00227
214		IY4 = FIYR + (Y4-YB)*YCONV	YAQUI1 00228
215		IF (I.EQ.1) CALL DRV (IX3,IY3,IX4,IY4)	YAQUI1 00229
216		IF (J.EQ.2) CALL DRV (IX4,IY4,IX1,IY1)	YAQUI1 00230
217		CALL DRV (IX1,IY1,IX2,IY2)	YAQUI1 00231
218		CALL DRV (IX2,IY2,IX3,IY3)	YAQUI1 00232
219	530	IJ = IPJ	YAQUI1 00233
220	539	IJP = IJPJ	YAQUI1 00234
221		CALL LOOP	YAQUI1 00235
222	549	CONTINUE	YAQUI1 00236
223		IF (NCYC.GT.0 .AND. GPDVEL.LT.EM10) GO TO 550	YAQUI1 00237
224		CALL LINCNT(59)	YAQUI1 00238
225		WRITE(12,4140) DRMIN,DRMAX,DZMIN,LZMAX,XR,YR,YT	YAQUI1 00239
226		WRITE(12,4080) JNM,NAME,T,NCYC	YAQUI1 00240
227	550	IF (VMAX.LT.EM10) GO TO 600	YAQUI1 00241
228		DROU = VV/VMAX	YAQUI1 00242
229		CALL ADV(1)	YAQUI1 00243
230		CALL START	YAQUI1 00244
231		DO 599 J=2,JP2	YAQUI1 00245
232		DO 589 I=1,IP1	YAQUI1 00246
233		IX1 = FIXL + (X(IJ)-XL)*XCONV	YAQUI1 00247
234		IY1 = FIYR + (Y(IJ)-YB)*YCONV	YAQUI1 00248
235		IX2 = FIXL + (X(IJ)+U(IJ)*DROU-XL)*XCONV	YAQUI1 00249
236		IY2 = FIYR + (Y(IJ)+V(IJ)*DROU-YB)*YCONV	YAQUI1 00250
237		IF (IY2.GE.1) GO TO 580	YAQUI1 00251
238		IX2 = IX1 + (IX2-IX1)*(IY1-1)/(IY1-IY2)	YAQUI1 00252
239		IY2 = 1	YAQUI1 00253
240	580	CALL DRV (IX1,IY1,IX2,IY2)	YAQUI1 00254
241		CALL PLT (IX1,IY1,16)	YAQUI1 00255
242	589	IJ = IJ + NQ	YAQUI1 00256
243		CALL LOOP	YAQUI1 00257
244	599	CONTINUE	YAQUI1 00258
245		CALL LINCNT(59)	YAQUI1 00259
246		WRITE(12,4150) VMAX	YAQUI1 00260
247		WRITE(12,4080) JNM,NAME,T,NCYC	YAQUI1 00261
248	600	IF (IRAR.EQ.1 .OR. JBAR.EQ.1) GO TO 490	YAQUI1 00262
249		L = 0	YAQUI1 00263
250	610	L = L+1	YAQUI1 00264
251		GO TO (620,620,640,490)L	YAQUI1 00265
252	620	CALL START	YAQUI1 00266
253		DO 639 J=2,JP1	YAQUI1 00267
254		DO 629 I=1,IRAR	YAQUI1 00268
255		CO(IJ) = RO(IJ+L-I)	YAQUI1 00269
256	629	IJ = IJ + NQ	YAQUI1 00270
257		CALL LOOP	YAQUI1 00271
258	639	CONTINUE	YAQUI1 00272

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259		CALL DONE		YAOUI1 00273
260		GO TO 700		YAOUI1 00274
261	640	CALL START		YAOUI1 00275
262		DN 650 J=2,JP1		YAOUI1 00276
263		DN 640 I=1,IBAR		YAOUI1 00277
264		IPJ = IJ * NO		YAOUI1 00278
265		IPJP = IPJ * NO		YAOUI1 00279
266		X1 = X(IPJ)		YAOUI1 00280
267		Y1 = Y(IPJ)		YAOUI1 00281
268		U1 = U(IPJ)		YAOUI1 00282
269		V1 = V(IPJ)		YAOUI1 00283
270		X2 = X(IPJP)		YAOUI1 00284
271		Y2 = Y(IPJP)		YAOUI1 00285
272		U2 = U(IPJP)		YAOUI1 00286
273		V2 = V(IPJP)		YAOUI1 00287
274		X3 = X(IPJ)		YAOUI1 00288
275		Y3 = Y(IPJ)		YAOUI1 00289
276		U3 = U(IPJ)		YAOUI1 00290
277		V3 = V(IPJ)		YAOUI1 00291
278		X4 = X(IJ)		YAOUI1 00292
279		Y4 = Y(IJ)		YAOUI1 00293
280		U4 = U(IJ)		YAOUI1 00294
281		V4 = V(IJ)		YAOUI1 00295
282		R1 = .125*VOL(IJ)*R(IPJ)*R(IPJP)*R(IJP)*R(IJ)		YAOUI1 00296
283		CO(IJ) = R1*((U1+U4)*(X1-X4)+(V1+V4)*(Y1-Y4)		YAOUI1 00297
		+ (U2+U1)*(X2-X1)+(V2+V1)*(Y2-Y1)		YAOUI1 00298
		+ (U3+U2)*(X3-X2)+(V3+V2)*(Y3-Y2)		YAOUI1 00299
		+ (U4+U3)*(X4-X3)+(V4+V3)*(Y4-Y3))		YAOUI1 00300
				YAOUI1 00301
284	649	IJ = IPJ		YAOUI1 00302
285		IJP = IPJP		YAOUI1 00303
286		CALL LOOP		YAOUI1 00304
287	659	CONTINUE		YAOUI1 00305
288		CALL DONE		YAOUI1 00306
289	700	QMN = 1.E+6		YAOUI1 00307
290		QMX = -QMN		YAOUI1 00308
291		CALL START		YAOUI1 00309
292		DN 711 J=2,JP1		YAOUI1 00310
293		DN 700 I=1,IBAR		YAOUI1 00311
294		QMN = AMIN1(CO(IJ),QMN)		YAOUI1 00312
295		QMX = AMAX1(CO(IJ),QMX)		YAOUI1 00313
296	709	IJ = IJ * NO		YAOUI1 00314
297		CALL LOOP		YAOUI1 00315
298	719	CONTINUE		YAOUI1 00316
299		XI = QMX/(QMN+EM10)		YAOUI1 00317
300		IF (XI+LE,2,0) GO TO 735		YAOUI1 00318
301		K = 10./ALOG10(XI)		YAOUI1 00319
302		XI = K.1		YAOUI1 00320
303		DN = 10.*XI/XI		YAOUI1 00321
304		K = ALOG10(QMN)		YAOUI1 00322
305		XI = 10.*K(K-1)		YAOUI1 00323
306		K = 1		YAOUI1 00324
307	770	XI = XI*DN		YAOUI1 00325
308		IF (XI+LT,QMN) GO TO 720		YAOUI1 00326
309	730	CONTINUE		YAOUI1 00327
310		IF (XI+GT,QMX) GO TO 740		YAOUI1 00328
311		K = K.1		YAOUI1 00329
312		XI = XI*DN		YAOUI1 00330
313		GO TO 730		YAOUI1 00330

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314	735	XX = QMX-QMN	YAQUI1	00331
315		IF (ARS(XX).LT.1.E-3)*ANAX1(ARS(QMX),ARS(QMN)) GO TO 610	YAQUI1	00332
316		NO = 1*(XX+.001)	YAQUI1	00333
317		ON 739 N=1,1	YAQUI1	00334
318	739	CON(K) = QMN*(FLOAT(K-1)+NO	YAQUI1	00335
319		K = 1	YAQUI1	00336
320	740	CALL ADV(1)	YAQUI1	00337
321		CALL LUNCHT (59)	YAQUI1	00338
322		ON TO (750,740,770) L	YAQUI1	00339
323	750	WRITE(12,4090)	YAQUI1	00340
324		ON TO 740	YAQUI1	00341
325	760	WRITE(12,4100)	YAQUI1	00342
326		ON TO 740	YAQUI1	00343
327	770	WRITE(12,4110)	YAQUI1	00344
328	780	WRITE(12,4120) QMN-QMX,CON(1),CON(K-1),NO	YAQUI1	00345
329		WRITE(12,4090) JNM,NAME,T,NCTC	YAQUI1	00346
330		CALL STABT	YAQUI1	00347
331		ON 800 J=2,JBAR	YAQUI1	00348
332		CALL LNDP	YAQUI1	00349
333		ON 889 I=1,M1	YAQUI1	00350
334		IPJ = 1J = NO	YAQUI1	00351
335		IPJM = 1JM = NO	YAQUI1	00352
336		N = 0	YAQUI1	00353
337		ON 879 KK=1,K	YAQUI1	00354
338		K1 = K2 = K3 = K4 = 0	YAQUI1	00355
339		IF (C011JM) .LE.C04(KK) K1=1	YAQUI1	00356
340		IF (C011PM) .LE.C04(KK) K2=1	YAQUI1	00357
341		IF (C011J) .LE.C04(KK) K3=1	YAQUI1	00358
342		IF (C011P) .LE.C04(KK) K4=1	YAQUI1	00359
343		IF (K1+K2+K3+K4 .NE. 0 .OR. K1+K2+K3+K4 .EQ. 0) GO TO 879	YAQUI1	00360
344		IF (N,GT,0) GO TO 800	YAQUI1	00361
345		1JA = 1JM	YAQUI1	00362
346		1JA = 1J	YAQUI1	00363
347		ON 790 JJ=1,2	YAQUI1	00364
348		ON 789 II=1,2	YAQUI1	00365
349		IPJA = 1JA=NO	YAQUI1	00366
350		IPJA = 1JA=NO	YAQUI1	00367
351		N = N+1	YAQUI1	00368
352		XC0(M) = .25*(X(IPJR)+X(IPJA)+X(1JA)+X(1JR))	YAQUI1	00369
353		YC0(M) = .25*(Y(IPJR)+Y(IPJA)+Y(1JA)+Y(1JR))	YAQUI1	00370
354		1JA = 1PJA	YAQUI1	00371
355	789	1JA = 1PJA	YAQUI1	00372
356		1JA = 1J	YAQUI1	00373
357	790	1JA = 1JP	YAQUI1	00374
358	800	LL = 0	YAQUI1	00375
359		IF (K1+K2,NE,1) GO TO 810	YAQUI1	00376
360		IC1 = 1	YAQUI1	00377
361		IC2 = 3	YAQUI1	00378
362		1J1 = 1JM	YAQUI1	00379
363		1J2 = 1J	YAQUI1	00380
364		4551GM 810 TO 881	YAQUI1	00381
365		ON TO 840	YAQUI1	00382
366	810	IF (K1+K2,NE,1) GO TO 820	YAQUI1	00383
367		IC1 = 1	YAQUI1	00384
368		IC2 = 2	YAQUI1	00385
369		1J1 = 1JM	YAQUI1	00386
370		1J2 = 1PJM	YAQUI1	00387
371		4551GM 820 TO 881	YAQUI1	00388

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372	A20	GO TO A40	YAUQ11 003A9	
373		IF (K2-K4.NE.1) GO TO A30	YAUQ11 003B0	
374		IC1 = 2	YAUQ11 003B1	
375		IC2 = 4	YAUQ11 003B2	
376		IJ1 = IJN	YAUQ11 003B3	
377		IJ2 = IJN	YAUQ11 003B4	
378		ASSIGN A30 TO K41	YAUQ11 003B5	
379		GO TO A40	YAUQ11 003B6	
380	A30	IF (K3-K4.NE.1) GO TO A79	YAUQ11 003B7	
381		IC1 = 3	YAUQ11 003B8	
382		IC2 = 4	YAUQ11 003B9	
383		IJ1 = IJ	YAUQ11 00400	
384		IJ2 = IJN	YAUQ11 00401	
385		ASSIGN A79 TO K41	YAUQ11 00402	
386	A40	LL = LL+1	YAUQ11 00403	
387		IF (CONV(K1-CO(IJ1))/CO(IJ2)-CO(IJ1))	YAUQ11 00404	
388		IVILL) = FILL * (XCO(IC1)-XCO(IC2)-XCO(IC1))-XCO(IC1))	YAUQ11 00405	
389		IVILL) = FIVN * (YCO(IC1)-YCO(IC2)-YCO(IC1))-YCO(IC1))	YAUQ11 00406	
390		IF (LL-1,2) GO TO K41	YAUQ11 00407	
391		CALL DGV (I1,IY1,IX2,IY2)	YAUQ11 00408	
392		IF (K4.EQ.1) CALL PLY (I1,IY1,IY3)	YAUQ11 00409	
393		IF (K4.EQ.K-1) CALL PLY (I1,IY1,IY2)	YAUQ11 00410	
394		LL = 0	YAUQ11 00411	
395	A79	IF (IJP.EQ.IPJN) GO TO A20	YAUQ11 00412	
396		CONTINUE	YAUQ11 00413	
397		IJM = IJN	YAUQ11 00414	
398		IJ = IJP	YAUQ11 00415	
399	A89	IJP = IJP-NQ	YAUQ11 00416	
400	B99	CONTINUE	YAUQ11 00417	
401		CALL START	YAUQ11 00418	
402		DO 949 J=2,J1	YAUQ11 00419	
403		DO 939 I=1,IAR	YAUQ11 00420	
404		IJP = IJ + NQ	YAUQ11 00421	
405		IJP = IJP + NQ	YAUQ11 00422	
406		IJ1 = FJL + (IJPJ) -XL)*XCONV	YAUQ11 00423	
407		IY1 = FJL + (IJPJ) -YH)*YCONV	YAUQ11 00424	
408		IJ2 = FJL + (IJPJ)-XL)*XCONV	YAUQ11 00425	
409		IY2 = FJL + (IJPJ)-YH)*YCONV	YAUQ11 00426	
410		IJ3 = FJL + (IJPJ) -XL)*XCONV	YAUQ11 00427	
411		IY3 = FJL + (IJPJ) -YH)*YCONV	YAUQ11 00428	
412		IJ4 = FJL + (IJPJ) -XL)*XCONV	YAUQ11 00429	
413		IY4 = FJL + (IJPJ) -YH)*YCONV	YAUQ11 00430	
414		IF (I.FO.1) CALL DGV (IJ3,IY3,IJ4,IY4)	YAUQ11 00431	
415		IF (I.FO.2) CALL DGV (IJ4,IY4,IJ1,IY1)	YAUQ11 00432	
416		IF (I.FO.IRAR) CALL DGV (IJ1,IY1,IJ2,IY2)	YAUQ11 00433	
417		IF (I.FO.JPJ1) CALL DGV (IJ2,IY2,IJ3,IY3)	YAUQ11 00434	
418		IJ = IJP	YAUQ11 00435	
419	939	IJP = IJP	YAUQ11 00436	
420		CALL LOOP	YAUQ11 00437	
421	949	CONTINUE	YAUQ11 00438	
422		GO TO A10	YAUQ11 00439	
423	1000	CALL START	YAUQ11 00440	
424		Y1 = ANCORNT	YAUQ11 00441	
425		DO 1099 J=2,J2	YAUQ11 00442	
426		DO 1089 I=1,I1	YAUQ11 00443	
427		I4J = IJ-NQ	YAUQ11 00444	
428		IJP = IJ-NQ	YAUQ11 00445	
429		IJP = IJP-NQ	YAUQ11 00446	

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488		X4 = X(IJ)	YAQUI1 00505
489		Y4 = Y(IJ)	YAQUI1 00506
490		R4 = R(IJ)	YAQUI1 00507
491		U4 = U(IJ)	YAQUI1 00508
492		V4 = V(IJ)	YAQUI1 00509
493		X12 = X1-X2	YAQUI1 00510
494		X23 = X2-X3	YAQUI1 00511
495		X34 = X3-X4	YAQUI1 00512
496		X41 = X4-X1	YAQUI1 00513
497		X24 = X2-X4	YAQUI1 00514
498		X31 = X3-X1	YAQUI1 00515
499		Y21 = Y2-Y1	YAQUI1 00516
500		Y32 = Y3-Y2	YAQUI1 00517
501		Y43 = Y4-Y3	YAQUI1 00518
502		Y14 = Y1-Y4	YAQUI1 00519
503		Y24 = Y2-Y4	YAQUI1 00520
504		Y31 = Y3-Y1	YAQUI1 00521
505		R12 = R1+R2	YAQUI1 00522
506		R23 = R2+R3	YAQUI1 00523
507		R34 = R3+R4	YAQUI1 00524
508		R41 = R4+R1	YAQUI1 00525
509		MR13 = .5*(R1+R3)	YAQUI1 00526
510		MR24 = .5*(R2+R4)	YAQUI1 00527
511		U12 = U1+U2	YAQUI1 00528
512		U23 = U2+U3	YAQUI1 00529
513		U34 = U3+U4	YAQUI1 00530
514		U41 = U4+U1	YAQUI1 00531
515		U24 = U2+U4	YAQUI1 00532
516		U13 = U1+U3	YAQUI1 00533
517		V12 = V1+V2	YAQUI1 00534
518		V23 = V2+V3	YAQUI1 00535
519		V34 = V3+V4	YAQUI1 00536
520		V41 = V4+V1	YAQUI1 00537
521		V24 = V2+V4	YAQUI1 00538
522		V13 = V1+V3	YAQUI1 00539
523		DT02M1 = DT02*RM(IJP)	YAQUI1 00540
524		DT02M2 = DT02*RM(IJP)	YAQUI1 00541
525		DT02M3 = DT02*RM(IJP)	YAQUI1 00542
526		DT02M4 = DT02*RM(IJP)	YAQUI1 00543
527		XY = X24*Y31-X31*Y24	YAQUI1 00544
528		D = .75*RVOL(IJ)*(R12*(U12*Y21+V12*X12)+R23*(U23*Y32+V23*X23)+R34*(U34*Y43+V34*X34)+R41*(U41*Y14+V41*X41))	YAQUI1 00545
529		1 XX = .5*(X2-X4+X1-X3)	YAQUI1 00546
530		YY = .5*(Y2-Y4+Y3-Y1)	YAQUI1 00547
531		IF (KXI.LT.0) GO TO 1130	YAQUI1 00548
532		AK = R0(IJ)**KXI	YAQUI1 00549
533		GO TO 1140	YAQUI1 00550
534	1130	VELIJ = U4**2 + V4**2	YAQUI1 00551
535		VELMX = 0.7 * AMAX1(ABS(U4*XX),ABS(V4*YY))	YAQUI1 00552
536		AK = R0(IJ)*COLAMU*(DT02*VELIJ + VELMX)	YAQUI1 00553
537	1140	LAMD = AMIN1(D+0.) *AK*LAM	YAQUI1 00554
538		MU02 = .5*AK*MU	YAQUI1 00555
539		MU04 = .5*MU02	YAQUI1 00556
540		XX = XX+XX	YAQUI1 00557
541		YY = YY+YY	YAQUI1 00558
542		IF (KXI.LT.0 .AND. DT.LT.DTPOS)	YAQUI1 00559
		1 AK = R0(IJ)*COLAMU*(.5*DTPOS*VELIJ + VELMX)	YAQUI1 00560
543		DQ = R0(IJ)*OMANC*XX*YY/(2.* AK*(LAM+2.*MU) *(XX+YY)*EM10)	YAQUI1 00561
			YAQUI1 00562

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544		DTV = AMIN1(DTV,.5*NO)	YAQUI1	00563
545		IF (DTVSAV.NE.DTV) JDTV = 1	YAQUI1	00564
546		IF (DTVSAV.NE.DTV) JDTV = J	YAQUI1	00565
547		DTVSAV = DTV	YAQUI1	00566
548		P1XX = MUN2*RVOL(IJ)*(R12*U12*Y21+R23*U23*Y32	YAQUI1	00567
		+R34*U34*Y43+R41*U41*Y14 -.5*CYL*(U12+U34)*XY) + LAMD	YAQUI1	00568
549		P1YY = MUN2*RVOL(IJ)*(R12*V12*X12+R23*V23*X23	YAQUI1	00569
		+R34*V34*X34+R41*V41*X41) + LAMD	YAQUI1	00570
550		P1XY = MUN4*RVOL(IJ)*(R12*(U12*V12+V12*Y21)+R23*(U23*V23+V23*Y32	YAQUI1	00571
		+R34*(U34*V34+V34*Y43)+R41*(U41*V41+V41*Y14)	YAQUI1	00572
		-.5*CYL*(V12+V34)*XY)	YAQUI1	00573
551		P1TH = .25*XY*CYL*(MUN4*RVOL(IJ)*(U12+U34)*XY) + LAMD)	YAQUI1	00574
552		XX = HR24*(P1XY*X24-P1XX*Y24)	YAQUI1	00575
553		YY = Y24*P(IJ)	YAQUI1	00576
554		UTIL(I PJ) = UTIL(I PJ) +DT02M1*(XX+R1*YY-P1TH)	YAQUI1	00577
555		UTIL(IJP) = UTIL(IJP) -DT02M3*(XX+R3*YY-P1TH)	YAQUI1	00578
556		XX = HR13*(P1XY*X31-P1XX*Y31)	YAQUI1	00579
557		YY = Y31*P(IJ)	YAQUI1	00580
558		UTIL(I PJP) = UTIL(I PJP) +DT02M2*(XX+R2*YY-P1TH)	YAQUI1	00581
559		UTIL(IJ) = UTIL(IJ) -DT02M4*(XX+R4*YY-P1TH)	YAQUI1	00582
560		PYYHP = P1YY*P(IJ)	YAQUI1	00583
561		XX = HR24*(PYYHP*X24-P1XY*Y24)	YAQUI1	00584
562		V1IL(I PJ) = V1IL(I PJ) +DT02M1*XX	YAQUI1	00585
563		V1IL(IJP) = V1IL(IJP) -DT02M3*XX	YAQUI1	00586
564		XX = HR13*(PYYHP*X31-P1XY*Y31)	YAQUI1	00587
565		V1IL(I PJP) = V1IL(I PJP) +DT02M2*XX	YAQUI1	00588
566		V1IL(IJ) = V1IL(IJ) -DT02M4*XX	YAQUI1	00589
567		XX = .5*HR24*(U24*(X24*P1XY-Y24*P1XX)-V24*(Y24*P1XY-X24*P1YY))	YAQUI1	00590
568		Q(I PJ) = Q(I PJ) +DT02M1*XX	YAQUI1	00591
569		Q(IJP) = Q(IJP) -DT02M3*XX	YAQUI1	00592
570		XX = .5*HR13*(U13*(X31*P1XY-Y31*P1XX)-V13*(Y31*P1XY-X31*P1YY))	YAQUI1	00593
571		Q(I PJP) = Q(I PJP) +DT02M2*XX	YAQUI1	00594
572		Q(IJ) = Q(IJ) -DT02M4*XX	YAQUI1	00595
573		IJ = I PJ	YAQUI1	00596
574	1199	IJP = I PJP	YAQUI1	00597
575		UTIL(IJ) = UTIL(IJP) = UTIL(IJP-NQ1A) = UTIL(IJ-NQ1B) = 0.	YAQUI1	00598
576		IF (J.NE.2) GO TO 1220	YAQUI1	00599
577		DO 1210 IJ=ISC2,ISC2,NQ	YAQUI1	00600
578	1210	V1IL(IJ) = 0.	YAQUI1	00601
579	1220	IF (J.NE.JP1) GO TO 1240	YAQUI1	00602
580		DO 1230 IJP=IJP5+LJP2,NQ	YAQUI1	00603
581	1230	V1IL(IJP) = 0.	YAQUI1	00604
582	1240	CALL LONP	YAQUI1	00605
583	1299	CONTINUE	YAQUI1	00606
584		CALL DONE	YAQUI1	00607
585	1300	CALL STANT	YAQUI1	00608
586		DO 1399 J=2,JP1	YAQUI1	00609
587		DO 1389 I=1,IBAR	YAQUI1	00610
588		I PJ = IJ + NQ	YAQUI1	00611
589		I PJP = IJP + NQ	YAQUI1	00612
590		ETIL(IJ) = E(IJ)+.25*(Q(I PJ)+Q(I PJP)+Q(IJP)+Q(IJ))	YAQUI1	00613
591		RIL(IJ) = R(IJ)	YAQUI1	00614
592		RCSO(IJ) = 1./(ASO+GGM)*AMAX1(STE(IJ),0.)	YAQUI1	00615
593		XX = (X(I PJP)-X(IJ)+X(I PJ)-X(IJP))*2	YAQUI1	00616
594		YY = (Y(I PJP)-Y(IJ)+Y(IJP)-Y(I PJ))*2	YAQUI1	00617
595		OTLHM(IJ) = DTR*(XX*YY)/(XX*YY)	YAQUI1	00618
596		IJ = I PJ	YAQUI1	00619
597	1389	IJP = I PJP	YAQUI1	00620

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656		MT = RO(IJP)/RVOL(IJP)	YAQUI1 00679
657		PT = P(IJP)	YAQUI1 00680
658	1539	IF (J.EQ.2) GO TO 1540	YAQUI1 00681
659		MR = RO(IJM)/RVOL(IJM)	YAQUI1 00682
660		PR = P(IJM)	YAQUI1 00683
661	1540	P12 = (MR*PC+MC*PR)/(MR+MC)	YAQUI1 00684
662		P23 = (MT*PC+MC*PT)/(MT+MC)	YAQUI1 00685
663		P34 = (ML*PC+MC*PLE)/(ML+MC)	YAQUI1 00686
664		P41 = (MB*PC+MC*PR)/(MR+MC)	YAQUI1 00687
665		ETIL(IJ) = ETIL(IJ)-DT04/MC*(R12*P12*(U12*Y21+V12*X12)	YAQUI1 00688
	1	+R23*P23*(U23*Y32+V23*X23)	YAQUI1 00689
	2	+R34*P34*(U34*Y43+V34*X34)	YAQUI1 00690
	3	+R41*P41*(U41*Y14+V41*X41))	YAQUI1 00691
666		IJ = IPJ	YAQUI1 00692
667		IJP = IPJP	YAQUI1 00693
668	1589	IJM = IJM+NQ	YAQUI1 00694
669		CALL LOOP	YAQUI1 00695
670	1599	CONTINUE	YAQUI1 00696
671		CALL DONE	YAQUI1 00697
672	2000	MUSTIT = 0	YAQUI1 00698
673		MUSTIT = 1	YAQUI1 00699
674		PLMAX = EM10	YAQUI1 00700
675	2010	CALL START	YAQUI1 00701
676		DO 2099 J=2,JP1	YAQUI1 00702
677		DO 2099 I=1,IBAR	YAQUI1 00703
678		IPJ = IJ + NQ	YAQUI1 00704
679		IPJP = IJP + NQ	YAQUI1 00705
680		X1 = X(IPJ)	YAQUI1 00706
681		Y1 = Y(IPJ)	YAQUI1 00707
682		R1 = R(IPJ)	YAQUI1 00708
683		U1 = UL(IPJ)	YAQUI1 00709
684		V1 = VL(IPJ)	YAQUI1 00710
685		X2 = X(IPJP)	YAQUI1 00711
686		Y2 = Y(IPJP)	YAQUI1 00712
687		R2 = R(IPJP)	YAQUI1 00713
688		U2 = UL(IPJP)	YAQUI1 00714
689		V2 = VL(IPJP)	YAQUI1 00715
690		X3 = X(IJP)	YAQUI1 00716
691		Y3 = Y(IJP)	YAQUI1 00717
692		R3 = R(IJP)	YAQUI1 00718
693		U3 = UL(IJP)	YAQUI1 00719
694		V3 = VL(IJP)	YAQUI1 00720
695		X4 = X(IJ)	YAQUI1 00721
696		Y4 = Y(IJ)	YAQUI1 00722
697		R4 = R(IJ)	YAQUI1 00723
698		U4 = UL(IJ)	YAQUI1 00724
699		V4 = VL(IJ)	YAQUI1 00725
700		D = .25*RVOL(IJ)*((R1+R2)*((U1+U2)*(Y2-Y1)+(V1+V2)*(X1-X2))	YAQUI1 00726
	1	+ (R2+R3)*((U2+U3)*(Y3-Y2)+(V2+V3)*(X2-X3))	YAQUI1 00727
	2	+ (R3+R4)*((U3+U4)*(Y4-Y3)+(V3+V4)*(X3-X4))	YAQUI1 00728
	3	+ (R4+R1)*((U4+U1)*(Y1-Y4)+(V4+V1)*(X4-X1)))	YAQUI1 00729
701		S = RDT*(ROL(IJ)-RO(IJ))+ROL(IJ)*D	YAQUI1 00730
702		RA = RCSQ(IJ)*(RDT+D)+DELSM(IJ)	YAQUI1 00731
703		DP = -OM*S/RA	YAQUI1 00732
704		ROL(IJ) = ROL(IJ) + RCSQ(IJ)*DP	YAQUI1 00733
705		PLMAX = AMAX1(PLMAX,ABS(PL(IJ)))	YAQUI1 00734
706		IF (ABS(DP).LE.EPS*PLMAX) GO TO 2080	YAQUI1 00735
707		MUSTIT = 1	YAQUI1 00736

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708		PL(IJ) = PL(IJ)*DP	YAQUI1 00737
709		Y24 = Y2*Y4	YAQUI1 00738
710		Y31 = Y3*Y1	YAQUI1 00739
711		XR13 = .5*(R1+R3)*(X1-X3)	YAQUI1 00740
712		XR24 = .5*(R2+R4)*(X2-X4)	YAQUI1 00741
713		XX = DT02*DP	YAQUI1 00742
714		DT02M1 = XX*RM(IPJ)	YAQUI1 00743
715		DT02M2 = XX*RM(IPJP)	YAQUI1 00744
716		DT02M3 = XX*RM(IJP)	YAQUI1 00745
717		DT02M4 = XX*RM(IJ)	YAQUI1 00746
718		UL(IPJ) = U1*DT02M1+R1*Y24	YAQUI1 00747
719		UL(IPJP) = U2*DT02M2+R2*Y31	YAQUI1 00748
720		UL(IJP) = U3*DT02M3+R3*Y24	YAQUI1 00749
721		UL(IJ) = U4*DT02M4+R4*Y31	YAQUI1 00750
722		IF (J-EQ.2) GO TO 2060	YAQUI1 00751
723		VL(IPJ) = V1*DT02M1+XR24	YAQUI1 00752
724		VL(IJP) = V4*DT02M4+XR13	YAQUI1 00753
725	2060	IF (J-EQ.JP1) GO TO 2080	YAQUI1 00754
726		VL(IPJP) = V2*DT02M2+XR13	YAQUI1 00755
727		VL(IJP) = V3*DT02M3+XR24	YAQUI1 00756
728	2080	IJ = IPJ	YAQUI1 00757
729	2085	UL(IJ) = UL(IJP) = UL(IJP+NJIR) = UL(IJ-NQIB) = 0.	YAQUI1 00758
730		CALL LOOP	YAQUI1 00759
731		CONTINUE	YAQUI1 00760
732	2099	CALL NONE	YAQUI1 00761
733		NUMIT = NUMIT+1	YAQUI1 00762
734		IF (MUSTIT.EQ.0) GO TO 3000	YAQUI1 00763
735		MUSTIT = 0	YAQUI1 00764
736		IF (NUMIT.LT.500) GO TO 2010	YAQUI1 00765
737		LPR = 2	YAQUI1 00766
738		PRINT 4130	YAQUI1 00767
739		IF (GROVEL.GT.1.99) GO TO 3150	YAQUI1 00768
740	3000	CALL START	YAQUI1 00769
741		DO 3019 J=2,JP2	YAQUI1 00770
742		DO 3009 I=1,IP1	YAQUI1 00771
743		UG(IJ) = UL(IJ)*GROVEL	YAQUI1 00772
744		VG(IJ) = VL(IJ)*GROVEL	YAQUI1 00773
745		IJ = IJ + NQ	YAQUI1 00774
746	3009	CALL LOOP	YAQUI1 00775
747		CONTINUE	YAQUI1 00776
748	3019	CALL NONE	YAQUI1 00777
749		CALL START	YAQUI1 00778
750	3100	DO 3119 J=2,JP2	YAQUI1 00779
751		DO 3109 I=1,IP1	YAQUI1 00780
752		X(IJ) = X(IJ)*UG(IJ)*DT	YAQUI1 00781
753		Y(IJ) = Y(IJ)*VG(IJ)*DT	YAQUI1 00782
754		R(IJ) = X(IJ)*CYL*OMCYL	YAQUI1 00783
755		IJ = IJ + NQ	YAQUI1 00784
756	3109	CALL LOOP	YAQUI1 00785
757		CONTINUE	YAQUI1 00786
758	3119	CALL NONE	YAQUI1 00787
759		GO TO 3200	YAQUI1 00788
760	3150	CALL REZONE	YAQUI1 00789
761	3200	CALL START	YAQUI1 00790
762		DO 3269 J=2,JP1	YAQUI1 00791
763		DO 3259 I=1,IBAR	YAQUI1 00792
764		IMJ = IJ-NQ	YAQUI1 00793
765			YAQUI1 00794

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766 IPJ = IJ*NQ
767 IPJP = IJP*NQ
768
769 X1 = X(IPJ)
770 Y1 = Y(IPJ)
771 R1 = R(IPJ)
772 X2 = X(IPJP)
773 Y2 = Y(IPJP)
774 R2 = R(IPJP)
775 X3 = X(IJP)
776 Y3 = Y(IJP)
777 R3 = R(IJP)
778 X4 = X(IJ)
779 Y4 = Y(IJ)
780 R4 = R(IJ)
781 UL1 = UL(IPJ)
782 VL1 = VL(IPJ)
783 UL2 = UL(IPJP)
784 VL2 = VL(IPJP)
785 UL3 = UL(IJP)
786 VL3 = VL(IJP)
787 UL4 = UL(IJ)
788 VL4 = VL(IJ)
789 UN1 = UG(IPJ)
790 UN2 = UG(IPJP)
791 UN3 = UG(IJP)
792 UN4 = UG(IJ)
793 UN1 = UG(IPJ)
794 UN2 = UG(IPJP)
795 UN3 = UG(IJP)
796 UN4 = UG(IJ)
797 X12 = X1-X2
798 X23 = X2-X3
799 X34 = X3-X4
800 X41 = X4-X1
801 Y21 = Y2-Y1
802 Y32 = Y3-Y2
803 Y43 = Y4-Y3
804 Y14 = Y1-Y4
805 Y31 = Y3-Y1
806 R12 = R1-R2
807 R23 = R2-R3
808 R34 = R3-R4
809 R41 = R4-R1
810 U12 = U1-U2
811 U23 = U2-U3
812 U34 = U3-U4
813 U41 = U4-U1
814 V12 = V1-V2
815 V23 = V2-V3
816 V34 = V3-V4
817 V41 = V4-V1
818
819 VOLT = VOLT + VOLC = 1./RVOL(IJ)
820 IF (I.NE.IHAR) VOLR = 1./RVOL(IPJ)
821 IF (J.NE.JP1) VOLR = 1./RVOL(IJP)
822 IF (I.EQ.1) GO TO 3280
      FL = -FR
      N = .25*RVOL(IJ)*R12*(U12*Y21-V12*U121+R23*(U23*Y32-V23*U231
      +R34*(U34*Y43-V34*U341+R41*(U41*Y14-V41*U411))

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YAOUT1 00795
YAOUT1 00796
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YAOUT1 00850
YAOUT1 00851
YAOUT1 00852

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823		AL = -AR	YAQUI1 00863
824	3230	IF (J.EQ.2) GO TO 3290	YAQUI1 00864
825		FB = -FT(I)	YAQUI1 00865
826		AB = -AT(I)	YAQUI1 00866
827	3240	FR = DT08*R12*(UD1+UD2)*Y21+(VD1+VD2)*X12)	YAQUI1 00867
828		AR = A0M*SIGN(1.,FR)*B0*4.*FR/(VOLR+VOLC)	YAQUI1 00868
829		FT(I) = DT08*R23*(UD2+UD3)*Y32+(VD2+VD3)*X23)	YAQUI1 00869
830		AT(I) = A0M*SIGN(1.,FT(I))*B0*4.*FT(I)/(VOL.T+VOLC)	YAQUI1 00860
831		XX = AMAX1(ABS(FB),ABS(FR),ABS(FT(I)),ABS(FL))	YAQUI1 00861
832		DTC = AMIN1(DTC,DTPOS+A0FAC/(XX*RVOL(IJ)*NTPOS*ABS(D)+EM10))	YAQUI1 00862
833		IF (DTCSAV.NE.DTC) IDTC = I	YAQUI1 00863
834		IF (DTCSAV.NE.DTC) JDTC = J	YAQUI1 00864
835		DTCSAV = DTC	YAQUI1 00865
836		MP(IJ) = RO(IJ)*VOLC	YAQUI1 00866
		1 *FR*((1.,-AR)*RO(IJ)+(1.,+AR)*RO(IJP))	YAQUI1 00867
		2 *FT(I)*((1.,-AT(I))*RO(IJ)+(1.,+AT(I))*RO(IJP))	YAQUI1 00868
		3 *FL*((1.,-AL)*RO(IJ)+(1.,+AL)*RO(IJM))	YAQUI1 00869
		4 *FR*((1.,-AR)*RO(IJ)+(1.,+AB)*RO(IJM))	YAQUI1 00870
837		ROE = RO(IJ)*ETIL(IJ)	YAQUI1 00871
838		EP(IJ) = 1./MP(IJ)*(ROE*VOLC	YAQUI1 00872
		1 *FR*((1.,-AR)*ROE+(1.,+AR)*RO(IJP)*ETIL(IJP))	YAQUI1 00873
		2 *FT(I)*((1.,-AT(I))*ROE+(1.,+AT(I))*RO(IJP)*ETIL(IJP))	YAQUI1 00874
		3 *FL*((1.,-AL)*ROE+(1.,+AL)*RO(IJM)*ETIL(IJM))	YAQUI1 00875
		4 *FR*((1.,-AR)*ROE+(1.,+AB)*RO(IJM)*ETIL(IJM))	YAQUI1 00876
839		ATR = .5*(X2*Y31-X1*Y32-X3*Y21)	YAQUI1 00877
840		ARL = .5*(X1*Y43+X3*Y14+X4*Y31)	YAQUI1 00878
841		RVOL(IJ) = 3./(ATR*(R1+R2+R3)+ARL*(R1+R3+R4))	YAQUI1 00879
842		IJ = IJP	YAQUI1 00880
843		IJP = IJJP	YAQUI1 00881
844	3259	IJM = IJM + NQ	YAQUI1 00882
845		CALL LOOP	YAQUI1 00883
846	3269	CONTINUE	YAQUI1 00884
847		CALL NONE	YAQUI1 00885
848		GO TO 3300	YAQUI1 00886
849	3280	FL = DT08*R34*(UD3+UD4)*Y43+(VD3+VD4)*X34)	YAQUI1 00887
850		AL = A0M*SIGN(1.,FL)*B0*2.*FL*RVOL(IJ)	YAQUI1 00888
851		GO TO 3230	YAQUI1 00889
852	3290	FR = DT08*R41*(UD4+UD1)*Y14+(VD4+VD1)*X41)	YAQUI1 00890
853		AB = A0M*SIGN(1.,FR)*B0*2.*FR*RVOL(IJ)	YAQUI1 00891
854		GO TO 3240	YAQUI1 00892
855	3300	CALL START	YAQUI1 00893
856		DO 3319 J=2,JP1	YAQUI1 00894
857		DO 3309 I=1,IBAR	YAQUI1 00895
858		RO(IJ) = MP(IJ)*RVOL(IJ)	YAQUI1 00896
859		F(IJ) = EP(IJ)	YAQUI1 00897
860		IF (J.EQ.2) RO(IJM) = RO(IJ)	YAQUI1 00898
861		IF (J.EQ.JP1) RO(IJP) = RO(IJ)	YAQUI1 00899
862		IF (I.EQ.IBAR) RO(IJ+NQ) = RO(IJ+NQ)	YAQUI1 00900
863		IJM = IJM+NQ	YAQUI1 00901
864		IJP = IJP+NQ	YAQUI1 00902
865	3309	IJ = IJ + NQ	YAQUI1 00903
866		CALL LOOP	YAQUI1 00904
867	3319	CONTINUE	YAQUI1 00905
868		CALL NONE	YAQUI1 00906
869		CALL STARTD	YAQUI1 00907
870		DO 3399 JJ=2,JP2	YAQUI1 00908
871		J = JP4-JJ	YAQUI1 00909
872		DO 3389 II=1,IP1	YAQUI1 00910

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873	I = IP2-IJ	YAOUI1 00911	
874	IMJ = IJ-NQ	YAOUI1 00912	
875	IMJM = IJM-NQ	YAOUI1 00913	
876	XX = 0.	YAOUI1 00914	
877	IF (I.NE.IP1 .AND. J.NE.JP2) XX = MP(IJM)	YAOUI1 00915	
878	IF (I.NE.IP1 .AND. J.NE.JP2) XX = XX+MP(IJ)	YAOUI1 00916	
879	IF (I.NE.I .AND. J.NE.JP2) XX = XX+MP(IMJ)	YAOUI1 00917	
880	IF (I.NE.I .AND. J.NE.JP2) XX = XX+MP(IMJM)	YAOUI1 00918	
881	RMP(IJ) = 4./XX	YAOUI1 00919	
882	IJ = IMJ	YAOUI1 00920	
883	IJM = IMJM	YAOUI1 00921	
884	CALL LOOPD	YAOUI1 00922	
885	CONTINUE	YAOUI1 00923	
886	CALL START	YAOUI1 00924	
887	DO 3499 J=2-JP2	YAOUI1 00925	
888	DO 3489 I=1-IP1	YAOUI1 00926	
889	XX = RMP(IJ)/RM(IJ)	YAOUI1 00927	
890	UP(IJ) = XX*UL(IJ)	YAOUI1 00928	
891	VP(IJ) = XX*VL(IJ)	YAOUI1 00929	
892	IJ = IJ + NQ	YAOUI1 00930	
893	CALL LOOP	YAOUI1 00931	
894	CONTINUE	YAOUI1 00932	
895	CALL NONE	YAOUI1 00933	
896	CALL START	YAOUI1 00934	
897	DO 3499 J=2-JP1	YAOUI1 00935	
898	DO 3599 I=1-IPR	YAOUI1 00936	
899	IPJ = IJ-NQ	YAOUI1 00937	
900	IPJP = IJP+NQ	YAOUI1 00938	
901	X1 = X(IPJ)	YAOUI1 00939	
902	Y1 = Y(IPJ)	YAOUI1 00940	
903	R1 = R(IPJ)	YAOUI1 00941	
904	UL1 = UL(IPJ)	YAOUI1 00942	
905	UG1 = UG(IPJ)	YAOUI1 00943	
906	VL1 = VL(IPJ)	YAOUI1 00944	
907	VG1 = VG(IPJ)	YAOUI1 00945	
908	X2 = X(IPJP)	YAOUI1 00946	
909	Y2 = Y(IPJP)	YAOUI1 00947	
910	R2 = R(IPJP)	YAOUI1 00948	
911	UL2 = UL(IPJP)	YAOUI1 00949	
912	UG2 = UG(IPJP)	YAOUI1 00950	
913	VL2 = VL(IPJP)	YAOUI1 00951	
914	VG2 = VG(IPJP)	YAOUI1 00952	
915	X3 = X(IJP)	YAOUI1 00953	
916	Y3 = Y(IJP)	YAOUI1 00954	
917	R3 = R(IJP)	YAOUI1 00955	
918	UL3 = UL(IJP)	YAOUI1 00956	
919	UG3 = UG(IJP)	YAOUI1 00957	
920	VL3 = VL(IJP)	YAOUI1 00958	
921	VG3 = VG(IJP)	YAOUI1 00959	
922	X4 = X(IJ)	YAOUI1 00960	
923	Y4 = Y(IJ)	YAOUI1 00961	
924	R4 = R(IJ)	YAOUI1 00962	
925	UL4 = UL(IJ)	YAOUI1 00963	
926	UG4 = UG(IJ)	YAOUI1 00964	
927	VL4 = VL(IJ)	YAOUI1 00965	
928	VG4 = VG(IJ)	YAOUI1 00966	
929	XX = NT016*ROL(IJ)	YAOUI1 00967	
930	UL13 = UL1+UL3	YAOUI1 00968	

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931		VL13 = VL1-VL3	YAQUI1 00969
932		UL24 = UL2-UL4	YAQUI1 00970
933		VL24 = VL2-VL4	YAQUI1 00971
934		F13 = XX*(R1+R3)*((UG1-UG3-UL13)*(Y3+1)+(VG1-VG3-VL13)*(X1-X3))	YAQUI1 00972
935		F24 = XX*(R2+R4)*((UG2-UG4-UL24)*(Y2-Y4)+(VG2-VG4-VL24)*(X4-X2))	YAQUI1 00973
936		F41 = F24+RMP(IJP)	YAQUI1 00974
937		F42 = F13+RMP(IJJP)	YAQUI1 00975
938		F43 = F24+RMP(IJP)	YAQUI1 00976
939		F44 = F13+RMP(IJP)	YAQUI1 00977
940		XX = HQ*4.0*RVOL(IJ)/POL(IJ)	YAQUI1 00978
941		AL13 = A0*SIGN(1.,F13)*XX*F13	YAQUI1 00979
942		AL24 = A0*SIGN(1.,F24)*XX*F24	YAQUI1 00980
943		OPAL13 = 1.-AL13	YAQUI1 00981
944		OPAL24 = 1.-AL24	YAQUI1 00982
945		OMAL13 = 1.-AL13	YAQUI1 00983
946		OMAL24 = 1.-AL24	YAQUI1 00984
947		XX = UL3+OMAL24*UL1+OPAL24	YAQUI1 00985
948		UP(IJP) = UP(IJP) - FM1*XX	YAQUI1 00986
949		UP(IJP) = UP(IJP) - FM3*XX	YAQUI1 00987
950		XX = UL4+OMAL13*UL2+OPAL13	YAQUI1 00988
951		UP(IJJP) = UP(IJJP) - FM2*XX	YAQUI1 00989
952		UP(IJ) = UP(IJ) - FM4*XX	YAQUI1 00990
953		XX = VL3+OMAL24*VL1+OPAL24	YAQUI1 00991
954		VP(IJP) = VP(IJP) - FM1*XX	YAQUI1 00992
955		VP(IJP) = VP(IJP) - FM3*XX	YAQUI1 00993
956		XX = VL4+OMAL13*VL2+OPAL13	YAQUI1 00994
957		VP(IJJP) = VP(IJJP) - FM2*XX	YAQUI1 00995
958		VP(IJ) = VP(IJ) - FM4*XX	YAQUI1 00996
959		IJ = IJP	YAQUI1 00997
960	3599	IJP = IJJP	YAQUI1 00998
961		UP(IJ) = UP(IJP) + UP(IJJP-HQ*IJ) = UP(IJ-HQ*IJ) = 0.	YAQUI1 00999
962		IF (J.NE.2) GO TO 3620	YAQUI1 01000
963		ON 3610 IJ=ISE2,ISEF2,NQ	YAQUI1 01001
964	3610	VP(IJ) = 0.	YAQUI1 01002
965	3620	IF (J.NE.JP1) GO TO 3640	YAQUI1 01003
966		ON 3630 IJP=IJP5,LJP2,NQ	YAQUI1 01004
967	3630	VP(IJP) = 0.	YAQUI1 01005
968	3640	CALL LONP	YAQUI1 01006
969	3694	CONTINUE	YAQUI1 01007
970		CALL NONE	YAQUI1 01008
971	3700	CALL STABT	YAQUI1 01009
972		ON 3710 J=2,JP2	YAQUI1 01010
973		ON 3720 I=1,IPI	YAQUI1 01011
974		U(IJ) = UP(IJ)	YAQUI1 01012
975		V(IJ) = VP(IJ)	YAQUI1 01013
976		R=(IJ) = RMP(IJ)	YAQUI1 01014
977	3709	IJ = IJ + HQ	YAQUI1 01015
978		CALL LONP	YAQUI1 01016
979	3719	CONTINUE	YAQUI1 01017
980		CALL NONE	YAQUI1 01018
981	3800	CALL STABT	YAQUI1 01019
982		ON 3810 J=2,JP1	YAQUI1 01020
983		ON 3820 I=1,IPI	YAQUI1 01021
984		IJP = IJ+NQ	YAQUI1 01022
985		IJP = IJP+NQ	YAQUI1 01023
986		SIG(IJ) = X(IJ)-.125*(U(IJP)**2+U(IJP)**2+U(IJP)**2+U(IJ)**2 +V(IJP)**2+V(IJP)**2+V(IJP)**2+V(IJ)**2)	YAQUI1 01024
987		IJP = IJP	YAQUI1 01025

LINE#	01/12/73	SUBROUTINE TAQU12	PAGE	54
994	3899	IJ = IPJ	TAQU11	01027
999		CALL LONP	TAQU11	01028
990	3899	CONTINUE	TAQU11	01029
901		CALL CONE	TAQU11	01030
992		IF INPT.CY.01 CALL PARTMOV	TAQU11	01031
993		GO TO 100	TAQU11	01032
		C	TAQU11	01033
994	4000	FNMAF1= T=1P12.5* CFC=15* DT=12.5* GRINDS=12.5* CIRC=	TAQU11	01034
		1 12.5* DT=12.5* 10TV.JDTV=13*.X13/44*1TVDS=14* CPM	TAQU11	01035
		1 12.5* DT=12.5* 10TC.JDT=13*.X131	TAQU11	01036
995	4010	FNMAF1=0 TAP CON=13* AT T=1P12.5* CCL=151	TAQU11	01037
996	4020	FNMAF1=0 RSTAP1=0 FMO= 10*131	TAQU11	01038
997	4030	FNMAF1=10.1044 T=1P12.5* CCL=151	TAQU11	01039
998	4040	FNMAF1=0 WMO=0 TAP = WMO/ CONP, 11	TAQU11	01040
999	4050	FNMAF1=111	TAQU11	01041
1000	4060	FNMAF1= 1 J=7T=112*11E=111*V=10E51E=0E=0*0E=VOL*10E	TAQU11	01042
		1 MO=1E=11E=011	TAQU11	01043
1001	4070	FNMAF1=13.13*.X13,10114.1P11.411	TAQU11	01044
1002	4080	FNMAF1=10.1044 T=1P12.5* CCL=151	TAQU11	01045
1003	4090	FNMAF1= 15*TV=12.51	TAQU11	01046
1004	4100	FNMAF1= 15*TV=12.51	TAQU11	01047
1005	4110	FNMAF1= V=12.51	TAQU11	01048
1006	4120	FNMAF1=12* W=10E=12.5* M=12.5* L=12.5* H=12.5* D=	TAQU11	01049
		1 12.51	TAQU11	01050
1007	4130	FNMAF1= 12*TV=12.51 12*TV=12.51 12*TV=12.51	TAQU11	01051
1008	4140	FNMAF1= 12*TV=12.51 12*TV=12.51 12*TV=12.51	TAQU11	01052
		1 12*TV=12.51 12*TV=12.51 12*TV=12.51	TAQU11	01053
1009	4150	FNMAF1= V=12.51 12*TV=12.51 12*TV=12.51	TAQU11	01054
1010		END	TAQU11	01055

SUBROUTINE YAQU12

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INDEX      01/12/73
640 -      251      261*
649 -      26300    285*
659 -      26200    287*
700 -      260      289*
709 -      29300    294*
710 -      29200    298*
720 -      307*     308
730 -      309*     313
735 -      300      314*
739 -      31700    318*
740 -      310      320*
750 -      322      323*
760 -      322      325*
770 -      322      327*
780 -      324      326
789 -      34800    355*
799 -      34700    357*
800 -      344      358*
810 -      359      364AS
820 -      366      371AS
830 -      373      378AS
840 -      365      372
879 -      33700    343
889 -      33300    399*
899 -      33100    400*
919 -      40300    419*
949 -      40200    421*
1000 -      67      423*
1015 -      432      436*
1020 -      435      438*
1025 -      438      442*
1030 -      441      444*
1035 -      444      448*
1040 -      447      450*
1045 -      450      454*
1050 -      453      456*
1089 -      42600    464*
1099 -      42500    466*
1130 -      531      534*
1140 -      533      537*
1199 -      47000    574*
1210 -      57700    578*
1220 -      576      579*
1230 -      58000    581*
1240 -      579      582*
1299 -      46900    583*
1389 -      58700    597*
1399 -      58600    599*
1510 -      649      652*
1520 -      652      655*
1530 -      655      658*
1540 -      658      661*
1589 -      60300    668*
1599 -      60200    670*
2010 -      675*     737
2060 -      722      725*
2080 -      706      725
2089 -      67700    729*

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395

386*

385AS 396*

366*

373*

380*

379

380

385AS

396*

328*

366*

373*

380*

379

380

385AS

396*

728*

SUBROUTINE YAOUI2

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INDEX 01/12/73
2099 - 67600 732*
3000 - 735 740*
3004 - 74300 746*
3019 - 74200 748*
3100 - 75200 756*
3119 - 75100 758*
3150 - 740 761*
3200 - 766 762*
3230 - 824* 851
3240 - 827* 854
3259 - 76400 844*
3269 - 76300 846*
3280 - 821 849*
3290 - 824 852*
3300 - 848 855*
3309 - 85700 865*
3319 - 85600 867*
3389 - 87200 883*
3399 - 87000 885*
3489 - 88800 892*
3499 - 88700 894*
3599 - 89800 900*
3610 - 96300 944*
3620 - 962 945*
3630 - 96600 947*
3640 - 945 948*
3699 - 89700 959*
3709 - 97300 977*
3719 - 97200 979*
3889 - 98300 988*
3899 - 98200 990*
4000 - 43WR 45PR 994*
4010 - 82PR 83WR 995*
4020 - 102PR 105WR 996*
4030 - 103PR 106WR 997*
4040 - 108PR 109WR 998*
4050 - 168PR 999*
4060 - 162WR 170PR 1000*
4070 - 157WR 164PR 1001*
4080 - 161WR 169PR 226WR
4090 - 323WR 1003*
4100 - 325WR 1004*
4110 - 327WR 1005*
4120 - 328WR 1006*
4130 - 73.98 1007*
4140 - 225WR 1008*
4150 - 246WR 1009*
AA (1)R 4C0 84WR 94 95RD 247WR 329WR 1002*
AASC (1)R 3C0 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ
AAJ (1)R 2LC 85WR 97RD 94 95RD 5EQ 5EQ 5EQ 5EQ 5EQ 5EQ
AAP (1)R 2LC 86WR 98RD 836 838 83R 823=
AB -R 826= 836
ABL -R 840= 841
ABS - 189SU 189SU 315SU 535SU 706SU 831SU 831SU 831SU 832SU
ADV - 120SU 181SU 229SU 320SU 315SU 535SU 535SU 706SU 831SU 831SU 831SU 832SU
AFSREL - 88SU 89SU 110SU
AK -R 532= 536* 542= 543
AL -R 823= 836 838 83R 838 850=

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INDEX		01/12/73		SUBROUTINE		YAQU12		PAGE		60	
ALOG10	-	301SU	304SU	945							
AL13	-R	941=	943	945							
AL24	-R	942=	944	946							
AMAX1	-	30SU	109SU	202SU	206SU	294SU	315SU	535SU	502SU	705SU	831SU
AMIN1	-	53SU	201SU	205SU	294SU	537SU	544SU	832SU			
ANC	-R	4C0	424								
AR	-R	R23	R28=	R36	R36	R38	R38				
ASQ	-R	4C0	31	32	33	592					
ASSIGN	-	72F	74F	77F	79F	113F	114F	115F	117F	118F	123F
AT	(R)	R01	9EQ	9EQ	9EQ	9EQ	9EQ	9EQ	926	830=	836
ATR	-R	R39=	R41								
AX	-R	457=	459	461							
AY	-R	458=	460	461							
A0	-R	4C0	941	942							
A0FAC	-R	4C0	832								
ADM	-R	4C0	R2R	R30	850	853	940	28	29	43WR	45PR
AD	-R	4C0	R2R	R30	850	853	940	28	29	43WR	45PR
CLC	-R	21=	28=	26	27=	27					
COLAMI	-R	4C0	536	542							
COMMON	-	3F	4F	10F							
CON	(R)	R01	9EQ	309=	318=	328WR	339	340	341	342	347
CQ	(R)	5EQ	701	P55=	2M3=	294	295	330	340	341	342
CYL	-R	4C0	543	550	551	755					
D	-R	129=	155=	157WR	164PR	520=	537	700=	701	102	832
DEL5M	(R)	5EQ	701	595=	702						
DEL5M1	-	7F	RF								
ONE	-	39SU	259SU	208SU	467SU	584SU	600SU	671SU	733SU	749SU	759SU
DP	-R	703=	704	706	708	713					
DO	-R	303=	307	312	316=	318	328WR	543=	544		
DRMAX	-R	183=	202=	202	2P5WR						
DRMIN	-R	182=	201=	201	225WR						
DRNU	-R	228=	235	236							
DT	-R	215SU	216SU	217SU	218SU	240SU	391SU	414SU	415SU	416SU	417SU
DT	-R	4C0	43WR	45PR	52=	52	53=	55	56	56=	57
DT	-R	65	66	459	460	461	542	753	754		
DT	-R	4C0	43WR	45PR	53	55=	832=	832	833	834	835
DT	-R	4C0	43WR	45PR	53	55=	832=	832	833	834	835
DT	-R	17=	833	834	835=						
DT	-R	4C0	54=	55							
DT	-R	4C0	64=								
DT	-R	4C0	65=								
DT	-R	4C0	66=								
DT	-R	4C0	67=								
DT	-R	4C0	68	70							
DT	-R	4C0	69	70							
DT	-R	4C0	62=	929							
DT	-R	4C0	59=	523	524	525	526	534	713		
DT	-R	523=	554	562	568	568	568	568	568	568	568
DT	-R	524=	558	565	571	571	571	571	571	571	571
DT	-R	525=	555	563	569	569	569	569	569	569	569
DT	-R	526=	559	566	572	572	572	572	572	572	572
DT	-R	4C0	60=	665							
DT	-R	4C0	61=	827	829	849	852	852	852	852	852
DT	-R	4C0	62=	53=	542	542	542	542	542	542	542
DT	-R	4C0	43WR	45PR	53	55=	544=	544	545	546	547
DT	-R	17=	545	546	546	547=					
DT	-R	4C0	63=	595							
DT	-R	4C0	34								
DT	-R	183=	206=	206	225WR						
DT	-R	182=	205=	205	225WR						

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FILE		SEQ	TOI	590	859=	986	61
FM10	-R	44SU	177SU	48	69	181	832
FM10	-R	4CO	46	48	859	543	674
EP	-R	11R	5EQ	70I	838=	227	543
FPS	-R	4CO	706	9F			
EQUIVAL - 5F							
ETIL	-R	5EQ	70I	590=	665=	838	838
F8	-R	825=	831	836	852=	837	838
F11L	-R	4CO	207	209	211	233	406
F11L	-R	4CO	208	210	212	234	410
F11L	-R	822=	831	836	849=	850	411
FL	-R	822=	831	836	849=	850	413
FLOAT - 34SU							
FM1	-R	926=	948	954			
FM2	-R	927=	951	957			
FM3	-R	938=	949	955			
FM4	-R	939=	952	958			
FR	-R	822=	827=	828	828	831	838
FT	-R	801	960	825	829=	830	838
F13	-R	934=	937	939	941	941	
F24	-R	935=	936	938	942	942	
GETO - 13SU							
GM1	-R	4CO	592				
GM1	-R	4CO	31	33			
GR	-R	4CO	64	457			
GRVCL	-R	4CO	181	190	223	740	745
GZ	-R	4CO	34	35	458		
GZP	-R	4CO	66	66	570		
HR13	-R	509=	556	564	570		
HR24	-R	510=	552	561	547		
I	-I	4CO	2300	26	27	12600	132
		41A	42600	432	444	47600	545
		826	829	830	830	830	831
		878	879	880	88000	89800	97300
IBAR	-I	4CO	18	2100	19600	248	25400
		85700	862	89800	98300	388	388
IC1	-I	360=	367=	374=	381=	388	389
IC2	-I	361=	368=	375=	382=	388	389
IDTC	-I	43WR	45PR	433=			
IDTC	-I	4CO	68	69	70	70	71=
IDTV	-I	43WR	45PR	445=			
II	-I	15AG	16	34800	87200	873	28
IJ	-I	4CO	24	26	26	27	28
		34	36=	128	145	147	148
		235	235	236	236	242	255
		283	284=	294	295	296	334
		427	428	437	458	459	460
		492	576	584	532	542	543
		564	572	572	575	575	57700
		594	595	596=	604	616	617
		695	696	697	698	700	701
		717	721	724	728=	730	744
		754	755	755	756=	766	777
		836	836	836	836	836	837
		859	859	862	862	865=	874
		892	899	922	923	924	926
		950=	961	961	96300	964	974
		986	988=				
IJA	-I	346=	350	352	353	354=	357=

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		352	353	354	355	356	357	358	359	360	361	362	363
IJR	-I	345	346	347	348	349	350	351	352	353	354	355	356
IJM	-I	400	401	402	403	404	405	406	407	408	409	410	411
		157WR	157WR	157WR	157WR	157WR	157WR	157WR	157WR	157WR	157WR	157WR	157WR
		464	465	466	467	468	469	470	471	472	473	474	475
		877	878	879	880	881	882	883	884	885	886	887	888
IJP	-I	400	401	402	403	404	405	406	407	408	409	410	411
		285	286	287	288	289	290	291	292	293	294	295	296
		487	488	489	490	491	492	493	494	495	496	497	498
		597	598	599	600	601	602	603	604	605	606	607	608
		716	717	718	719	720	721	722	723	724	725	726	727
		838	839	840	841	842	843	844	845	846	847	848	849
		955	956	957	958	959	960	961	962	963	964	965	966
IJS	-I	400	401	402	403	404	405	406	407	408	409	410	411
IJ1	-I	362	363	364	365	366	367	368	369	370	371	372	373
IJ2	-I	363	364	365	366	367	368	369	370	371	372	373	374
IJ3	-I	427	428	429	430	431	432	433	434	435	436	437	438
IJ4	-I	875	876	877	878	879	880	881	882	883	884	885	886
IMI	-I	400	401	402	403	404	405	406	407	408	409	410	411
IPJ	-I	24	25	26	27	28	29	30	31	32	33	34	35
		264	265	266	267	268	269	270	271	272	273	274	275
		445	446	447	448	449	450	451	452	453	454	455	456
		588	589	590	591	592	593	594	595	596	597	598	599
		681	682	683	684	685	686	687	688	689	690	691	692
		836	837	838	839	840	841	842	843	844	845	846	847
		959	960	961	962	963	964	965	966	967	968	969	970
IPJA	-I	350	351	352	353	354	355	356	357	358	359	360	361
IPJR	-I	349	350	351	352	353	354	355	356	357	358	359	360
IPJ1	-I	127	128	129	130	131	132	133	134	135	136	137	138
		25	26	27	28	29	30	31	32	33	34	35	36
		429	430	431	432	433	434	435	436	437	438	439	440
		590	591	592	593	594	595	596	597	598	599	600	601
		715	716	717	718	719	720	721	722	723	724	725	726
		841	842	843	844	845	846	847	848	849	850	851	852
		911	912	913	914	915	916	917	918	919	920	921	922
IP1	-I	400	401	402	403	404	405	406	407	408	409	410	411
IP2	-I	400	401	402	403	404	405	406	407	408	409	410	411
ISC2	-I	400	401	402	403	404	405	406	407	408	409	410	411
IX1	-I	400	401	402	403	404	405	406	407	408	409	410	411
IX2	-I	400	401	402	403	404	405	406	407	408	409	410	411
IX3	-I	400	401	402	403	404	405	406	407	408	409	410	411
IX4	-I	400	401	402	403	404	405	406	407	408	409	410	411
IY1	-I	400	401	402	403	404	405	406	407	408	409	410	411
IY2	-I	400	401	402	403	404	405	406	407	408	409	410	411
IY3	-I	400	401	402	403	404	405	406	407	408	409	410	411
IY4	-I	400	401	402	403	404	405	406	407	408	409	410	411
J	-I	400	401	402	403	404	405	406	407	408	409	410	411
		40200	40201	40202	40203	40204	40205	40206	40207	40208	40209	40210	40211
		74200	74201	74202	74203	74204	74205	74206	74207	74208	74209	74210	74211
JBAR	-I	400	401	402	403	404	405	406	407	408	409	410	411
JOTC	-I	400	401	402	403	404	405	406	407	408	409	410	411
JOTV	-I	400	401	402	403	404	405	406	407	408	409	410	411
JJ	-I	400	401	402	403	404	405	406	407	408	409	410	411
JNM	-I	400	401	402	403	404	405	406	407	408	409	410	411
JNSC	-I	400	401	402	403	404	405	406	407	408	409	410	411
JP1	-I	400	401	402	403	404	405	406	407	408	409	410	411
		85600	85601	85602	85603	85604	85605	85606	85607	85608	85609	85610	85611
JP2	-I	400	401	402	403	404	405	406	407	408	409	410	411
		12500	12501	12502	12503	12504	12505	12506	12507	12508	12509	12510	12511

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																63	

INDEX	01/12/73	155	155	155	485=	586=	507	509	SUBROUTINE	YAOUT2	555	615=	628	629	PAGE	65	700	711	720	776=
R3	-R	147=	155	155	485=	586=	507	509	586=	507	509	555	615=	628	629	692=	700	711	720	776=
R34	-R	807=	807	841	841	917=	934	665	807=	817	849	807=	817	849	630	697=	700	712	721	779=
R4	-R	152=	155	155	490=	507	508	510	559	618=	629	559	618=	629	630	697=	700	712	721	779=
R41	-R	807	808	841	924=	935	935	665	808=	817	852	808=	817	852						
S	-R	508=	528	548	549	550	630=	665	808=	817	852	808=	817	852						
S	-R	701=	703	703	701=	703	703	703	701=	703	703	701=	703	703						
SECOND	-	115U	415U	30	133	592	986=													
SIF	(R	5EQ	70I	30	133	592	986=													
SIFT	-R	30=	31	33	853SU	941SU	942SU													
SIGN	-	A28SU	A30SU	A50SU	A50SU	A50SU	A50SU													
SOPT	-	199SU	204SU	204SU	204SU	204SU	204SU													
START	-	28SU	174SU	184SU	230SU	252SU	261SU	291SU	330SU	401SU	423SU	468SU	545SU	601SU	675SU	741SU	750SU	762SU		
T	-R	895SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU	896SU
T	-R	4C0	43MR	45PR	44	50	56	56	56	57=	57=	57=	57=	57=	82PR	83MR	103PR	106MR	169PR	226MR
TRASE	-R	11AG	12	49	49	101=	101													
TLIM	-R	16=	19=	19	49	101=	101													
TLIMD	-R	4C0	19	101																
TOLO	-R	40=	42	54	56	68=	68	70=												
TOUT	-R	4C0	46	54	56	68=	68	70=												
TWFIN	-R	4C0	50	76=	43MR	45PR	48	49	76											
T1	-R	12=	48	76=	43MR	45PR	48	49	76											
T2	-R	40	41AG	42	2A	29	29	13R	143	14R	153	14R	153	157MR	164PR	189	235	268	272	276
T20MD	-R	4C0	41AG	42	2A	29	29	13R	143	14R	153	14R	153	157MR	164PR	189	235	268	272	276
U	(R	5EQ	70I	2R	2A	29	29	13R	143	14R	153	14R	153	157MR	164PR	189	235	268	272	276
UD1	-R	280	433	439	445	451	457	459	461	476	481	476	481	486	491	574=	986	986	986	986
UD2	-R	78R=	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27
UD3	-R	790=	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27
UD4	-R	792=	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27	A27
UG	(R	5EQ	70I	744=	753	768	790	792	794	905	912	905	912	919	926					
UG1	-R	905=	934	70I	744=	753	768	790	792	794	905	912	919	926						
UG2	-R	912=	935																	
UG3	-R	919=	934																	
UG4	-R	924=	935																	
UL	(R	5EQ	70I	683	688	693	698	718=	719=	720=	721=	720=	721=	730=	730=	730=	730=	744	780	782
UL1	-R	784	786	890	904	911	918	925	930	947										
UL13	-R	780=	788	809	812	904=	930	947												
UL2	-R	930=	934	809	810	911=	932	950												
UL24	-R	782=	790	809	810	911=	932	950												
UL3	-R	932=	935	810	811	918=	930	947												
UL4	-R	786=	794	811	812	925=	932	950												
UP	(R	5EQ	70I	890=	948=	948=	949=	949=	951=	951=	952=	951=	952=	952=	952=	961=	961=	961=	974	974
UTL	(R	5EQ	70I	459=	554=	554=	555=	555=	558=	558=	559=	558=	559=	559=	559=	575=	575=	575=	631	632
U1	-R	633	634	13R=	155	155	268=	283	283	433=	439=	433=	439=	439=	445	451=	451=	457	476=	511
U12	-R	514	516	631=	639	642	683=	700	700	718=	817	718=	817	817	817	817	817	817	817	817
U13	-R	516=	570	548	548	550	551	639=	665	809=	817	665	809=	817	817	817	817	817	817	817
U2	-R	143=	155	155	272=	283	283	481=	511	512	515	512	515	515	632=	639	640	688=	700	719
U23	-R	512=	528	548	550	550	640=	665	810=	817	817	817	817	817	817	817	817	817	817	817
U24	-R	515=	567	155	276=	283	283	486=	512	513	516	513	516	516	633=	640	641	693=	700	720
U3	-R	148=	155	155	276=	283	283	486=	512	513	516	513	516	516	633=	640	641	693=	700	720
U34	-R	513=	528	548	548	550	551	641=	665	811=	817	665	811=	817	817	817	817	817	817	817
U4	-R	153=	155	155	280=	283	283	491=	513	514	515	514	515	515	534	535	641	642	698=	700
U4	-R	700	721																	

INDEX	01/12/73	43PR	45PR	299=	SUBROUTINE YAQUI2					PAGE 67							
-R	42=	316	387=	388	300	301	302=	303	305=	307=	307	308	309	310	312=	312	314=
-R	43=	315	387=	388	389	430=	437=	449=	450	529=	535	540=	540	540	543	543	552=
-R	44=	554	555	556=	558	559	562	563	564=	565	566	567=	568	569	570=	571	572
-R	45=	593=	595	595	713=	714	715	716	717	831=	832	877=	878=	879	879	880=	880=
-R	46=	880	881	889=	890	891	929=	934	935	940=	941	942	947=	948	950=	951	952
-R	47=	953=	954	955	956=	957	958										
XY	-R	527=	548	550	551												
XY14	-R	199=	201	202													
XY21	-R	203=	205	206													
XY23	-R	200=	201	202													
XY34	-R	204=	205	206													
X1	-R	135=	155	155	191=	199	203	207	266=	283	283	431=	430=	442=	448=	448	454=
	-R	454	456=	456	457	458	473=	493	496	498	529	607=	619	622	680=	700	711
X12	-R	768=	796	799	839	840	901=	934	917	827	283	478=	493	494	497	529	610=
X2	-R	140=	155	155	192=	200	203	209	270=	283	908=	935					619
X23	-R	620	685=	700	700	712	771=	796	797	839	908=	935					
X24	-R	494=	528	549	550	550	665	797=	817	824							
X3	-R	497=	527	552	561	567	567										
X33	-R	145=	155	155	193=	200	204	211	274=	283	203	483=	494	495	498	529	620
	-R	621	690=	700	700	711	774=	797	798	839	840	915=	934				613=
X31	-R	498=	527	556	564	570	570	798	817	849							
X34	-R	495=	528	550	550	621=	665	798	817	849	263	488=	495	496	497	529	621
X4	-R	150=	155	155	194=	199	204	213	278=	283	263	488=	495	496	497	529	610=
	-R	622	695=	700	700	712	777=	798	799	840	922=	935					
X41	-R	496=	528	549	550	623=	665	798	817	852							
Y	(R	5EO	701	26	26	27	27	136	141	146	151	157WR	164PR	195	196	197	198
Y	(R	236	267	271	275	276	353	353	353	353	407	409	411	413	413	479	484
Y	(R	594	594	594	594	604	611	614	617	681	686	691	696	754	754	769	775
YB	-R	4CO	34	208	210	212	212	214	225WR	234	236	389	407	411	413		
YCO	(R	AD1	9EO	353=	389	389	389	389	236	236	389	407	411	413			
YCONV	-R	4CO	208	210	212	212	214	234	236	236	389	407	411	413			
YPAR	(R	5EO	701	26	26	27	27	136	141	146	151	157WR	164PR	195	196	197	198
YT	-R	4CO	34	225WR	460	530=	535	541=	541	541	543	543	553=	554	555	557=	559
YY	-R	430=	443=	455=													
	-R	594=	595	595	195=	199	203	208	267=	283	283	424=	457	458	474=	499	504
Y1	-R	136=	155	155	195=	199	203	208	267=	283	283	424=	457	458	474=	499	504
	-R	530	608=	623	626	681=	700	700	710	769=	800	803	804	804	934		
Y14	-R	502=	528	548	550	624=	665	803=	817	840	852						
Y2	-R	141=	155	155	196=	200	203	210	271=	283	283	479=	499	500	503	530	623
	-R	624	606=	700	700	709	772=	800	801	809=	935						
Y21	-R	499=	528	548	550	623=	665	808=	817	827	839						
Y24	-R	503=	527	552	553	561	567	567	709=	718	720						
Y3	-R	146=	155	155	197=	200	204	210	275=	283	283	484=	500	501	504	530	624
	-R	625	691=	700	700	710	775=	801	802	804	916=						
Y31	-R	504=	527	556	557	564	570	570	710=	719	721	804=	839	840			
Y32	-R	500=	528	548	550	624=	665	808=	817	829	839						
Y4	-R	151=	155	155	198=	199	204	214	279=	283	283	480=	501	502	503	530	625
	-R	626	696=	700	700	709	778=	802	803	803	923=	935					
Y43	-R	501=	528	548	550	625=	665	802=	817	840	849						
ZZ	-R	4CO	94														

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1		SUBROUTINE PARTMOV	YAQUI1 01056
2		COMMON /YSC1/ AASC(4242)	COMMON2 00002
3		COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,R1,COLAMU,CYL,	COMMON2 00003
1		DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTN(10),DTNC(10),	COMMON2 00004
2		DT016,DT02,DT04,DT08,DTPOS,DTV,DTA,DZ,EM10,EPS,FIBP,	COMMON2 00005
3		FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXP,FIYB,FIYT,FJBP,	COMMON2 00006
4		FRET,GGM1,GMI,GR,GNDVEL,GZ,GZP,I,IR,IR,IRP,IRP1,COLOR,	COMMON2 00007
5		IDT0,IJ,IJH,IJP,IJPS,IM0ME3,IM0M,I1,I1M6,	COMMON2 00008
6		IPAR,IPXL,IPXR,IPYB,IPYT,IP1,IP2,ISC1,ISC2,ISC3,	COMMON2 00009
7		ITV,IUNF,IYL,IXR,IYR,IYT,J,JRAB,JRP,JRP2,JCFN,JM10,	COMMON2 00010
8		JM14,JP1,JP2,JP4,JP402,JINF,JUNF02,KXI,LAM,LJP2,LPR,	COMMON2 00011
9		LPR,MU,NAMF(10),NCYC,NLC,NPS,NPT,NQ,NQ1,NQIN,NQ12,NSC,	COMMON2 00012
1		NUMIT,NUHTN,OM,OMANC,OMCYL,OMEM10,OMEM10,POR,PUZ,PXCONV,	COMMON2 00013
2		PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,ROZ,RFZRON,REZSIE,	COMMON2 00014
3		REZIE,REZVE,REZJT,REZY0,RIBAR,PIRJA,RIAP,RJAP,RHMFAR,	COMMON2 00015
4		RON,RPNR,RPNR0Z,RPNZ,T,TMIRD,TLM0,TOUT,TWFIN,TZOM0,	COMMON2 00016
5		VV,XCONV,XL,XR,YB,YCONV,YT,ZZ	COMMON2 00017
4		EQUIVALENCE (AASC(1),X,XPAR),(AASC(2),R,YPAR),(AASC(3),Y,MPAR),	EQUIREAL 00002
1		(AASC(4),U,UG,DELSM),(AASC(5),J,VG),(AASC(6),R0),	EQUIREAL 00003
2		(AASC(7),SIE,MP,RMP,RCS0),(AASC(8),E,ETIL),	EQUIREAL 00004
3		(AASC(9),RVDL),(AASC(10),M,RM,YP),(AASC(11),P,PL,EP,	EQUIREAL 00005
4		UP,PM0),(AASC(12),UTIL,UL,C0,PMX,PU),(AASC(13),VTIL,	EQUIREAL 00006
5		VL,PHY,PV),(AASC(14),Q,R0L)	EQUIREAL 00007
5		REAL LAM,LAM0,M,MR,MC,ML,MP,PAR,MR,MT,MTE,MU,MU02,MU04	EQUIREAL 00008
6		DIMENSION X(1),XPAR(1),R(1),YPAR(1),Y(1),MPAR(1),U(1),UG(1),	DIMEN 00002
1		DELSM(1),V(1),VG(1),R0(1),SIE(1),MP(1),RMP(1),RCS0(1),	DIMEN 00003
2		E(1),ETIL(1),MVDL(1),M(1),RM(1),YP(1),P(1),PL(1),EP(1),	DIMEN 00004
3		UP(1),UTIL(1),UL(1),C0(1),PMX(1),PU(1),VTIL(1),VL(1),	DIMEN 00005
4		PHY(1),PV(1),Q(1),R0L(1),PM0(1)	DIMEN 00006
7		DIMENSION X1(4)	YAQUI1 01060
8		EQUIVALENCE (X1(2),X2),(X1(3),X3),(X1(4),X4)	YAQUI1 01061
9		COMMON /YSC3/ JNP	YAQUI1 01062
10		CALL START	YAQUI1 01063
11		DO 1019 J=2,JP2	YAQUI1 01064
12		DO 1009 I=1,IP1	YAQUI1 01065
13		PMX(IJ) = PMY(IJ) * PM0(IJ) * 0.0	YAQUI1 01066
14	1009	IJ = IJ+NQ	YAQUI1 01067
15		CALL LOOP	YAQUI1 01068
16	1019	CONTINUE	YAQUI1 01069
17		CALL DONE	YAQUI1 01070
18		DO 1099 J=2,JP2	YAQUI1 01071
19		IEC = (J-1)*NQ1	YAQUI1 01072
20		CALL ECRD (AASC,IEC,NQ1,NE)	YAQUI1 01073
21		IJ = 1	YAQUI1 01074
22		DO 1089 I=1,IP1	YAQUI1 01075
23		IF (X(IJ).GT,PXRP,OR, Y(IJ).LT,PYBM) GO TO 1099	YAQUI1 01076
24		IF (Y(IJ).GT,PYTP) GO TO 1000	YAQUI1 01077
25		KI = X(IJ) * RPNR * OPEM10	YAQUI1 01078
26		KJ = (Y(IJ)-PYR)*RPNZ * OPEM10	YAQUI1 01079
27		IFC = KJ*NQ1	YAQUI1 01080
28		CALL ECRD (AASC(ISC2),IEC,NQ12,NE)	YAQUI1 01081
29		KIJ = (KI-1)*NQ1ISC2	YAQUI1 01082
30		KIJP = KIJ*NQ1	YAQUI1 01083
31		W = X(IJ) - FLOAT(KI-1)*PNR	YAQUI1 01084
32		H = (Y(IJ)-PYR)-FLOAT(KJ-1)*PNZ	YAQUI1 01085
33		XX = RPNR0Z/RM(IJ)	YAQUI1 01086
34		HTE = PNZ-H	YAQUI1 01087
35		DO 1049 JJ=1,2	YAQUI1 01088

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36		WTE = PDR-W		09
37		DO 1039 I=1,2		01089
38		X1 = X*WTE*WTE		01090
39		PMX(KIJ) = PMX(KIJ) + X1*U(IJ)		01091
40		PMY(KIJ) = PMY(KIJ) + X1*V(IJ)		01092
41		PM0(KIJ) = PM0(KIJ) + X1		01093
42		WTE = W		01094
43		KIJ = KIJ+NO		01095
44		HTL = H		01096
45		KIJ = KIJ		01097
46		CALL ECWR (AASC(ISC2),IEC,NOI2,NE)		01098
47		IJ = IJ+NO		01099
48		CONTINUE		01100
49		CALL START		01101
50		KK = 0		01102
51		DO 1199 J=2,JBP2		01103
52		DO 1189 I=1,I8P1		01104
53		RPM0 = PM0(IJ)		01105
54		IF (RPM0,NE,0.) PM0(IJ) = RPM0 = 1./RPM0		01106
55		IF (RPM0,EQ,0.) KK = 1		01107
56		PV(IJ) = PMX(IJ)*RPM0		01108
57		PV(IJ) = PMY(IJ)*RPM0		01109
58		IF (I,EQ,1) PV(IJ) = 0.		01110
59	1189	IJ = IJ + NO		01111
60		CALL LOOP		01112
61		CONTINUE		01113
62		CALL NONE		01114
63		IF (KK,EQ,0) GO TO 1400		01115
64		CALL START		01116
65		DO 1299 J=2,JBP2		01117
66		DO 1289 I=1,I8P1		01118
67		IF (PM0(IJ),GT,0.) GO TO 1289		01119
68		ITESTL = ITESTR = I		01120
69		PVL = PVL + PVR = PVR = 0.		01121
70		XWL = XWL + 1.		01122
71		IL = IR = IJ		01123
72	1210	ITESTL = ITESTL-1		01124
73		IF (ITESTL,LT,1) GO TO 1230		01125
74		IL = IL+NO		01126
75		IF (PM0(IL),GT,0.) GO TO 1220		01127
76		XWL = XWL + 1.		01128
77		GO TO 1210		01129
78	1220	PVL = PV(IL)		01130
79		PVL = PV(IL)		01131
80	1230	ITESTR = ITESTR+1		01132
81		IF (ITESTR,GT,I8P1) GO TO 1250		01133
82		IR = IR+NO		01134
83		IF (PM0(IR),GT,0.) GO TO 1240		01135
84		XWR = XWR + 1.		01136
85		GO TO 1230		01137
86	1240	PVR = PV(IR)		01138
87		PVR = PV(IR)		01139
88	1250	DEN = 1./(XWL*XWR)		01140
89		WTL = XWR*DEN		01141
90		WTR = XWL*DEN		01142
91		PV(IJ) = PVL*WTL + PVR*WTR		01143
92		PV(IJ) = PVL*WTL + PVR*WTR		01144
93	1289	IJ = IJ+NO		01145
				01146

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152		IF (J.LT.1 .OR. J.GT.JRP .OR. I.LT.1 .OR. I.GT.IRP) GO TO 2180	YAQUI1 01205
153		IF (J.EQ.JOLO) GO TO 2030	YAQUI1 01206
154		JOLO = J * IMONE3	YAQUI1 01207
155		IEC = J*NQI	YAQUI1 01208
156		CALL ECRD (AASC(ISC2),IEC,NQI2,NE)	YAQUI1 01209
157	2030	IJ = (I-1)*NQ+ISC2	YAQUI1 01210
158		IPJ = IJ*NQ	YAQUI1 01211
159		IJP = IJ*NQI	YAQUI1 01212
160		IPJP = IPJ * NQI	YAQUI1 01213
161		W = XTE - FLOAT(I-1)*PDR	YAQUI1 01214
162		H = (YTE-PYB) - FLOAT(J-1)*PDZ	YAQUI1 01215
163		PDRHW = PDR-W	YAQUI1 01216
164		PQZMH = PQZ-H	YAQUI1 01217
165		X1 = PDRHW*PDZMH	YAQUI1 01218
166		X2 = W*PDZMH	YAQUI1 01219
167		X3 = PDRHW* H	YAQUI1 01220
168		X4 = W* H	YAQUI1 01221
169		UK = (PU(IJ)*X1 + PU(IPJ)*X2 + PU(IJP)*X3 + PU(IPJP)*X4) * RPNRDZ	YAQUI1 01222
170		VK = (PV(IJ)*X1 + PV(IPJ)*X2 + PV(IJP)*X3 + PV(IPJP)*X4) * RPNRDZ	YAQUI1 01223
171		UPAR = SHIFT(XTE,30)	YAQUI1 01224
172		VPAR = SHIFT(YTE,30)	YAQUI1 01225
173		DTDRAG = DT*DRAG	YAQUI1 01226
174		RDTRAG = 1./(1.-DTDRAG)	YAQUI1 01227
175		URAND = VRAND = 0.0	YAQUI1 01228
176		UPAR = (UPAR + DTDRAG*(UK+URAND) + DTGR) * RDTDRG	YAQUI1 01229
177		VPAR = (VPAR + DTDRAG*(VK+VRAND) + DTGZP) * RDTDRG	YAQUI1 01230
178		XTE = XTE + DT*UPAR	YAQUI1 01231
179		YTE = YTE + DT*VPAR	YAQUI1 01232
180		USH = SHIFT(UPAR,30).AND.7777777777	YAQUI1 01233
181		VSH = SHIFT(VPAR,30).AND.7777777777	YAQUI1 01234
182		XPAR(KP) = (XTE.AND..NOT.7777777777).OR.USH	YAQUI1 01235
183		YPAR(KP) = (YTE.AND..NOT.7777777777).OR.VSH	YAQUI1 01236
184		IF (IMOMX.EQ.0) GO TO 2150	YAQUI1 01237
185		MTE = SHIFT(DRAG,30)	YAQUI1 01238
186		H = MTE*RPNRDZ*DTDRAG	YAQUI1 01239
187		KIJ = IJ	YAQUI1 01240
188		KK = 0	YAQUI1 01241
189		DO 2149 JJ=1,2	YAQUI1 01242
190		DO 2139 II=1,2	YAQUI1 01243
191		KK = KK+1	YAQUI1 01244
192		X1 = X1(KK)*H	YAQUI1 01245
193		PUL = PU(KIJ)	YAQUI1 01246
194		PVL = PV(KIJ)	YAQUI1 01247
195		XX = (SHIFT(PUL,30))*X1*(UK+UPAR+URAND)	YAQUI1 01248
196		YY = (SHIFT(PVL,30))*X1*(VK+VPAR+VRAND)	YAQUI1 01249
197		PU(KIJ) = (PUL.AND..NOT.7777777777).OR. 1 (SHIFT(XX,30).AND.7777777777)	YAQUI1 01250 YAQUI1 01251
198		PV(KIJ) = (PVL.AND..NOT.7777777777).OR. 1 (SHIFT(YY,30).AND.7777777777)	YAQUI1 01252 YAQUI1 01253
199	2139	KIJ = KIJ*NQ	YAQUI1 01254
200	2149	KIJ = IJP	YAQUI1 01255
201		CALL ECWR (AASC(ISC2),IEC,NQI2,NE)	YAQUI1 01256
202	2150	NPMT = NPMT+1	YAQUI1 01257
203		IF (NPMT.EQ.NPT) GO TO 2190	YAQUI1 01258
204		KP = KP+3	YAQUI1 01259
205		IF (KP.LT.LPB) GO TO 2020	YAQUI1 01260
206		CALL ECWR (AASC,IECP,LPR,NE)	YAQUI1 01261
207		IECP = IECP+LPB	YAQUI1 01262

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208		GO TO 2010	YAQUI1	01263
209	2180	XPAR(KP) = -1.E+3	YAQUI1	01264
210		GO TO 2150	YAQUI1	01265
211	2190	CALL ECWR (AASC,IECP,LPB,NE)	YAQUI1	01266
212	2500	IF (I40MX.EQ.0) RETURN	YAQUI1	01267
213		DO 2599 J=2,JP2	YAQUI1	01268
214		IEC = (J-1)*NOI	YAQUI1	01269
215		CALL ECRD (AASC,IEC,NOI,NE)	YAQUI1	01270
216		IJ = 1	YAQUI1	01271
217		DO 2599 I=1,IP1	YAQUI1	01272
218		IF (X(IJ).GT.PXRP .OR. Y(IJ).LT.PYBM) GO TO 2599	YAQUI1	01273
219		IF (Y(IJ).GT.PYTP) RETURN	YAQUI1	01274
220		KI = X(IJ) *PPDR * OPEM10	YAQUI1	01275
221		KJ = (Y(IJ)-PYR)*PPDZ * OPEM10	YAQUI1	01276
222		IECP = KJ*NOI	YAQUI1	01277
223		CALL FCRD (AASC(ISC2),IECP,NOI2,NE)	YAQUI1	01278
224		KIJ = (KI-1)*NO*ISC2	YAQUI1	01279
225		KIJP = KIJ*NOI	YAQUI1	01280
226		W = X(IJ) = FLOAT(KI-1)*PPDR	YAQUI1	01281
227		H = (Y(IJ)-PYR) = FLOAT(KJ-1)*PPDZ	YAQUI1	01282
228		HTE = PDZ*H	YAQUI1	01283
229		DO 2549 JJ=1,2	YAQUI1	01284
230		WTE = PDR*W	YAQUI1	01285
231		DO 2539 II=1,2	YAQUI1	01286
232		XX = RPPDZ*WTE*HTE*PMO(KIJ)	YAQUI1	01287
233		U(IJ) = U(IJ) -XX*(SHIFT(PU(KIJ),30))	YAQUI1	01288
234		V(IJ) = V(IJ) -XX*(SHIFT(PV(KIJ),30))	YAQUI1	01289
235		WTE = W	YAQUI1	01290
236	2539	KIJ = KIJ*NO	YAQUI1	01291
237		HTE = H	YAQUI1	01292
238	2549	KIJ = KIJP	YAQUI1	01293
239	2589	IJ = IJ*NO	YAQUI1	01294
240	2599	CALL ECWR (AASC,IEC,NOI,NE)	YAQUI1	01295
241		RETURN	YAQUI1	01296
242		ENTRY PARPLOT	YAQUI1	01297
243		CALL ANV(1)	YAQUI1	01298
244		CALL FRAME (IPXL,IPXR,IPYT,IPYR)	YAQUI1	01299
245		CALL FRAME (IPXL,IPXR,IPYT,IPYR)	YAQUI1	01300
246		IF (LPR.EQ.0) GO TO 3000	YAQUI1	01301
247		CALL LINCNT(59)	YAQUI1	01302
248		WRITE (12,3090) PDR,PDZ,PXR,PYR,PYT	YAQUI1	01303
249		WRITE (12,3095) JNM,NAME,T,NCYC	YAQUI1	01304
250	3000	IECP = IPAR	YAQUI1	01305
251		IF (ICOLOR.GT.0) CALL COLOR(1)	YAQUI1	01306
252		IF (ICOLOR.GT.0) CALL COLOR(1)	YAQUI1	01307
253		NPPT = 0	YAQUI1	01308
254	3010	CALL ECRD (AASC,IECP,LPB,NE)	YAQUI1	01309
255		KP = 1	YAQUI1	01310
256	3020	IF (XPAR(KP).LT.0.) GO TO 3050	YAQUI1	01311
257		IX1 = FIPXL * (XPAR(KP)-PXL)*PPCONV	YAQUI1	01312
258		IY1 = FIPYR * (YPAR(KP)-PYR)*PPCONV	YAQUI1	01313
259		CALL PLT (IX1,IY1,42)	YAQUI1	01314
260	3050	NPPT = NPPT + 1	YAQUI1	01315
261		IF (NPPT.EQ.NPT) GO TO 3060	YAQUI1	01316
262		KP = KP+3	YAQUI1	01317
263		IF (KP.LT.LPR) GO TO 3020	YAQUI1	01318
264		IECP = IECP+LPR	YAQUI1	01319
265		GO TO 3010	YAQUI1	01320

INDEX	01/12/73	SUBROUTINE PARTMOV	PAGE	73
266	3060	IF (ICOLOR.GT.0) CALL COLOR(0)	YAQUI1	01321
267		RETURN	YAQUI1	01322
		C	YAQUI1	01323
268	3090	FORMAT(4 PARTICLES*/11X*PDR=*IPE12.5* PDZ=*E12.5* PXR=*E12.5	YAQUI1	01324
		1 * PYR=*E12.5* PYT=*E12.5)	YAQUI1	01325
269	3095	FORMAT(5X,A10,10AR* T=*IPE12.5* CYCLE=*IS)	YAQUI1	01326
270		END	YAQUI1	01327

INDEX 01/12/73
SINGLY REFERENCED VARIABLES

SUBROUTINE PARTMOV

PAGE 74

1200	=	63*	DT0C	(R)	3C0	FIYT	-R	3C0	ISC3	-I	3C0	LINCNT	=	247SU	OMEM10	-R	3C0	THIRD	-R	3C0
1300	=	97*	DT016	-R	3C0	FJRP	-R	3C0	ITY	-I	3C0	LJP2	-I	3C0	PARPLO7	=	242SU	TLMD	-R	3C0
2500	=	212*	DT02	-R	3C0	FRFZ	-R	3C0	IUNF	-I	3C0	MR	-R	5RL	PARTMOV	=	1SU	TOUT	-R	3C0
AA	(R)	3C0	DT04	-R	3C0	GGM1	-R	3C0	IXL	-I	3C0	MC	-R	5RL	PLT	=	259SU	TWFIN	-R	3C0
ADV	=	243SU	DT08	-R	3C0	GM1	-R	3C0	IXR	-I	3C0	ML	-R	5RL	RDY	-R	3C0	T20MD	-R	3C0
ANC	-R	3C0	DTPOS	-R	3C0	GR	-R	3C0	IYR	-I	3C0	MR	-R	5RL	REAL	=	5F	VV	-R	3C0
ASQ	-R	3C0	DTV	-R	3C0	GRDVEL	-R	3C0	IYT	-I	3C0	MT	-R	5RL	REZRON	-R	3C0	XCONV	-R	3C0
A0	-R	3C0	DT8	-R	3C0	GZ	-R	3C0	JRAR	-I	3C0	MU02	-R	5RL	REZSIE	-R	3C0	XL	-R	3C0
A0FAC	-R	3C0	D7	-R	3C0	GZP	-R	3C0	JCEN	-I	3C0	MU04	-R	5RL	REZUE	-R	3C0	XR	-R	3C0
A0M	-R	3C0	EM10	-R	3C0	IBAR	-I	3C0	JM10	-I	3C0	NLC	-I	3C0	REZVE	-R	3C0	Y8	-R	3C0
RD	-R	3C0	ENTRY	=	242F	IDT0	-I	3C0	JM14	-I	3C0	NPS	-I	3C0	REZVT	-R	3C0	YCONV	-R	3C0
COLAMU	-R	3C0	EPS	-R	3C0	IJM	-I	3C0	JP1	-I	3C0	NQIR	-I	3C0	REZY0	-R	3C0	YSC1	=	2CN
CYL	-R	3C0	FIBP	-R	3C0	IJPS	-I	3C0	JP4	-I	3C0	NSC	-I	3C0	RIRAR	-R	3C0	YSC2	=	3CN
DR	-R	3C0	FIPXR	-R	3C0	IM1	-I	3C0	JP402	-I	3C0	NUMIT	-I	3C0	RIHJB	-R	3C0	YSC3	=	9CN
DTC	-R	3C0	FIPYT	-R	3C0	IM6	-I	3C0	JUNF	-I	3C0	NUMTD	-I	3C0	RIRP	-R	3C0	YT	-R	3C0
DTFAC	-R	3C0	FIXL	-R	3C0	IP2	-I	3C0	JUNF02	-I	3C0	OM	-R	3C0	RJBP	-R	3C0	ZZ	-R	3C0
DTGZ	-R	3C0	FIXR	-R	3C0	ISCFL	-I	3C0	KX1	-I	3C0	OMANC	-R	3C0	ROMFR	-R	3C0			
DT0	(R)	3C0	FIYR	-R	3C0	ISCFL2	-I	3C0	LAMD	-R	5RL	OMCYL	-R	3C0	RON	-R	3C0			

MULTIPLY-REFERENCED VARIABLES

1009	=	1200	14*	
1019	=	1100	16*	
1039	=	3700	43*	
1049	=	3500	45*	
1089	=	2200	47*	
1099	=	1800	23	48*
1100	=	24	49*	
1189	=	5200	59*	
1199	=	5100	61*	
1210	=	72*	77	
1220	=	75	78*	
1230	=	73	80*	85
1240	=	83	86*	
1250	=	81	88*	
1289	=	6600	67	93*
1290	=	6500	95*	
131	=	108*	114	
13	=	112	115*	
1330	=	109	117*	123
1340	=	121	124*	
1350	=	118	126*	
1389	=	10100	102	131*
1399	=	9700	132*	
1400	=	63	133*	
1489	=	13600	139*	
1499	=	13500	141*	
2000	=	133	143*	
2010	=	145*	208	
2020	=	147*	205	
2030	=	153	157*	
2139	=	19000	199*	
2149	=	18900	200*	
2150	=	184	202*	210
2180	=	152	209*	
2190	=	203	211*	
2539	=	23100	236*	
2549	=	22900	238*	

SUBROUTINE PARTMOV

01/12/73

INDEX

240*

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2589 = 217DC 239*
2599 = 21300 218
3000 = 246 250*
3010 = 254* 265
3020 = 256* 263
3050 = 256 260*
3060 = 261 266*
3090 = 248WR 268*
3095 = 249WR 269*
AASC (R 2C0 4EQ
      4AAG 99AG 111AG 120AG 132AG 145AG 156AG 201AG 206AG 211AG 215AG 223AG 240AG 254AG
COLOR = 251SU 252SU 266SU
COMMON = 2F 3F 9F
CO (R 4EQ 60I
DELSH (R 4EQ 60I
DEN -R 88= 89 90 126= 127 128
DIMENSI = 6F 7F 96SU 142SU
DME -R 17SU 62SU
DRAG -R 140= 173 185*
DT -R 3C0 173 178 179
DTRAG -R 173= 174 176 177 186
DTR -R 3C0 176
DTRGP -R 3C0 177
F (R 4EQ 60I
FCRD = 20SU 28SU
FCWR = 46SU 132SU 201SU 206SU 211SU 240SU
FP (R 4EQ 60I
EQUIVAL = 4F 8F
FTIL (R 4EQ 60I
FLPL -R 3C0 257
FLPLR -R 3C0 258
FLOAT = 31SU 32SU
FRAME = 244SU 245SU
H 32= 34
HTE -R 34= 38 44* 228= 232 237*
I 1 3C0 1200 2200 5200
IB -R 106= 112 115 116
IBP -R 3C0 152
IBP1 -R 3C0 5200
ICOLOR = 1 3C0 251 252 266 27* 28AG 98= 99AG 107 132AG 155= 156AG 201AG 214* 215AG 240AG
IEC -R 19= 20AG
IECR -R 107= 110= 110 111AG
IECP -R 143= 145AG 208AG 207= 207 211AG 222= 223AG 250= 254AG 264= 264
IECT -R 107= 119= 119 120AG
II -R 3700 19000 23100
IJ -R 3C0 13 13 14= 14 21= 21 23 23 24 25 26 31 32 33 39 40
      47* 47 53 54 56 57 58 59= 59 67 71 91 92 93
      100= 102 102 106 129 130 131= 131 137 138 139= 139 157= 158
      159 169 170 187 216= 218 218 219 220 221 226 227 233 234 239*
      239
IJP -R 3C0 159= 169 170 200 79
IL -R 71= 74= 74 75 79
IMOME3 -R 3C0 154
IMOMX -R 3C0 133 184 212
IPAR -R 3C0 143 250
IPJ -R 158= 160 169 170
IPJP -R 160= 169 170
IPXL -R 3C0 244AG 245AG

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INDEX		01/12/73		SUBROUTINE		PARTMOV		PAGE 77										
PU	(I)R	4EQ	6DI	56=	58=	78	86	91=	102	115	124	129=	137=	137	169	169	169	169
PUR	-R	193	197=	233														
PUL	-R	104=	115=	129														
PUR	-R	69=	78=	91	193=	195	197											
PUT	-R	104=	124=	129														
PV	(I)R	4EQ	6DI	57=	79	87	92=	102	116	125	130=	138=	138	170	170	170	170	194
		198=	234															
PVR	-R	104=	116=	130														
PVL	-H	69=	79=	92	194=	196	198											
PVR	-R	69=	87=	92														
PVT	-H	104=	125=	130														
PXCONV	-R	3C0	257															
PXL	-R	3C0	257															
PXR	-R	3C0	248WR															
PXRP	-R	3C0	23	21A														
PYA	-R	3C0	26	32	151	162	221	227	248WR	25A								
PYAM	-R	3C0	23	21B														
PYCONV	-R	3C0	25A															
PYT	-R	3C0	248WR															
PYTP	-R	3C0	24	219														
R	(I)R	4EQ	6DI															
R	(I)R	4EQ	6DI															
RCSO	(I)R	4EQ	6DI															
RDTDRG	-R	174=	176	177														
RETURN	-	212F	219F	241F	267F													
RM	(I)R	4EQ	6DI	33														
RMP	(I)R	4EQ	6DI															
RO	(I)R	4EQ	6DI															
ROL	(I)R	4EQ	6DI															
RPNR	-R	3C0	25	150	220													
RPNRNDZ	-R	3C0	33	169	170	186	232											
RPNZ	-R	3C0	26	151	221													
RPMO	-R	53=	54	54=	54	55	56	57										
RVAL	(I)R	4EQ	6DI															
SHIFT	-	171SU	172SU	180SU	181SU	185SU	195SU	196SU	197SU	198SU	233SU	234SU						
SIE	(I)R	4EQ	6DI															
START	-	10SU	49SU	64SU	134SU													
T	-H	3C0	249WR															
U	(I)R	4EQ	6DI	39	233=	233												
UG	(I)R	4EQ	6DI															
UK	-R	169=	176	195														
UL	(I)R	4EQ	6DI															
UP	(I)R	4EQ	6DI															
UPAR	-R	171=	176=	176	178	180	195											
VRAND	-H	175=	176	195														
USH	-R	180=	182															
UTTL	(I)R	4EQ	6DI															
V	(I)R	4EQ	6DI	40	234=	234												
VG	(I)R	4EQ	6DI															
VK	-R	170=	177	196														
VL	(I)R	4EQ	6DI															
VP	(I)R	4EQ	6DI															
VPAR	-H	172=	177=	177	179	181	196											
VRAND	-R	175=	177	196														
VSH	-H	181=	183															
VTIL	(I)R	4EQ	6DI															
W	-R	31=	36	42	161=	163	166	168	226=	230	235							

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WRITE	=	24AF	249F																
WTR	-R	127=	129	130															
WTF	-R	36=	38	42=	230=	232	235=												
WTL	-R	80=	91	92															
WTR	-R	90=	91	92															
WTY	-R	128=	129	130															
X	()R	4EQ	60I	23	25	31	218	220	226										
XPAP	()R	4EQ	60I	147	147=	209=	256	257											
XTF	-R	147=	150	161	171	178=	178	182											
XWR	-R	105=	113=	113	126	128													
XWL	-R	70=	76=	76	88	90													
XWR	-R	70=	84=	84	88	89													
XWT	-R	105=	122=	122	126	127													
XX	-R	33=	38	195=	197	232=	233	234											
X1	()R	70I	8EQ	8EQ	8EQ	3A=	39	40	41	165=	169	170	192=	192	195	196			
X2	-R	8EQ	166=	169	170														
X3	-R	8EQ	167=	169	170														
X4	-R	8EQ	168=	169	170														
Y	()R	4EQ	60I	23	24	26	32	218	219	221	227								
YPAP	()R	4EQ	60I	148	183=	258													
YTE	-R	148=	151	162	172	179=	179	183											
YY	-R	196=	198																

	INDEX	01/12/73	SUBROUTINE REZONE	PAGE 79
	1		SUBROUTINE REZONE	YAQUI1 01328
	2		COMMON /YSC1/ AASC(4242)	COMMON2 00002
	3		COMMON /YSC2/ AA(I),ANC,ASQ,A0,A0FAC,A0M,R0,C0LAMU,CYL,	COMMON2 00003
		1	DR,NT,DTG,DTFAC,DTGR,DTGZ,DTGZP,DT0(10),DT0C(10),	COMMON2 00004
		2	DT016,DT02,DT04,DT08,DT0S,DTV,DTR,DZ,EMI0,EP5,FIRP,	COMMON2 00005
		3	FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIIYB,FIIYT,FJRP,	COMMON2 00006
		4	FREZ,GGM1,GMI,GR,GRDVEL,GZ,GZP,I,IRAR,IRP,IRP1,ICOLOR,	COMMON2 00007
		5	IDT0,IJ,IJM,IJP,IJPS,IMOME3,IMOMX,IM1,IM6,	COMMON2 00008
		6	IPAR,IPXL,IPXR,IPYR,IPYY,IP1,IP2,ISC1,ISC2,ISC3,ISC4,	COMMON2 00009
		7	ITV,IUNF,IXL,IXR,IYR,IYT,J,JRAR,JRP,JBP2,JCEN,JM10,	COMMON2 00010
		8	JM14,JP1,JP2,JP4,JP402,JUNF,JUNF02,IX1,LAM,LJP2,LPR,	COMMON2 00011
		9	LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQ1,NQIR,NQI2,NSC,	COMMON2 00012
		1	NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OMEM10,PDR,PDZ,PXCONV,	COMMON2 00013
		2	PXL,PXR,PXP,PYG,PYBM,PYCONV,PYT,PYTP,ROT,REZRON,REZSIE,	COMMON2 00014
		3	REZUE,REZVE,REZVT,REZY0,RIBAR,RIRJH,RIRP,RJRP,ROMFR,	COMMON2 00015
		4	RON,RPDR,RPDRDZ,RPDZ,T,THIRD,TLIMD,ROUT,TWIN,YZCMD,	COMMON2 00016
		5	VV,XCONV,XL,XR,YB,YCONV,YT,ZZ	COMMON2 00017
	4		EQUIVALENCE (AASC(1),X,XPAR),(AASC(2),R,YPAR),(AASC(3),Y,MPAR),	EQVREAL 00002
		1	(AASC(4),U,UG,DELSM),(AASC(5),V,VG),(AASC(6),R0),	EQVREAL 00003
		2	(AASC(7),SIE,MP,RMP,RCSQ),(AASC(8),E,ETIL),	EQVREAL 00004
		3	(AASC(9),RVOL),(AASC(10),M,RM,VP),(AASC(11),P,PL,EP,	EQVREAL 00005
		4	UP,PMH),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL,	EQVREAL 00006
		5	VL,PMY,PV),(AASC(14),Q,R0L)	EQVREAL 00007
	5		REAL LAM,LAMD,M,MR,MC,ML,MP,MPAR,MR,MT,MTE,MU,MU02,MU04	EQVREAL 00008
	6		DIMENSION X(1),XPAR(1),R(1),YPAR(1),Y(1),MPAR(1),U(1),UG(1),	DIMEN 00002
		1	DELSM(1),V(1),VG(1),R0(1),SIE(1),MP(1),RMP(1),RCSQ(1),	DIMEN 00003
		2	E(1),ETIL(1),RVOL(1),M(1),RM(1),VP(1),P(1),PL(1),EP(1),	DIMEN 00004
		3	UP(1),UTIL(1),UL(1),CQ(1),PMX(1),PU(1),VTIL(1),VL(1),	DIMEN 00005
		4	PMH(1),PV(1),Q(1),R0L(1),PM0(1)	DIMEN 00006
	7		DIMENSION UGTE(100)	YAQUI1 01332
	8		REZOMG = 0.15*ROT	YAQUI1 01333
	9		REZBTA = 0.002	YAQUI1 01334
	10		XX = -1.E+6	YAQUI1 01335
	11		CALL START	YAQUI1 01336
	12		FCR = FCT = FCB = XXX = XOMSUM = YOMSUM = OMSUM = 0.	YAQUI1 01337
	13		DO 1049 J=2,JP2	YAQUI1 01338
	14		DO 1039 I=1,IP1	YAQUI1 01339
	15		AVEL = AMAX1(ABS(UL(IJ)),ABS(VL(IJ)))	YAQUI1 01340
	16		XXX = AMAX1(XXX,AVEL)	YAQUI1 01341
	17		IF (I.EQ.IM6) FCR = AMAX1(FCR,AVEL)	YAQUI1 01342
	18		IF (J.EQ.JM14) FCT = AMAX1(FCT,AVEL)	YAQUI1 01343
	19		IF (J.EQ.9) FCB = AMAX1(FCR,AVEL)	YAQUI1 01344
	20	1039	IJ = IJ + NQ	YAQUI1 01345
	21		CALL LOOP	YAQUI1 01346
	22	1049	CONTINUE	YAQUI1 01347
	23		FCR = SQRT(FCR*XXX)	YAQUI1 01348
	24		FCT = SQRT(FCT*XXX)	YAQUI1 01349
	25		FCR = SQRT(FCR*XXX)	YAQUI1 01350
	26		CALL START	YAQUI1 01351
	27		DO 1069 J=2,JP1	YAQUI1 01352
	28		IF (J.EQ.JP402) YCEN = Y(IJ)	YAQUI1 01353
	29		DO 1059 I=1,IBAR	YAQUI1 01354
	30		IPJ = IJ+NQ	YAQUI1 01355
	31		IPJP = IJP+NQ	YAQUI1 01356
	32		IF (J.LT.10.OR.J.RT.JM10.OR.I.GT.IM6) GO TO 1055	YAQUI1 01357
	33		X1 = X(IPJ)	YAQUI1 01358
	34		Y1 = Y(IPJ)	YAQUI1 01359
	35		U1 = UL(IPJ)	YAQUI1 01360

INOEX	01/12/73	SUBROUTINE REZONE	PAGE	80
36		V1 = VL(IPJ)	YAQU11	01361
37		X2 = X(IPJP)	YAQU11	01362
38		Y2 = Y(IPJP)	YAQU11	01363
39		U2 = UL(IPJP)	YAQU11	01364
40		V2 = VL(IPJP)	YAQU11	01365
41		X3 = X(IPJP)	YAQU11	01366
42		Y3 = Y(IPJP)	YAQU11	01367
43		U3 = UL(IPJP)	YAQU11	01368
44		V3 = VL(IPJP)	YAQU11	01369
45		X4 = X(IPJ)	YAQU11	01370
46		Y4 = Y(IPJ)	YAQU11	01371
47		U4 = UL(IPJ)	YAQU11	01372
48		V4 = VL(IPJ)	YAQU11	01373
49		R1 = .125*RVOL(IJ)*R(IPJ)*R(IPJP)*R(IPJP)*P(IJ)	YAQU11	01374
50		YY = R1*(U1*U4)*(X1-X4)*(Y1-Y4)*(V1-V4)	YAQU11	01375
		1 * (U2*U1)*(X2-X1)*(Y2-Y1)*(V2-V1)	YAQU11	01376
		2 * (U3*U2)*(X3-X2)*(Y3-Y2)*(V3-V2)	YAQU11	01377
		3 * (U4*U3)*(X4-X3)*(Y4-Y3)*(V4-V3)	YAQU11	01378
51		IF (YY.GT.0.) GO TO 1055	YAQU11	01379
52		YY = YY*Y	YAQU11	01380
53		XOMSUM = XOMSUM + YY*X4	YAQU11	01381
54		YOMSUM = YOMSUM + YY*Y4	YAQU11	01382
55		OMSUM = OMSUM + YY	YAQU11	01383
56			YAQU11	01384
57	1055	IJ = IPJ	YAQU11	01385
58	1059	CALL LOOP	YAQU11	01386
59	1069	CONTINUE	YAQU11	01387
60		XC = XOMSUM/OMSUM	YAQU11	01388
61		YC = YOMSUM/OMSUM	YAQU11	01389
62		REZVT = AMAX1(0.5*(REZOMG*.5*(YC-YCEN)))	YAQU11	01390
63		CALL START	YAQU11	01391
64		DO 1099 J=2,JP2	YAQU11	01392
65		YRAR = .5*(Y(IPJ)*Y(IJM))*REZRTA*(YC-Y(IJ))	YAQU11	01393
66		VGTE = REZOMG*(YRAR-Y(IJ))*REZVT	YAQU11	01394
67		IF (J.EQ.2) VGTE = -FCB	YAQU11	01395
68		IF (J.EQ.JP2) VGTE = FCT	YAQU11	01396
69		DO 1089 I=1,IP1	YAQU11	01397
70		IPJ = IJ+NQ	YAQU11	01398
71		IF (J.GT.2) GO TO 1080	YAQU11	01399
72		XRAR = .5*(X(IPJ)*X(IJ-NQ))*REZRTA*(XC-X(IJ))	YAQU11	01400
73		UGTE(I) = REZOMG*(XRAR-X(IJ))	YAQU11	01401
74		IF (I.EQ.1) UGTE = 0.0	YAQU11	01402
75		IF (I.EQ.IP1) UGTE(I) = FCR	YAQU11	01403
76	1080	UG(IJ) = UGTE(I)	YAQU11	01404
77		VG(IJ) = VGTE	YAQU11	01405
78	1089	IJ = IPJ	YAQU11	01406
79		CALL LOOP	YAQU11	01407
80	1099	CONTINUE	YAQU11	01408
81		CALL DONE	YAQU11	01409
82	1200	CALL START	YAQU11	01410
83		XIP1 = YJP2 = 0.	YAQU11	01411
84		Y2 = 1.E+20	YAQU11	01412
85		DO 1299 J=2,JP2	YAQU11	01413
86		DO 1279 I=1,IP1	YAQU11	01414
87		X(IJ) = X(IJ)*UG(IJ)*DT	YAQU11	01415
88		Y(IJ) = Y(IJ)*VG(IJ)*DT	YAQU11	01416
89		R(IJ) = X(IJ)*CYL*OMCYL	YAQU11	01417
90		IF (J.EQ.2) Y2 = AMIN1(Y(IJ)*Y2)	YAQU11	01418

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91		IF (J.EQ.JP2) YJP2 = AMAX1(Y(IJ)+YJP2)	YAQUI1	01419
92		IF (I.EQ.IP1) XIP1 = AMAX1(X(IJ)+XIP1)	YAQUI1	01420
93	1279	IJ = IJ+NQ	YAQUI1	01421
94		CALL LOOP	YAQUI1	01422
95	1289	CONTINUE	YAQUI1	01423
96		CALL DONE	YAQUI1	01424
97		PDR = XIP1+RIBP	YAQUI1	01425
98		PDZ = (YJP2-Y2)*RJBP	YAQUI1	01426
99		PYB = 0.0	YAQUI1	01427
100		CALL FILMCO	YAQUI1	01428
101		CALL START	YAQUI1	01429
102		YY = ARS(GZ)/(GM1+REZSIE)	YAQUI1	01430
103		DO 1399 J=2,JP1	YAQUI1	01431
104		DO 1389 I=1,IRAR	YAQUI1	01432
105		IPJ = IJ + NQ	YAQUI1	01433
106		IPJP = IJP + NQ	YAQUI1	01434
107		Y4 = REZY0 + 0.25*(Y(IJP)+Y(IPJP)+Y(IJ)+Y(IPJ))	YAQUI1	01435
108		IF (J.EQ.2) ROL(IJM) = REZRON*EXP((Y4-Y(IJ)-Y(IPJ))*YY)	YAQUI1	01436
109		IF (I.EQ.IRAR) ROL(IPJ) = REZRON*EXP((Y4-Y(IPJ)-Y(IPJP))*YY)	YAQUI1	01437
110		IF (J.EQ.JP1) ROL(IJP) = REZRON*EXP((Y4-Y(IJP)-Y(IPJP))*YY)	YAQUI1	01438
111		IJM = IJM + NQ	YAQUI1	01439
112		IJP = IJP + NQ	YAQUI1	01440
113	1389	IJ = IPJ	YAQUI1	01441
114		CALL LOOP	YAQUI1	01442
115	1399	CONTINUE	YAQUI1	01443
116		CALL DONE	YAQUI1	01444
117		RETURN	YAQUI1	01445
118		END	YAQUI1	01446

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					76	39	43	47					
UGTE (IR	70I	73=	74=	75=									
UL (IR	4EQ	60I	15	35									
UP (IR	4EQ	60I											
UTL (IR	4EQ	60I											
U1 -R	35=	50	50										
U2 -R	39=	50	50										
U3 -R	43=	50	50										
U4 -R	47=	50	50										
V (IR	4EQ	60I											
V6 (IR	4EQ	60I	77=	88									
VGTE -R	66=	67=	68=	77									
VL (IR	4EQ	60I	15	36	46		44	48					
VP (IR	4EQ	60I											
VTIL (IR	4EQ	60I											
V1 -R	36=	50	50										
V2 -R	40=	50	50										
V3 -R	44=	50	50										
V4 -R	48=	50	50										
X (IR	4EQ	60I	33	37	41		45	72	72	72	73	87	89
XBAR -R	72=	73											92
XC -R	60=	72											
XIP1 -R	83=	92=	92	97									
XONSUM -R	12=	53=	53	60									
XPAN (IR	4EQ	60I											
XXX -R	12=	16=	16	23	24		25						
X1 -R	33=	50	50										
X2 -R	37=	50	50										
X3 -R	41=	50	50										
X4 -R	45=	50	50	53									
Y (IR	4EQ	60I	28	34	38	42	46	65	65	65	66	88=	88
	107	107	108	108	109	109	110	110				90	91
YBAR -R	65=	66	65										107
YC -R	61=	62	65										107
YCEH -R	28=	62											107
YJP2 -R	83=	91=	91	98									107
YONSUM -R	12=	54=	54	61									107
YPAR (IR	4EQ	60I											107
Y1 -R	50=	51	52=	52	52	53	54	55	102=	108	109	110	
Y1 -R	34=	50	50										
Y2 -R	38=	50	50	8 =	90=	90	98						
Y3 -R	42=	50	50										
Y4 -R	46=	50	50	54	107=	108	109	110					

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LIST OF ALL VARIABLES DEFINED IN INPUT
C MEANS VARIABLE WAS DEFINED IN COMMON IN THAT ROUTINE
D MEANS VARIABLE WAS DEFINED IN OTHER DECLARATIONS
NON-RANK NUMERIC IS NUMBER OF NON-DECLARATORY REFERENCES
S PRECEDING MEANS SUBROUTINE (PROGRAM,FUNCTION) NAME
L PRECEDING MEANS COMMON(LCM) NAME
F PRECEDING MEANS FORTRAN KEYWORD
* PRECEDING MEANS VARIABLE IS DECLARED, NOT USED ANYWHERE

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VARIABLE	ROUTINE	TYPE	ROUTINE	TYPE	ROUTINE	TYPE	ROUTINE	TYPE	ROUTINE	TYPE	ROUTINE	TYPE	ROUTINE	TYPE	ROUTINE	TYPE	ROUTINE	TYPE
AA	YAQUI	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	3C	PARTMOV	C	REZONE	C
AA5C	YAQUI	D	LOOP	11C	FILMCO	CD	YASET1	CD	PARTGEN	2CD	MESHMKR	1CD	YAQUI2	CD	PARTMOV	16CD	REZONE	CD
AA1	YAQUI	D	YASET1	2D	PARTGEN	D	YAQUI2	2D	PARTGEN									
AA2	YAQUI	D	YASET1	D			YAQUI2	2D										
AR	YAQUI2	6																
ARL	YASET1	2	YAQUI2	2														
S ARS	MESHMKR	1	YAQUI2	14	REZONE	3												
S ADV	YAQUI	1	YAQUI2	4	PARTMOV	1												
S AFSREL	YAQUI2	4																
AK	YAQUI2	6																
AL	YAQUI2	6																
S ALOG10	YAQUI2	2																
AL13	YAQUI2	3																
AL24	YAQUI2	3																
S AMAX1	FILMCO	4	YAQUI2	10	REZONE	8												
S AMIN1	FILMCO	1	YAQUI2	7	REZONE	1												
ANC	YAQUI	C	LOOP	C	FILMCO	C	YASET1	2C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
AR	YAQUI2	6																
ASQ	YAQUI	C	LOOP	C	FILMCO	C	YASET1	2C	PARTGEN	C	MESHMKR	C	YAQUI2	4C	PARTMOV	C	REZONE	C
F ASSIGN	YASET1	2	YAQUI2	14														
AT	YAQUI2	6D																
ATR	YASET1	2	YAQUI2	2														
AVEL	REZONE	5																
AX	YAQUI2	3																
AY	YAQUI2	3																
AO	YAQUI	1C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
AOFAC	YAQUI	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
AOM	YAQUI	1C	LOOP	C	FILMCO	C	YASET1	3C	PARTGEN	C	MESHMKR	C	YAQUI2	4C	PARTMOV	C	REZONE	C
RO	YAQUI	1C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	5C	PARTMOV	C	REZONE	C
CIRC	YAQUI2	11																
COLAMU	YAQUI	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
S COLOR	PARTMOV	3																
F COMMON	YAQUI	2	LOOP	2	FILMCO	2	YASET1	2	PARTGEN	2	MESHMKR	2	YAQUI2	3	PARTMOV	3	REZONE	2
CON	YAQUI2	9D																
CO	YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	11D	PARTMOV	D	REZONE	D		
CYL	YAQUI	1C	LOOP	C	FILMCO	C	YASET1	2C	PARTGEN	1C	MESHMKR	2C	YAQUI2	4C	PARTMOV	C	REZONE	1C
D	YAQUI2	11																
S DATAREL	YAQUI2	1																
DELSM	YAQUI	D	FILMCO	D														

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DRMIN	YAQUI2	4																
OROU	YAQUI2	3																
ORPAR	PARTGEN	6																
S ORV	YAQUI2	10																
DT	YAQUI	C	LOOP	C	FILMCO	C	YASET1	4C	PARTGEN	C	MESHMKR	C	YAQUI2	24C	PARTMOV	3C	REZONE	2C
DTG	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	9C	PARTMOV	C	REZONE	C
DTCSAV	YAQUI2	4																
DTDRAG	PARTMOV	5																
DTFAC	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
DTGR	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	1C	REZONE	C
DTGZ	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
DTGZP	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	1C	REZONE	C
DTG	YAQUI	C	LOOP	C	FILMCO	C	YASET1	3C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
DTG	YAQUI	C	LOOP	C	FILMCO	C	YASET1	2C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
DTG	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
DTG	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	7C	PARTMOV	C	REZONE	C
DTG2M1	YAQUI2	7																
DTG2M2	YAQUI2	7																
DTG2M3	YAQUI2	7																
DTG2M4	YAQUI2	7																
DTG4	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
DTG8	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	5C	PARTMOV	C	REZONE	C
DTG8S	YAQUI	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	6C	PARTMOV	C	REZONE	C
DTV	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	9C	PARTMOV	C	REZONE	C
DTVSAV	YAQUI2	4																
DTB	YAQUI	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
DZ	YAQUI	1C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	2C	MESHMKR	4C	YAQUI2	1C	PARTMOV	C	REZONE	C
DZMAX	YAQUI2	4																
DZMIN	YAQUI2	4																
DZPAR	PARTGEN	5																
E	YAQUI	D	FILMCO	D	YASET1	1D	PARTGEN	D	MESHMKR	4D	YAQUI2	3D	PARTMOV	D	REZONE	D		
S ECRD	LOOP	6	PARTMOV	1D														
S ECWR	LOOP	5	PARTGEN	2	PARTMOV	6												
S EMPTY	YAQUI	1	YAQUI2	2														
EMIO	YAQUI	C	LOOP	C	FILMCO	C	YASET1	4C	PARTGEN	1C	MESHMKR	C	YAQUI2	11C	PARTMOV	C	REZONE	C
F ENTRY	LOOP	7	PARTMOV	1														
EP	YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	2D	PARTMOV	D	REZONE	D		
EPS	YAQUI	C	LOOP	C	FILMCO	C	YASET1	2C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
F EQUIVAL	YAQUI	1	FILMCO	1	YASET1	1	PARTGEN	1	MESHMKR	1	YAQUI2	2	PARTMOV	2	REZONE	1		
ETIL	YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	8D	PARTMOV	D	REZONE	D		
S FXP	MESHMKR	1	REZONE	3														
FR	YAQUI2	7																
FCB	REZONE	6																
FCR	REZONE	6																
FCT	REZONE	6																
FDEN	MESHMKR	7																
FIBP	YAQUI	C	LOOP	C	FILMCO	1C	YASET1	C	PARTGEN	2C	MESHMKR	C	YAQUI2	C	PARTMOV	C	REZONE	C
FILM	YAQUI	2																
S FILMCO	FILMCO	1	YASET1	1	REZONE	1												
FIPXL	YAQUI	C	LOOP	C	FILMCO	3C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	1C	REZONE	C
FIPXR	YAQUI	C	LOOP	C	FILMCO	3C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	C	REZONE	C
FIPYB	YAQUI	C	LOOP	C	FILMCO	3C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	1C	REZONE	C
FIPYT	YAQUI	C	LOOP	C	FILMCO	3C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	C	REZONE	C
FIXL	YAQUI	C	LOOP	C	FILMCO	3C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	11C	PARTMOV	C	REZONE	C
FIXR	YAQUI	C	LOOP	C	FILMCO	3C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	C	REZONE	C
FIYB	YAQUI	C	LOOP	C	FILMCO	3C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	11C	PARTMOV	C	REZONE	C
FIYT	YAQUI	C	LOOP	C	FILMCO	3C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	C	REZONE	C
FJBP	YAQUI	C	LOOP	C	FILMCO	1C	YASET1	C	PARTGEN	2C	MESHMKR	C	YAQUI2	C	PARTMOV	C	REZONE	C

INDEX			MASTER INDEX										PAGE 90							
N	NAME	01/12/73	YASET1	8	YAQUI2	18	FILMCO	C	YASET1	2C	PARTGEN	C	MESHMKR	C	YAQUI2	7C	PARTMOV	1C	REZONE	C
NB	NB2		MESHMKR	4																
NCYC	NE		YASET1	C	LOOP		FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	20C	PARTMOV	1C	REZONE	C
NL	NLC		LOOP	11	PARTGEN	2	PARTMOV	16												
NLI	NFM1		MESHMKR	4																
NPPT	NPS		YASET1	C	LOOP	C	FILMCO	C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
NPT	NO		YASET1	C	LOOP	C	FILMCO	1C	YASET1	C	PARTGEN	6C	MESHMKR	C	YAQUI2	4C	PARTMOV	2C	REZONE	C
NO	NO1		YASET1	1C	LOOP	1C	FILMCO	1C	YASET1	8C	PARTGEN	C	MESHMKR	10C	YAQUI2	55C	PARTMOV	16C	REZONE	10C
NO1B	NO1M		YASET1	C	LOOP	21C	FILMCO	C	YASET1	7C	PARTGEN	2C	MESHMKR	1C	YAQUI2	C	PARTMOV	20C	REZONE	C
NO12	NR		YASET1	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	6C	PARTMOV	C	REZONE	C
NR	NR1		MESHMKR	2																
NSC	NT		YASET1	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	5C	REZONE	C
NT	NT2		MESHMKR	6																
NUM1T	NUMTD		YASET1	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
OM	OMAL13		YASET1	C	LOOP	C	FILMCO	C	YASET1	2C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
OMAL24	OMANC		YASET1	3																
OMCYL	OMEN10		YASET1	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
OMEN10	OMSUM		YASET1	C	LOOP	C	FILMCO	1C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	C	REZONE	C
OPAL13	OPAL24		REZONE	5																
OPEM10	OUT		YAQUI2	3																
OVERLAY	P		YAQUI	2																
P	PARPLOT		YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	13D	PARTMOV	D	REZONE	D		
PARPLOT	PARTGEN		YAQUI2	1	PARTMOV	1														
PARTGEN	PARTMOV		YASET1	1	PARTGEN	1														
PARTMOV	PB		YAQUI2	1	PARTMOV	1														
PB	PC		YAQUI2	3																
PC	PDR		YAQUI2	5																
PDR	PDRMW		YAQUI	C	LOOP	C	FILMCO	2C	YASET1	2C	PARTGEN	1C	MESHMKR	C	YAQUI2	C	PARTMOV	7C	REZONE	1C
PDRMW	PDZ		PARTMOV	3																
PDZ	PDZMW		YAQUI	C	LOOP	C	FILMCO	2C	YASET1	2C	PARTGEN	1C	MESHMKR	C	YAQUI2	C	PARTMOV	7C	REZONE	1C
PDZMW	PITH		YAQUI	3																
PITH	PIXX		YAQUI2	5																
PIXX	PIXY		YAQUI2	5																
PIXY	PIYY		YAQUI2	9																
PL	PLE		YAQUI2	4																
PLE	PLMAX		YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	3D	PARTMOV	D	REZONE	D		
PLMAX	PLT		YAQUI2	3																
PLT	PMX		YAQUI2	3	PARTMOV	1														
PMX	PMY		YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	D	PARTMOV	4D	REZONE	D		
PMY	PMO		YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	D	PARTMOV	4D	REZONE	D		
PMO			YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	D	PARTMOV	120	REZONE	D		

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MASTER INDEX

INDEX

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6

YAQUI2

ROE

7

MESHKKR

R01

2

MESHKKR

ROJ1

2

MESHKKR

ROJ1

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MESHKKR

ROJ1

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MESHKKR

INDEX	01/12/73	FILMCO	D	MASTER INDEX	D	YASET1	D	PARTGEN	D	MESHMKR	40	YAQUI2	270	PARTMOV	D	REZONE	50
UL	YAQUI	0															
UL1	YAQUI2	7															
UL13	YAQUI2	2															
UL2	YAQUI2	7															
UL24	YAQUI2	7															
UL3	YAQUI2	7															
UL4	YAQUI2	7															
UP	YAQUI	0															
UPAR	PARTGEN	4															
URAND	PARTMOV	3															
USH	PARTGEN	2															
UTL	YAQUI	0															
U1	YAQUI2	26															
U12	YAQUI2	10															
U13	YAQUI2	12															
U2	YAQUI2	17															
U23	YAQUI2	8															
U24	YAQUI2	2															
U3	YAQUI2	17															
U34	YAQUI2	10															
U4	YAQUI2	19															
U41	YAQUI2	8															
V	YAQUI	0															
V1	YAQUI2	3															
V2	YAQUI2	3															
V3	YAQUI2	3															
V4	YAQUI2	3															
VELIJ	YAQUI2	3															
VELIX	YAQUI2	3															
V6	YAQUI	0															
V61	REZONE	4															
V62	YAQUI2	2															
V63	YAQUI2	2															
V64	YAQUI2	2															
V7	MESHMKR	7															
VK	PARTMOV	3															
VL	YAQUI	0															
VL1	YAQUI2	7															
VL13	YAQUI2	2															
VL2	YAQUI2	7															
VL24	YAQUI2	2															
VL3	YAQUI2	7															
VL4	YAQUI2	7															
VMAX	YAQUI2	6															
VOLC	YAQUI2	5															
VOLR	YAQUI2	3															
VOLY	YAQUI2	3															
VP	YAQUI	0															
VPAR	PARTGEN	4															
VRAND	PARTMOV	3															
VSH	PARTGEN	2															
V11L	YAQUI	0															
VV	YAQUI	0															
V1	YAQUI2	26															
V12	YAQUI2	9															
V13	YAQUI2	2															
V2	YAQUI2	17															

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V23	YAQUI2	8															
V24	YAQUI2	2															
V3	YAQUI2	17	REZONE	3													
V34	YAQUI2	9															
V4	YAQUI2	19	REZONE	3													
V41	YAQUI2	8															
W	PARTMOV	10															
F WRITE	YASET1	8	PARTGEN	2	MESHMKR	1	YAQUI2	20	PARTMOV	2							
WTR	PARTMOV	3															
WTE	PARTMOV	6															
WTL	PARTMOV	3															
WTR	PARTMOV	3															
WTT	PARTMOV	3															
S WIROM	LOOP	1	MESHMKR	4													
X	YAQUI	D	FILMCO	10	YASET1	40	PARTGEN	D	MESHMKR	60	YAQUI2	55D	PARTMOV	60	REZONE	120	
XBAR	REZONE	2															
XC	PARTGEN	4	REZONE	2													
XCO	YAQUI2	40															
XCONV	YAQUI	C	LOOP	C	FILMCO	1C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	11C	PARTMOV	C	REZONE
X0	FILMCO	10	PARTGEN	8													
XIP1	REZONE	A															
XL	YAQUI	C	LOOP	C	FILMCO	2C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	11C	PARTMOV	C	REZONE
XMAX	PARTGEN	3															
XOMSUM	REZONE	4															
XPAR	YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	10	MESHMKR	D	YAQUI2	D	PARTMOV	50	REZONE	D	
XR	YAQUI	C	LOOP	C	FILMCO	6C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE
XR13	YAQUI2	3															
XR24	YAQUI2	3															
XTE	PARTGEN	7	PARTMOV	7													
XWB	PARTMOV	5															
XWL	PARTMOV	5															
XWR	PARTMOV	5															
XWT	PARTMOV	5															
XX	YASET1	9	MESHMKR	14	YAQUI2	91	PARTMOV	7	REZONE	1							
XXX	REZONE	6															
XY	YAQUI2	5															
XY14	YAQUI2	3															
XY21	YAQUI2	3															
XY23	YAQUI2	3															
XY34	YAQUI2	3															
X1	YASET1	3	YAQUI2	41	PARTMOV	110	REZONE	3									
X12	YAQUI2	9															
X2	YASET1	2	YAQUI2	28	PARTMOV	30	REZONE	3									
X23	YAQUI2	9															
X24	YAQUI2	6															
X3	YASET1	3	YAQUI2	29	PARTMOV	30	REZONE	3									
X31	YAQUI2	6															
X34	YAQUI2	9															
X4	YASET1	2	YAQUI2	28	PARTMOV	30	REZONE	4									
X41	YAQUI2	9															
Y	YAQUI	D	FILMCO	20	YASET1	40	PARTGEN	D	MESHMKR	120	YAQUI2	540	PARTMOV	80	REZONE	230	
S YAQUI	YAQUI	1															
S YAQUI1	YAQUI1	1															
S YAQUI2	YAQUI1	1	YAQUI2	1													
S YASET	YASET	1															
S YASET1	YASET	1	YASET1	1													
YB	YAQUI	C	LOOP	C	FILMCO	7C	YASET1	2C	PARTGEN	C	MESHMKR	2C	YAQUI2	13C	PARTMOV	C	REZONE
YBAR	REZONE	2															

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YROT	PARTGEN	4														
YC	PARTGEN	7	REZONE	3												
YCN	REZONE	2														
YCO	YAQUI2	40														
YCONV	YAQUI	C	LOOP	C	FILMCO	1C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	11C	PARTMOV	C
YD	PARTGEN	6														
YJC2	MESHMKR	2														
YJP2	REZONE	4														
L YLC1	YAQUI	1	YASET1	1	PARTGEN	1	YAQUI2	1								
L YLC2	YAQUI	1	YASET1	1	PARTGEN	1	YAQUI2	1								
YMAX	PARTGEN	3														
YMIN	PARTGEN	3														
YOMSUM	REZONE	4														
YPAR	YAQUI	D	FILMCO	D	YASET1	D	PARTGEN	D	MESHMKR	D	YAQUI2	D	PARTMOV	3D	REZONE	D
L YSC1	YAQUI	1	LOOP	1	FILMCO	1	YASET1	1	PARTGEN	1	MESHMKR	1	YAQUI2	1	PARTMOV	1
L YSC2	YAQUI	1	LOOP	1	FILMCO	1	YASET1	1	PARTGEN	1	MESHMKR	1	YAQUI2	1	PARTMOV	1
L YSC3	YAQUI2	1	PARTMOV	1												
YT	YAQUI	C	LOOP	C	FILMCO	5C	YASET1	C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C
YTE	PARTGEN	6	PARTMOV	1												
YTOP	PARTGEN	4														
YY	FILMCO	14	MESHMKR	8	YAQUI2	20	PARTMOV	2	REZONE	12						
Y1	YASET1	5	YAQUI2	31	REZONE	3										
Y14	YAQUI2	10														
Y2	YASET1	3	YAQUI2	27	REZONE	7										
Y21	YAQUI2	10														
Y24	YAQUI2	10														
Y3	YASET1	5	YAQUI2	20	REZONE	3										
Y31	YAQUI2	13														
Y32	YAQUI2	10														
Y4	YASET1	3	YAQUI2	27	REZONE	8										
Y43	YAQUI2	10														
ZZ	YAQUI	C	LOOP	C	FILMCO	C	YASET1	1C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C

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ROUTINES INDEXED									
ROUTINE	PAGE	ROUTINE	PAGE	ROUTINE	PAGE	ROUTINE	PAGE	ROUTINE	PAGE
FILMCO	9	MESHMKR	29	PARTMOV	68	YAQUI	2	YAQUI2	38
LOOP	5	PARTGEN	24	REZONE	79	YAQUI1	36	YASET	15
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*****END OF COMPUTATION*****					
2183 CARDS PROCESSED					
2835 MAXIMUM BUFFER USED BY ANY ROUTINE					
2048 TOTAL ECS REQUIRED BY INDEX					
7.454 SECONDS OF CP TIME USED					