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by

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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 FØRTRAN 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.

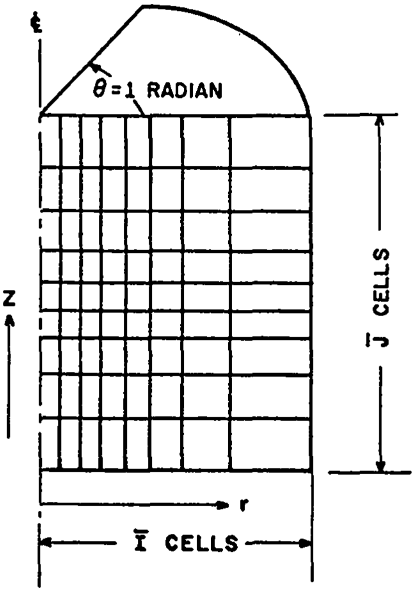


Fig. 1. A typical ICED-ALE mesh in cylindrical coordinates.

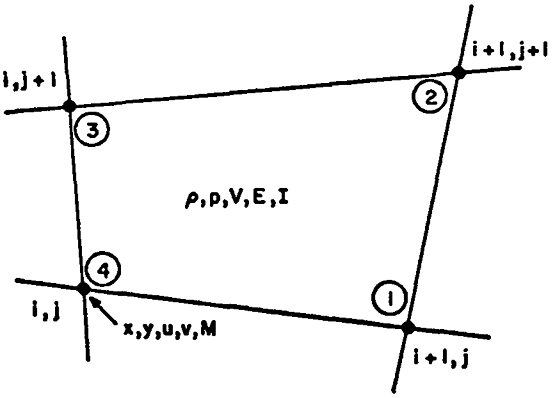


Fig. 2. A typical ICED-ALE cell showing the locations of the principal variables. The numbers are in the shorthand vertex notation used in the equations that follow and in the YAQUI code.

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

$$p = p\ (\rho, I) \quad ,$$

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

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

where

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

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

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

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

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

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

To maintain energy conservation throughout the entire calculational cycle, it is necessary to calculate and store E, 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

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

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,

$$\tilde{u}_i^j = {}^n u_i^j + \delta t\ A_x \quad ,$$

and

$$\tilde{v}_i^j = {}^n v_i^j + \delta t\ A_y \quad ,$$

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

$$A_{x_i}^{\ j} = g_r \quad \text{and} \quad A_{y_i}^{\ j} = g_z \quad .$$

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

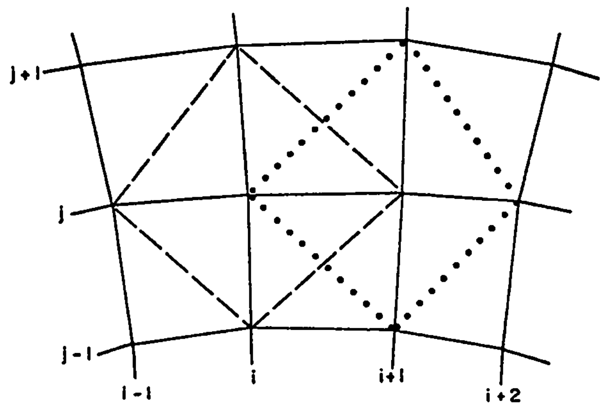


Fig. 3. Momentum-integration areas about cells $\binom{j}{i}$ and $\binom{j}{i+1}$, indicated by dashed lines and dotted lines, respectively.

obtaining the most accurate results, consider the integration area for the next cell $\binom{j}{i+1}$, indicated by the dotted lines in Fig. 3. This indicates that values at four different vertices, $\binom{j}{i+2}$, $\binom{j+1}{i+1}$, $\binom{j}{i}$, and $\binom{j-1}{i+1}$, 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

$$A_{x_i}^{\,j} = g_r + \frac{1}{a_{nc}\delta t}\left({}^n\langle u\rangle_i^j - {}^nu_i^j\right) ,$$

and

$$A_{y_i}^{\,j} = g_z + \frac{1}{a_{nc}\delta t}\left({}^n\langle v\rangle_i^j - {}^nv_i^j\right) ,$$

where

$${}^n\langle u\rangle_i^j = \frac{1}{4}\left({}^nu_{i+1}^j + {}^nu_i^{j+1} + {}^nu_{i-1}^j + {}^nu_i^{j-1}\right) ,$$

$${}^n\langle v\rangle_i^j = \frac{1}{4}\left({}^nv_{i+1}^j + {}^nv_i^{j+1} + {}^nv_{i-1}^j + {}^nv_i^{j-1}\right) ,$$

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:

$$\tilde{u}_i^j = \left(1 - \frac{1}{a_{nc}}\right){}^nu_i^j + \left(\frac{1}{a_{nc}}\right){}^n\langle u\rangle_i^j + \delta t g_r ,$$

and

$$\tilde{v}_i^j = \left(1 - \frac{1}{a_{nc}}\right){}^nv_i^j + \left(\frac{1}{a_{nc}}\right){}^n\langle v\rangle_i^j + \delta t g_z ,$$

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 $\delta t \to 0$, 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

$$Q_i^j = \delta t\left[\left(A_x{}^nu\right)_i^j + \left(A_y{}^nv\right)_i^j\right] .$$

One might expect to see, instead,

$$Q_i^j = \frac{\delta t}{2}\left[A_{x_i}^{\,j}\left({}^nu + \tilde{u}\right)_i^j + A_{y_i}^{\,j}\left({}^nv + \tilde{v}\right)_i^j\right] ,$$

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:[3]

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

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

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

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

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:

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

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

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

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

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

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

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

then

$$\tilde{u}_1 = \tilde{u}_1 + \frac{\delta t}{2M_1}\left\{\frac{1}{2}\,(r_2 + r_4)\left[\Pi_{xx}(y_4 - y_2) + \Pi_{xy}\ (x_2 - x_4)\right] + r_1(y_2 - y_4)\,p - \mathrm{PTH}\right\} \ ,$$

$$\tilde{u}_2 = \tilde{u}_2 + \frac{\delta t}{2M_2}\left\{\frac{1}{2}\,(r_3 + r_1)\left[\Pi_{xx}(y_1 - y_3) + \Pi_{xy}(x_3 - x_1)\right] + r_2(y_3 - y_1)\ p - \mathrm{PTH}\right\} \ ,$$

$$\tilde{u}_3 = \tilde{u}_3 + \frac{\delta t}{2M_3}\left\{\frac{1}{2}\,(r_4 + r_2)\ \left[\Pi_{xx}\ (y_2 - y_4) + \Pi_{xy}(x_4 - x_2)\right] + r_3(y_4 - y_2)\ p - \mathrm{PTH}\right\} \ ,$$

$$\tilde{u}_4 = \tilde{u}_4 + \frac{\delta t}{2M_4}\left\{\frac{1}{2}\,(r_1 + r_3)\left[\Pi_{xx}(y_3 - y_1) + \Pi_{xy}(x_1 - x_3)\right] + r_4(y_1 - y_3)\ p - \mathrm{PTH}\right\} \ ,$$

$$\tilde{v}_1 = \tilde{v}_1 + \frac{\delta t}{2M_1}\left\{\frac{1}{2}\,(r_2 + r_4)\left[\Pi_{xy}(y_4 - y_2) + (\Pi_{yy} - p)(x_2 - x_4)\right]\right\} \ ,$$

$$\tilde{v}_2 = \tilde{v}_2 + \frac{\delta t}{2M_2}\left\{\frac{1}{2}\,(r_3 + r_1)\left[\Pi_{xy}(y_1 - y_3) + (\Pi_{yy} - p)(x_3 - x_1)\right]\right\} \ ,$$

$$\tilde{v}_3 = \tilde{v}_3 + \frac{\delta t}{2M_3}\left\{\frac{1}{2}\,(r_4 + r_2)\left[\Pi_{xy}(y_2 - y_4) + (\Pi_{yy} - p)(x_4 - x_2)\right]\right\} \ ,$$

$$\tilde{v}_4 = \tilde{v}_4 + \frac{\delta t}{2M_4}\left\{\frac{1}{2}\,(r_1 + r_3)\left[\Pi_{xy}(y_3 - y_1) + (\Pi_{yy} - p)(x_1 - x_3)\right]\right\} \ ,$$

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:

$$Q_1 = Q_1 + \frac{\delta t\ (r_2 + r_4)}{8M_1}\left\{(u_2 + u_4)\left[\Pi_{xy}(x_2 - x_4) - \Pi_{xx}(y_2 - y_4)\right] - (v_2 + v_4)\left[\Pi_{xy}(y_2 - y_4) - \Pi_{yy}\ (x_2 - x_4)\right]\right\} \ ,$$

$$Q_2 = Q_2 + \frac{\delta t\ (r_3 + r_1)}{8M_2}\left\{(u_3 + u_1)\left[\Pi_{xy}(x_3 - x_1) - \Pi_{xx}(y_3 - y_1)\right] - (v_3 + v_1)\left[\Pi_{xy}(y_3 - y_1) - \Pi_{yy}(x_3 - x_1)\right]\right\} \ ,$$

$$Q_3 = Q_3 + \frac{\delta t\ (r_4 + r_2)}{8M_3}\left\{(u_4 + u_2)\left[\Pi_{xy}(x_4 - x_2) - \Pi_{xx}(y_4 - y_2)\right] - (v_4 + v_2)\left[\Pi_{xy}(y_4 - y_2) - \Pi_{yy}(x_4 - x_2)\right]\right\} \ ,$$

$$Q_4 = Q_4 + \frac{\delta t\ (r_1 + r_3)}{8M_4}\left\{(u_1 + u_3)\left[\Pi_{xy}(x_1 - x_3) - \Pi_{xx}(y_1 - y_3)\right] - (v_1 + v_3)\left[\Pi_{xy}(y_1 - y_3) - \Pi_{yy}(x_1 - x_3)\right]\right\} \ .$$

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 < > to identify that the pressures were omitted from the Q terms:

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

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:

$$p_{12} = \frac{M_{i+3/2}^{j+\frac{1}{2}}\; {}^{n}p_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}\; {}^{n}p_{i+3/2}^{j+\frac{1}{2}}}{M_{i+3/2}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} \quad ,$$

$$p_{23} = \frac{M_{i+\frac{1}{2}}^{j+3/2}\; {}^{n}p_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}\; {}^{n}p_{i+\frac{1}{2}}^{j+3/2}}{M_{i+\frac{1}{2}}^{j+3/2} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} \quad ,$$

$$p_{34} = \frac{M_{i-\frac{1}{2}}^{j+\frac{1}{2}}\; {}^{n}p_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}\; {}^{n}p_{i-\frac{1}{2}}^{j+\frac{1}{2}}}{M_{i-\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} \quad ,$$

$$p_{41} = \frac{M_{i+\frac{1}{2}}^{j-\frac{1}{2}}\; {}^{n}p_{i+\frac{1}{2}}^{j+\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}\; {}^{n}p_{i+\frac{1}{2}}^{j-\frac{1}{2}}}{M_{i+\frac{1}{2}}^{j-\frac{1}{2}} + M_{i+\frac{1}{2}}^{j+\frac{1}{2}}} \quad .$$

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

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

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

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

or

(New Total Energy) = (Old Total Energy)

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

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 ${}^{n+1}\rho$.) As the tilde quantities $\tilde{u}$, $\tilde{v}$, and ${}^{n}p$ 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 ${}^{n}\rho$, 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 ${}^{n}I$ 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.

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

(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

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

and

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

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, as 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 Δr and Δz represent the average δr and δz of the cell:

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

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

If the mesh is strongly rotated or distorted, more sophisticated Δr 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 isothermal 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,

$$\delta p = -\,\omega A S \quad ,$$

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

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

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.

$$\rho_L = \rho\left(p_L, {}^{n}I\right), \text{ or } \rho_L = \rho_L + \frac{\delta p}{c^2} ,$$

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

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

$$u_{L1} = u_{L1} + \frac{\delta t}{2M_1} r_1 (y_2 - y_4) \delta p ,$$

$$u_{L2} = u_{L2} + \frac{\delta t}{2M_2} r_2 (y_3 - y_1) \delta p ,$$

$$u_{L3} = u_{L3} + \frac{\delta t}{2M_3} r_3 (y_4 - y_2) \delta p ,$$

$$u_{L4} = u_{L4} + \frac{\delta t}{2M_4} r_4 (y_1 - y_3) \delta p ,$$

$$v_{L1} = v_{L1} + \frac{\delta t}{2M_1} \left(\frac{r_2 + r_4}{2}\right) (x_4 - x_2) \delta p ,$$

$$v_{L2} = v_{L2} + \frac{\delta t}{2M_2} \left(\frac{r_3 + r_1}{2}\right) (x_1 - x_3) \delta p ,$$

$$v_{L3} = v_{L3} + \frac{\delta t}{2M_3} \left(\frac{r_4 + r_2}{2}\right) (x_2 - x_4) \delta p ,$$

$$v_{L4} = v_{L4} + \frac{\delta t}{2M_4} \left(\frac{r_1 + r_3}{2}\right) (x_3 - x_1) \delta p .$$

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 ${}^{n}\vec{x}$, not ${}^{n+1}\vec{x}$. The neglect of higher-order terms causes ${}^{n+1}\rho$ 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 ${}^{n+1}\rho$ will be calculated from ${}^{n}\rho$ 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 $\tilde{E}$ 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 rezone: 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 ${}^{n+1}M_{cell}$ to ${}^{n+1}M_{vertex}$ and compute the vertex quantities. Finally, ${}^{n+1}I$ can be calculated.

The rezoning can be accomplished using either the old ${}^{n}x, {}^{n}y$ coordinates or the new ${}^{n+1}x$, ${}^{n+1}y$ 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 rezone calculations, as numerical methods are usually slightly more stable when time-advanced quantities are used. The new coordinates for all vertices are given by

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

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

and

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

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:

$$FR = \frac{\delta t(r_1 + r_2)}{8}\Big[(u_{G1} - u_{L1} + u_{G2} - u_{L2})\ (y_2 - y_1)$$

$$+ (v_{G1} - v_{L1} + v_{G2} - v_{L2})\ (x_1 - x_2)\Big] \quad ,$$

$$FT = \frac{\delta t(r_2 + r_3)}{8}\Big[(u_{G2} - u_{L2} + u_{G3} - u_{L3})(y_3 - y_2)$$

$$+ (v_{G2} - v_{L2} + v_{G3} - v_{L3})\ (x_2 - x_3)\Big] \quad ,$$

$$FL = \frac{\delta t(r_3 + r_4)}{8}\Big[(u_{G3} - u_{L3} + u_{G4} - u_{L4})(y_4 - y_3)$$

$$+ (v_{G3} - v_{L3} + v_{G4} - v_{L4})\ (x_3 - x_4)\Big] \quad ,$$

$$FB = \frac{\delta t(r_4 + r_1)}{8}\Big[(u_{G4} - u_{L4} + u_{G1} - u_{L1})(y_1 - y_4)$$

$$+ (v_{G4} - v_{L4} + v_{G1} - v_{L1})(x_4 - x_1)\Big] \quad .$$

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 $(i+3/2),j+\frac{1}{2})$, and FT for cell $(i+\frac{1}{2},j+\frac{1}{2})$ is equal to −FB for cell $(i+\frac{1}{2},j+3/2)$.

Recall that the momentum equations in the tilde 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 rezone, 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 in 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_o and β_o:

$$\alpha_R = \alpha_o \text{ sign FR} + 4\text{FR}\ \beta_o\Big/\left(V^{j+\frac{1}{2}}_{i+3/2} + V^{j+\frac{1}{2}}_{i+\frac{1}{2}}\right) \quad ,$$

$$\alpha_T = \alpha_o \text{ sign FT} + 4\text{FT}\ \beta_o\Big/\left(V^{j+3/2}_{i+\frac{1}{2}} + V^{j+\frac{1}{2}}_{i+\frac{1}{2}}\right) \quad ,$$

$$\alpha_L = \alpha_o \text{ sign FL} + 4\text{FL}\ \beta_o\Big/\left(V^{j+\frac{1}{2}}_{i-\frac{1}{2}} + V^{j+\frac{1}{2}}_{i+\frac{1}{2}}\right) \quad ,$$

$$\alpha_B = \alpha_o \text{ sign FB} + 4\text{FB}\ \beta_o\Big/\left(V^{j-\frac{1}{2}}_{i+\frac{1}{2}} + V^{j+\frac{1}{2}}_{i+\frac{1}{2}}\right) \quad ,$$

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

and the input constants allow these combinations:

$\alpha_o = 0$ and $\beta_o = 0$ ⇒ centered,

$\alpha_o = 1$ and $\beta_o = 0$ ⇒ donor cell,

$\alpha_o = 0$ and $\beta_o = 2$ ⇒ interpolated donor cell.

Note, however, that α_o must be sufficiently positive^2 for the mass equation to be stable. As full donor-cell differencing is too diffusive for most circumstances, generally $0 < \alpha_o < 1$.

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

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

and

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

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

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

The new volume and density replace ${}^{n}V$ and ${}^{n}\rho$. The new vertex masses are then calculated using the M^j_i 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

$$
{}^{n+1}u^j_i = \left(\frac{{}^{n}M}{{}^{n+1}M}\right)^j_i u_{L}{}^j_i \quad ,
$$

and

$$
{}^{n+1}v^j_i = \left(\frac{{}^{n}M}{{}^{n+1}M}\right)^j_i v_{L}{}^j_i \quad .
$$

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:

$$
\begin{aligned}
F13 = \frac{\delta t \rho_L{}^{j+\frac{1}{2}}_{i+\frac{1}{2}} (r_1+r_3)}{16} & \Big[(u_{G1}-u_{L1}+u_{G3}-u_{L3})(y_3-y_1) \\
& + (v_{G1}-v_{L1}+v_{G3}-v_{L3})(x_1-x_3)\Big] \quad ,
\end{aligned}
$$

$$
\begin{aligned}
F24 = \frac{\delta t \rho_L{}^{j+\frac{1}{2}}_{i+\frac{1}{2}} (r_4+r_2)}{16} & \Big[(u_{G4}-u_{L4}+u_{G2}-u_{L2})(y_2-y_4) \\
& + (v_{G4}-v_{L4}+v_{G2}-v_{L2})(x_4-x_2)\Big] \quad ,
\end{aligned}
$$

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

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

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, α13, and α24 for a given cell, the vertex contributions are given by:

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

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

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

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

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

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

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

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

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

$$ {}^{n+1}I^{j+\frac12}_{i+\frac12} = {}^{n+1}E^{j+\frac12}_{i+\frac12} - \frac{1}{8}\left(u_1^2+u_2^2+u_3^2+u_4^2+v_1^2+v_2^2+v_3^2+v_4^2\right) , $$

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. Subservient 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 MESHMKR, 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.

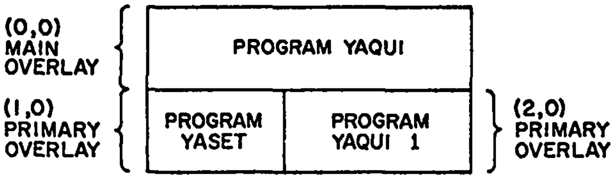


Fig. 4. The YAQUI 3 program overlay structure.

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 ^{n}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: PARTM0V moves and plots particles, and REZ0NE 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

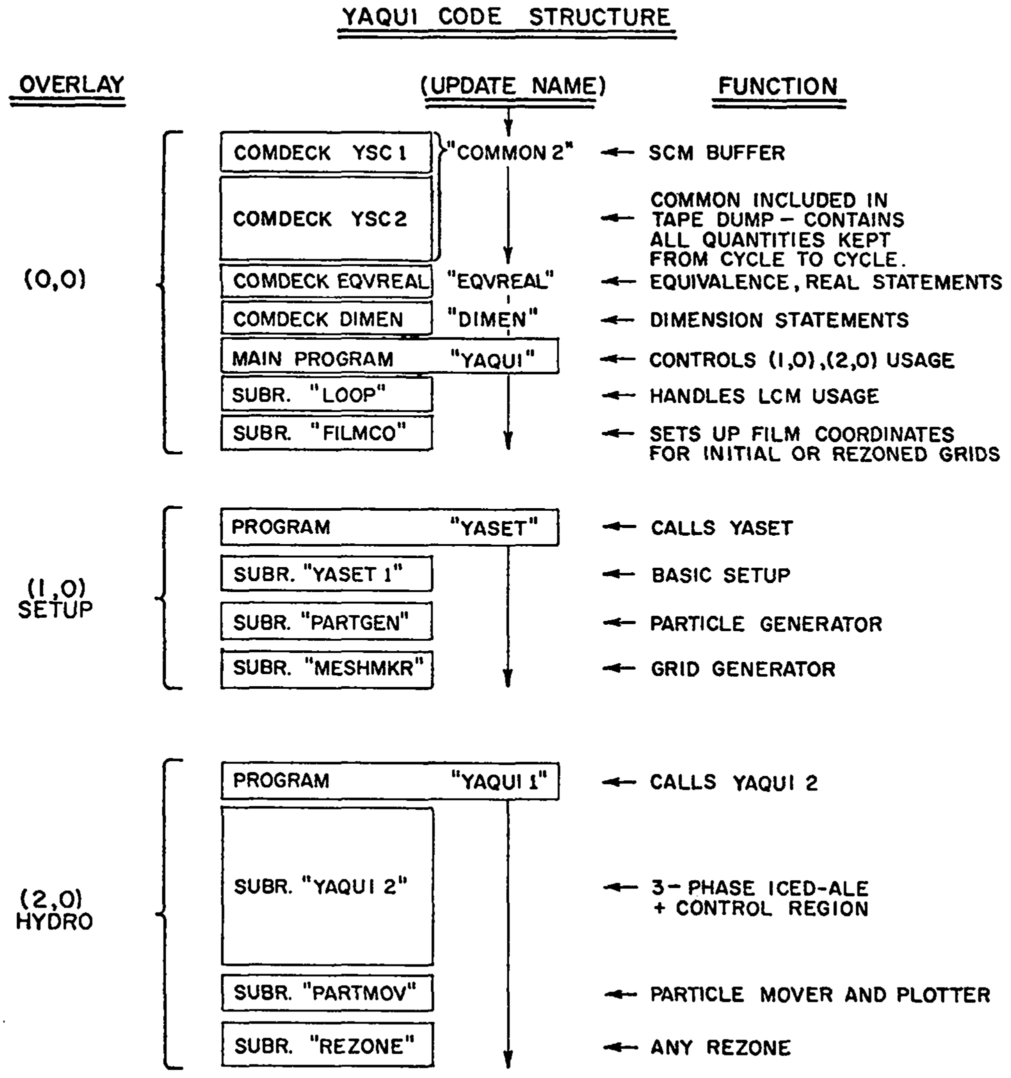


Fig. 5. Detailed breakdown of the YAQUI overlays, describing the functions of all sections and the UPDATE nomenclature.

are directly calculated in YAQUI2 in a simple, straightfoward fashion. The REZØNE 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 REZØNE 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_i^j simply as "X(I,J)," but $p_{i+\frac{1}{2}}^{j+\frac{1}{2}}$ 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 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.

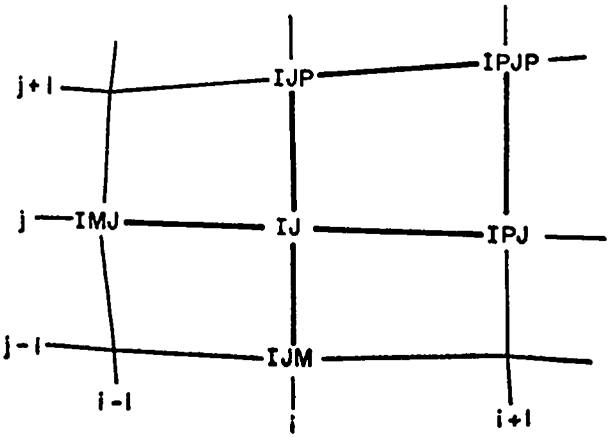


Fig. 6. Single subscript notation for vertex quantities.

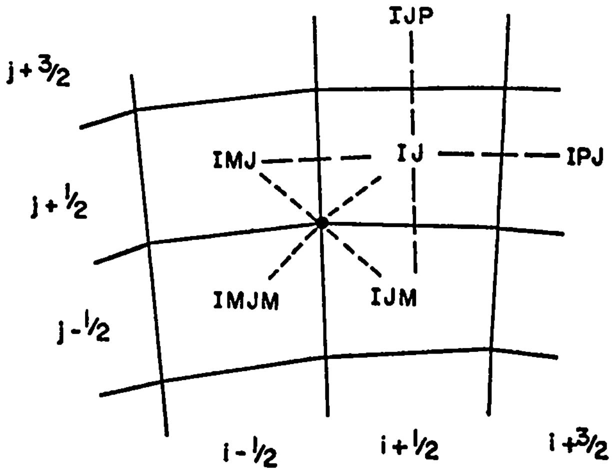


Fig. 7. Single subscript notation for cell quantities.

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

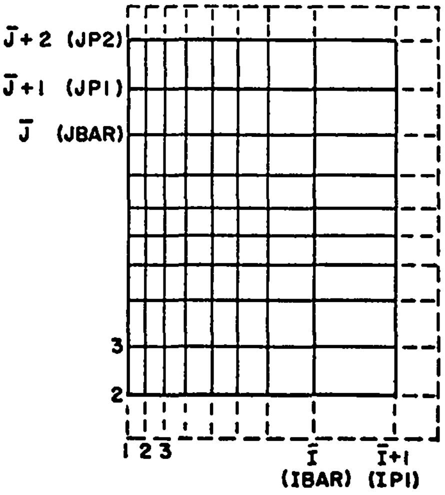


Fig. 8. An actual YAQUI mesh, corresponding to the conceptual mesh of Fig. 1, showing vertex notation. Fictitious cells are denoted by dashed lines.

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.

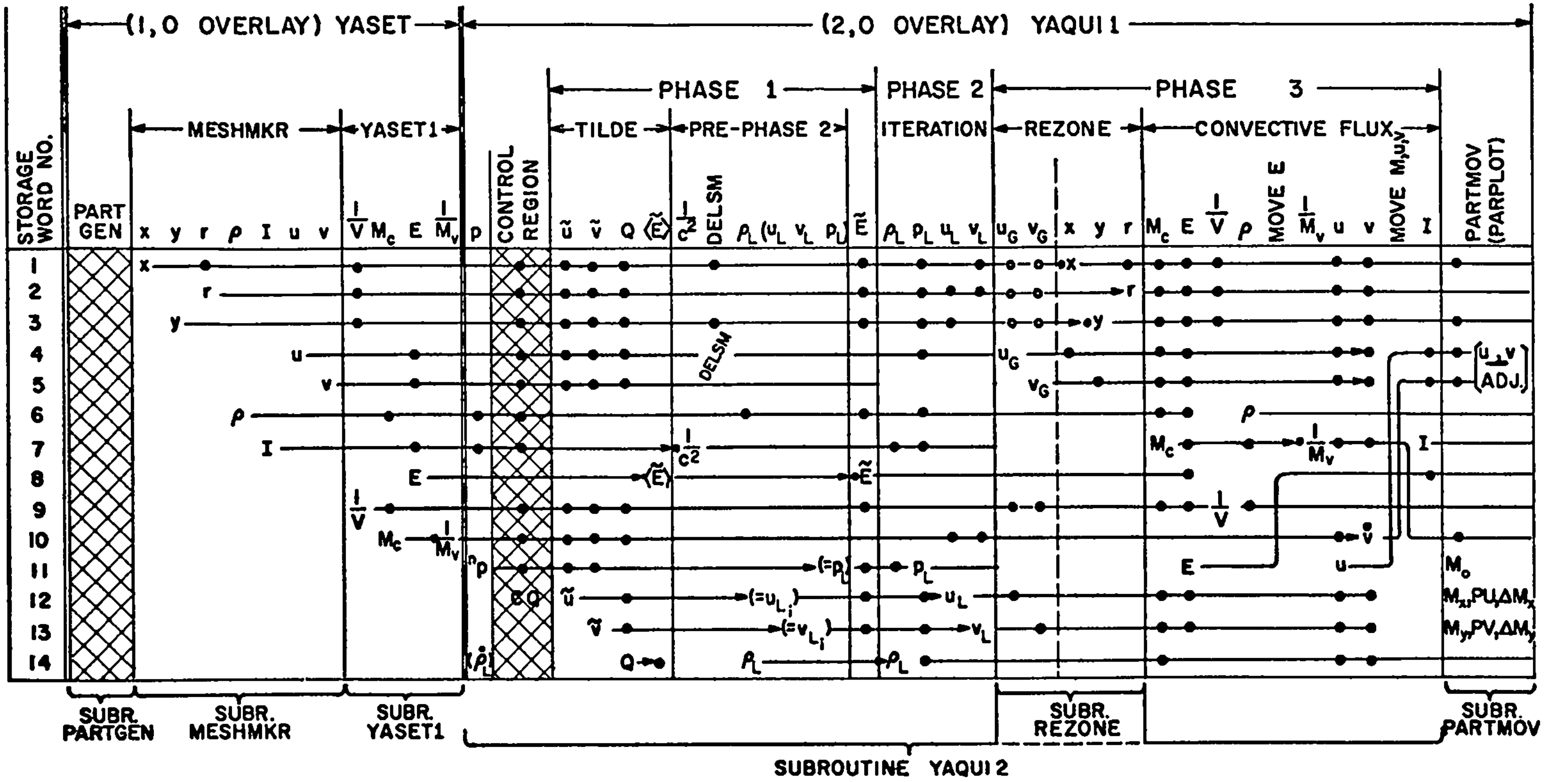
The contour quantity (CQ) in the control region denotes the field of some chosen cell variable for which a contour plot is drawn on microfilm. The quantities referred to in the PARTMØV subroutine are described in Sec. II E.

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, AA1, dimensioned at 131000_{10} 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 LØØP, 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.



Number Word	Equivalence	Code Name	Number Word	Equivalence	Code Name
1	x	X	8	E, $\langle\tilde{E}\rangle$, $\tilde{E}$	E, ETIL, ETIL
2	r	R	9	$1/V$	RVØL
3	y	Y	10	$^{n}M_c$, $1/{}^{n}M_v$, ^{n+1}v	M, RM, VP
4	u, $2\delta t\left(\frac{1}{\Delta r^2}+\frac{1}{\Delta z^2}\right)$, u_G	U, DELSM, UG	11	p, p_L, ^{n+1}E, ^{n+1}u, M_o	P, PL, EP, UP, PMO
5	v, v_G	V, VG	12	$\tilde{u}$, u_L, M_x, PU	UTIL, UL, PMX, PU, (CQ)
6	ρ	RØ	13	$\tilde{v}$, v_L, M_y, PV	VTIL, VL, PMY, PV
7	I, $1/c^2$, $^{n+1}M_c$, $1/{}^{n+1}M_v$	SIE, RCSQ, MP, RMP	14	Q, ρ_L	Q, RØL

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 FØRTRAN 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 * IP1 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.

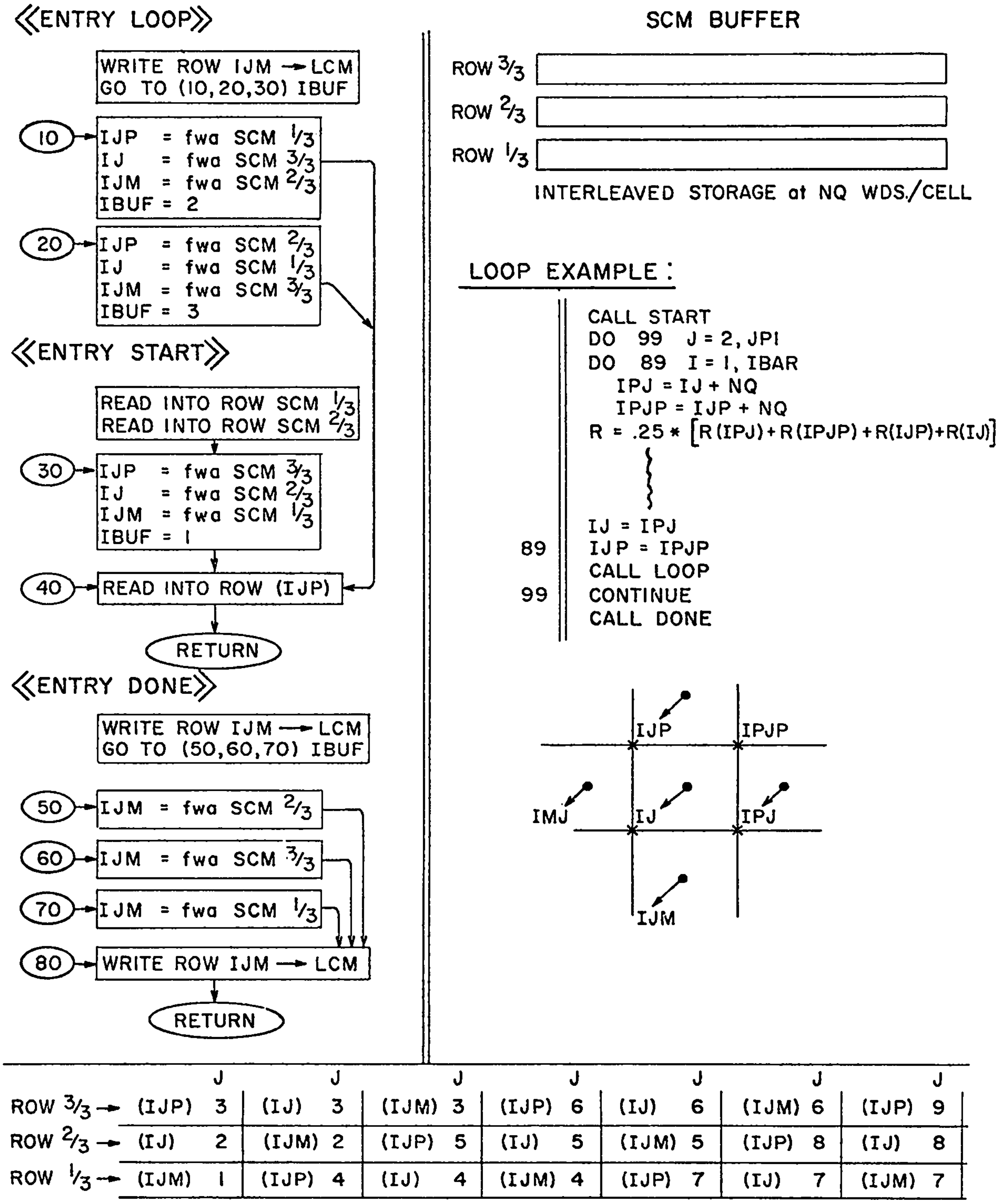
(4) LØØP returns to statement No. 99 in the sample calling program, and rows are processed similarly until all the rows specified by the J DØ-loop have been processed, at which time control passes to the "CALL DØNE" statement.

(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.



```
      CALL START
      DO  99  J = 2, JP1
      DO  89  I = 1, IBAR
        IPJ = IJ + NQ
        IPJP = IJP + NQ
      R = .25 * [R(IPJ)+R(IPJP)+R(IJP)+R(IJ)]

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

	J	J	J	J	J	J	J
ROW 3/3 →	(IJP) 3	(IJ) 3	(IJM) 3	(IJP) 6	(IJ) 6	(IJM) 6	(IJP) 9
ROW 2/3 →	(IJ) 2	(IJM) 2	(IJP) 5	(IJ) 5	(IJM) 5	(IJP) 8	(IJ) 8
ROW 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 $\bar{I} \leq 100$.

Other entry points in the L00P subroutine, not shown in Fig. 10, allow the user to access any cell at random easily, and to perform D0 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 r or z 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 $x \leq$ PXR and PYB $\leq y \leq$ 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_o) according to

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

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

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

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

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

(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

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

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.

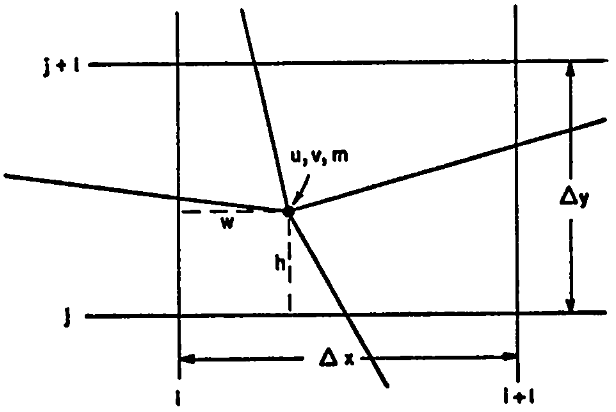


Fig. 11. Assigning YAQUI vertex quantities to the surrounding particle-grid cell.

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

$$u_p = \Big[PU^j_{i+1}\,(w)(\Delta y - h) + PU^{j+1}_{i+1}\,(w)(h)$$

$$+ PU^{j+1}_{i}\,(\Delta x - w)(h)$$

$$+ PU^{j}_{i}\,(\Delta x - w)(\Delta y - h)\Big]/\Delta x\ \Delta y \quad ,$$

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

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

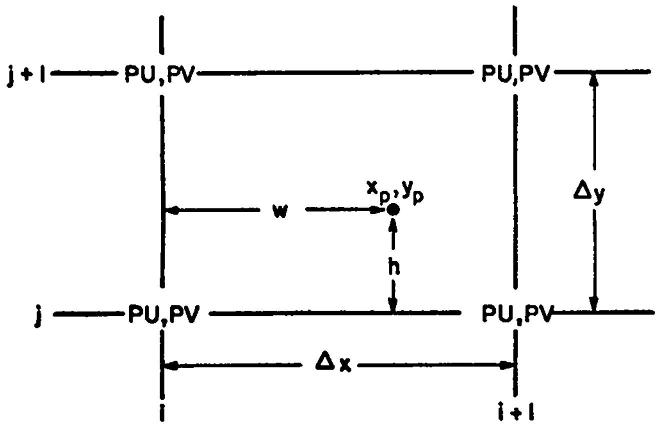


Fig. 12. Area weighting the particle p within the particle grid cell.

(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 PU 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

$${}^{n+1}u_p = \frac{{}^{n}u_p + \delta t\eta_p\,(u_{fl} + u_{rand}) + \delta t g_r}{1 + \delta t\eta_p} \quad ,$$

in which u_{fl} 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

$$\left(\overline{\Delta M}_x\right)_p = m_p\ \delta t\eta_p\ \left(u_{fl} - {}^{n+1}u_p + u_{rand}\right) \quad ,$$

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

$$\left(\Delta M_x\right)^j_{i+1} = \left(\Delta M_x\right)^j_{i+1} + \frac{w\ (\Delta y - h)}{\Delta x\ \Delta y}\ \left(\overline{\Delta M}_x\right)_p \quad ,$$

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

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

$$\left(\Delta M_x\right)^{j}_{i} = \left(\Delta M_x\right)^{j}_{i} + \frac{(\Delta x - w)\ (\Delta y - h)}{\Delta x\ \Delta y}\ \left(\overline{\Delta M}_x\right)_p \quad .$$

A similar distribution is performed for ΔM_y, where

$$\left(\overline{\Delta M}_y\right)_p = m_p \; \delta t \eta_p \left(v_{fl} - {}^{n+1}v_p + v_{rand}\right) \quad .$$

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

$$\begin{aligned} u = u - \Bigg[& \left(\frac{\Delta M_x}{M_o}\right)_{i+1}^{j} (w)\;(\Delta y - h) + \left(\frac{\Delta M_x}{M_o}\right)_{i+1}^{j+1} (w)(h) \\ & + \left(\frac{\Delta M_x}{M_o}\right)_{i}^{j+1} (\Delta x - w)(h) \\ & + \left(\frac{\Delta M_x}{M_o}\right)_{i}^{j} (\Delta x - w)(\Delta y - h)\Bigg] \Big/ \Delta x \; \Delta y \quad , \end{aligned}$$

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 $m_p = 0$, $\eta_p \to \infty$, 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 131000_{10} 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_o, 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_i^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

$$\left(\lambda_{eff}\right)_i^j = k\lambda_{input}$$

and

$$\left(\mu_{eff}\right)_i^j = k\mu_{input} \quad ,$$

where

$$k = \left(\rho_i^j\right)^\xi$$

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

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

We define

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

where ε is a coefficient, u_1^2 is the square of a representative velocity at vertex $\binom{j}{i}$ of the cell,

$$u_1^2 = \left(u^2 + v^2\right)_i^j \quad ,$$

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

$$u'\delta x^2 = \frac{(u\delta x)_{max}}{n} = \frac{1}{n} \max \left(|u_i^j| \Delta r, |v_i^j| \Delta z \right) \quad ,$$

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

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

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

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 ρ_{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

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

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

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

Combining these two conditions, we obtain

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

from which δt_v may be reset as

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

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

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

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 $U = u_{fluid} - u_{grid}$, 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:

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

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

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

according to which we reset δt_c, if necessary, by

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

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, MESHMKR. 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 MESHMKR 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 MESHMKR generates exactly this uniform grid.

The version of MESHMKR 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 JCEN + $\frac{\text{JUNF}}{2}$, and below JCEN - $\frac{\text{JUNF}}{2}$. For accuracy, FREZ generally should not exceed about 1.1. The above expression will retain uniform zoning throughout if FREZ = 1.0. A simple program modification would allow for different expansion rates in the two directions.

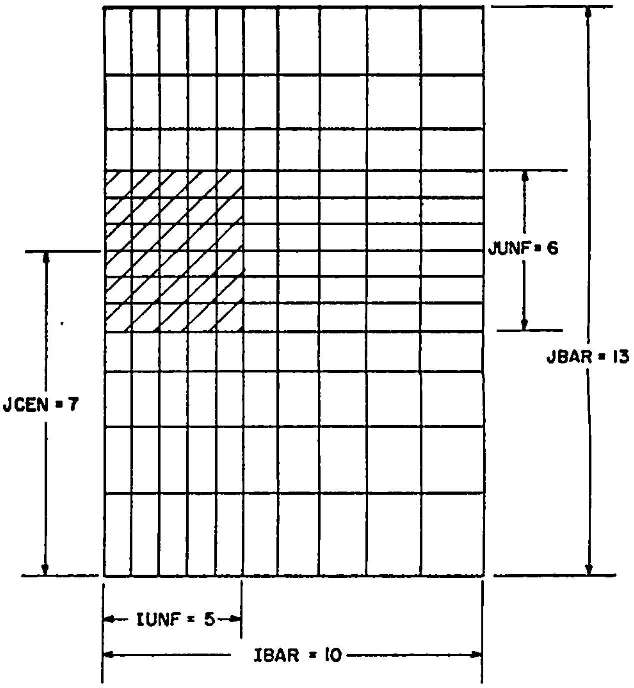


Fig. 13. An initial YAQUI grid with variable zoning. The region of uniform δr and δz zones (IUNF zones by JUNF zones, centered at JCEN zones up from the bottom) is denoted by shading.

If variable zoning is employed (FREZ > 1.0), user calculation of YB would be inconvenient, so, instead, the input quantity REZYO, which is the y coordinate of the center of expansion, y_o, determines the vertical placement of the mesh. REZYO refers to the YAQUI vertex (1, JCEN + 2), and allows YAQUI to calculate the actual value of YB.

Although the variable zoning shown in Fig. 13 for this version of MESHMKR is of a simple rectilinear form, we emphasize that neither the technique nor the code is by any means limited to this. MESHMKR may be modified easily to create any curvilinear grid, and, indeed, simple iterative techniques[5] have been used in MESHMKR 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 calculationally 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:

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

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

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

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

(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

$y_c = \sum_k y_k\, \omega_k \Big/ \sum_k \omega_k$, 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,

$x_c = \sum_k x_k\, \omega_k \Big/ \sum_k \omega_k$, as well as the vertical y_c, to move. The interior vertices are then made to satisfy the relations

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

and

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

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

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

and

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

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 δr_{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 $\beta_F = \left(2\beta_G + \beta_G^2\right)^{\frac{1}{2}}$. 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 = REZØNE.

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

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

BO = β_o 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 = u_{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, REZYO, REZUE, REZVE, REZVT, REZRØN, REZSIE (Format 8F8.3), where:

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

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

REZRON = the ρ_o of the ambient atmosphere at altitude REZYO 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 = $\bar{I}_{\text{particles}}$

JBP = $\bar{J}_{\text{particles}}$

(IBP, JBP): If no particles are to be used, set IBP = 0. Then the rest of Card No. 5 is 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 $\leq$ IBAR, and JBP $\leq$ JBAR.

PDR = Δx

PDZ = Δy

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

PYB = $YB_{\text{particles}}$, 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, T20MD, 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.

T20MD = 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 ($t \geq$ 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.

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

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

<u>Card No. 8</u>: (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.

<u>Card No. 9</u>: DRPAR, DZPAR, XC, YC, XD, YD, UPAR, VPAR, MTE, DRAG (Format 10F8.3).
This is a particle-region card, to be expected <u>only</u> 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, <u>not</u> 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 PARTMØV assumes that all particles lie within the mesh.)

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

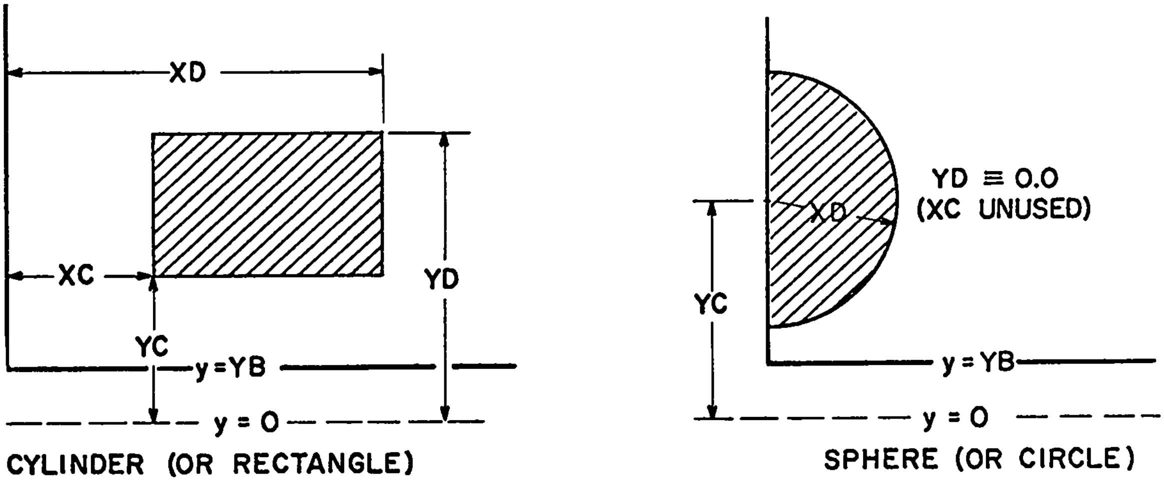


Fig. 14. Particle-region shapes available in PARTGEN. Note that the named dimensions are measured from x = 0 and y = 0.

UPAR VPAR	Initial u and v velocity components for the particles in this region; will be 0.0 for true marker particles.
MTE	Mass per particle = MTE*$r_{particle}$. Use MTE = 0.0 for markers.
DRAG	Drag coefficient, η, for these particles. 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 < 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 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 = $\bar{J}$.

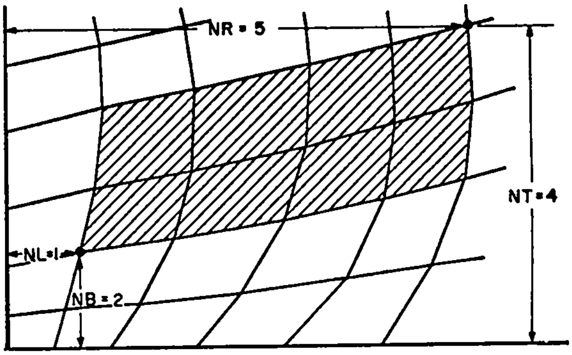


Fig. 15. The basic fluid region available in MESHMKR, defined by the number of zones over and up to two corners.

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

RØI = ρ_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, RØI, 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 fanfold paper. Both forms are automatically provided at cycles 0 and 1, and thereafter at intervals specified by DTØ and DTØC 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 CØM (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 REZØNE runs (GRDVEL ⩾ 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

$$x_2 = x_1 + \left(u_i^j\right) (\text{DRØU}) \quad ,$$

and

$$y_2 = y_1 + \left(v_i^j\right) (\text{DRØU}) \quad ,$$

where DRØU is a scaling coefficient defined as

$$\text{DRØU} = (0.9)\ (\text{VEL}_{\text{max}}) \left(\frac{x_{i=\text{IP1}}}{\bar{I}}\right) \quad .$$

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 $\left(x_{i=\text{IP1}}/\bar{I}\right)$. 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_i^j, y_i^j, u_i^j, v_i^j, I_i^j, ρ_i^j, V_i^j, D_i^j, $M_{v_i}^{\ j}$, and p_i^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 = δt 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 T2CMD and/or TLIMD, 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 ${}^{n+1}p$, to account for ρ changes that occurred in the Phase-3 convection. Nevertheless, the implicit treatment[1] 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 $\varepsilon = 0$ 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

$${}^{n}p = a^2\left({}^{n}\rho - \rho_o\right) + (\gamma - 1)\,{}^{n}\rho\,{}^{n}I \quad .$$

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 CØMMØN Block YSC2

The following list provides the names, descriptions, and sources of all quantities in the SCM CØMMØN YSC2 in the (0,0) overlay. This CØMMØN 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.
0 = (0,0) Main Overlay
L = (0,0) Subroutine LØØP
F = (0,0) Subroutine FILMCØ
S = (1,0) Subroutine YASET1
P = (1,0) Subroutine PARTGEN
2 = (2,0) Subroutine YAQUI2
R = (2,0) Subroutine REZØNE

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(0)
AOFAC	$\alpha_{oM}/\left[2\left(1+\alpha_{oM}^2\right)\right]$, used in calculating δt_c.	S
AOM	α_{oM}, the α_o used in Phase-3 M and E calculation.	I(0)
BO	β_o, determines Phase-3 differencing form, used with α_o and α_{oM}.	I(0)
COLAMU	$(1+\varepsilon)/(\lambda+2\mu)$, used in Phase-1 viscosity-coefficient calculation.	S
CYL	= 1. if cylindrical coordinates, = 0. if plane coordinates.	I(0)
DR	δr, the cell size in the radial direction if uniformly zoned.	I(0)
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
DTO	Problem time interval between outputs (plots and prints).	I(S)
DTOC	Problem time at which to change to next DTO in the set.	I(S)
DTO16	$\delta t/16$.	2
DTO2	$\delta t/2$.	2
DTO4	$\delta t/4$.	2
DTO8	$\delta t/8$.	2
DTPOS	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(0)
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(0)
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 C0MM0N because of ENTRY SETIJ in L00P.	--
IBAR	$\bar{I}$, the number of interior fluid zones in the r direction.	I(0)
IBP	I_p, the number of particle-grid zones in the r direction.	I(S)
IBP1	I_p+1, index of rightmost column of particle-grid vertices.	P
IC0L0R	= 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 L00P.	L
IJM	Index for cell (i,j-1), initialized by L00P.	L
IJP	Index for cell (i,j+1), initialized by L00P.	L
IJPS	Index for cell (i,j+1), saved for later reference to cell (1,j+1).	L
IM0ME3	IM0MX*1000, forces resetting of J in statement No. 2020 in PARTM0V if IM0MX = 1.	P
IM0MX	= 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	L0CF(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-NQ, 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	I_{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 C0MM0N because of ENTRY R1R0W and W1R0W in L00P.	--
JBAR	$\bar{J}$, the number of interior fluid zones in the z direction.	I(0)
JBP	J_p, the number of particle-grid zones in the z direction.	I(S)
JBP2	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
NUMTD	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 REZYO 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
REZYO	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

NAME	DESCRIPTION	SOURCE
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)
TØUT	The next output time for plots/prints.	S,2
TWFIN	Time-When-to-Finish: calculation completed when $t \geq$ TWFIN.	I(S)
T20MD	= 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

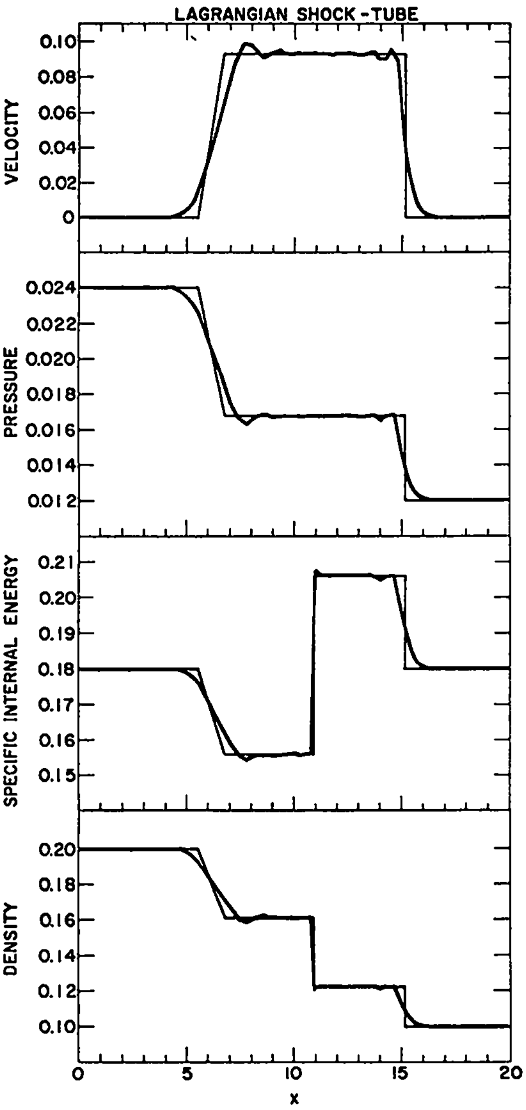


Fig. 16. One-dimensional YAQUI Lagrangian calculation of a 2:1-density-ratio shock tube.

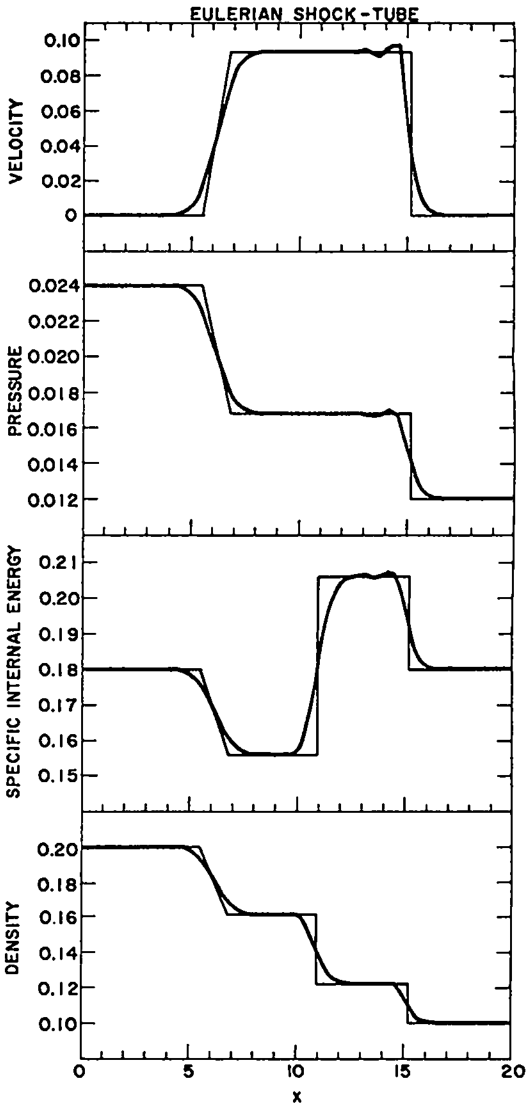


Fig. 17. One-dimensional YAQUI Eulerian calculation of a 2:1-density-ratio shock tube.

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 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.

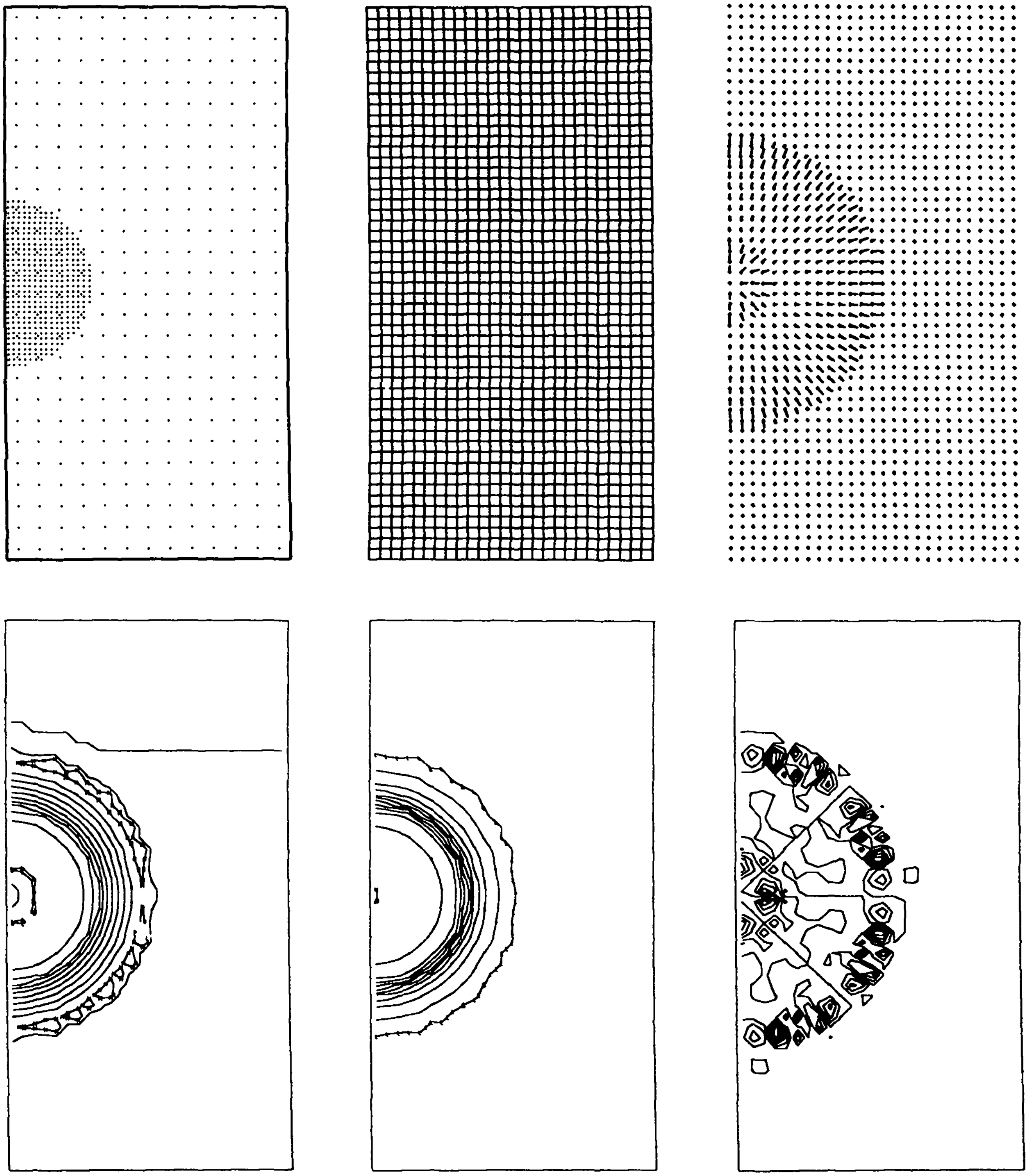


Fig. 18. YAQUI low-altitude explosion calculation at t = 0. The six plots represent the marker particles, computing mesh, and velocity vectors (top) and isopycnic, isotherm, and vorticity contour plots (bottom).

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) Continuative 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

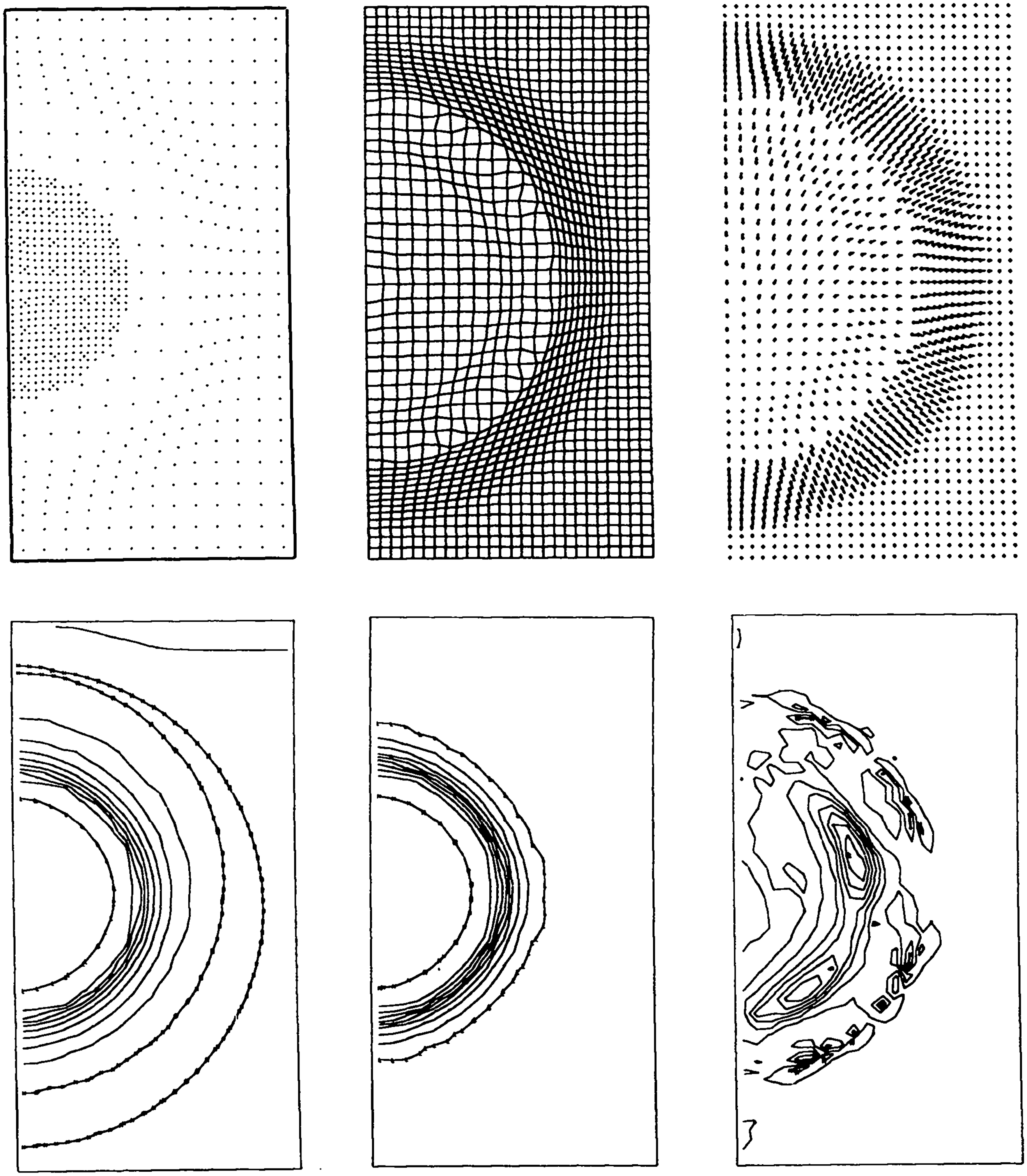


Fig. 19. A Lagrangian calculation at t = 1 sec of the problem setup of Fig. 18.

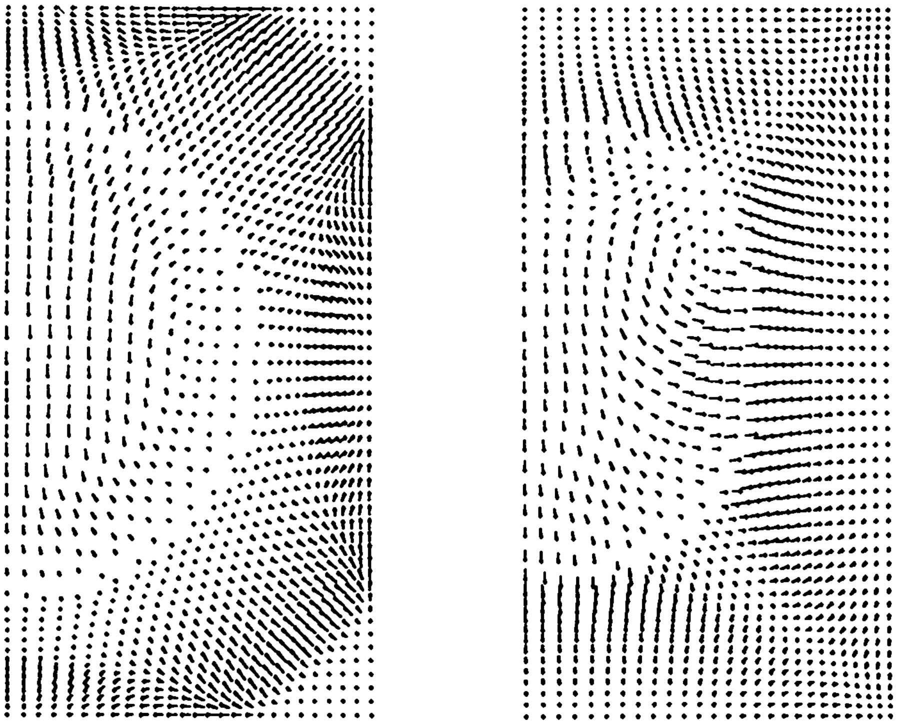


Fig. 20. Velocity-vector plots at t = 2 and t = 3 sec of the problem shown in Fig. 19, showing shock reflection from the boundaries.

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

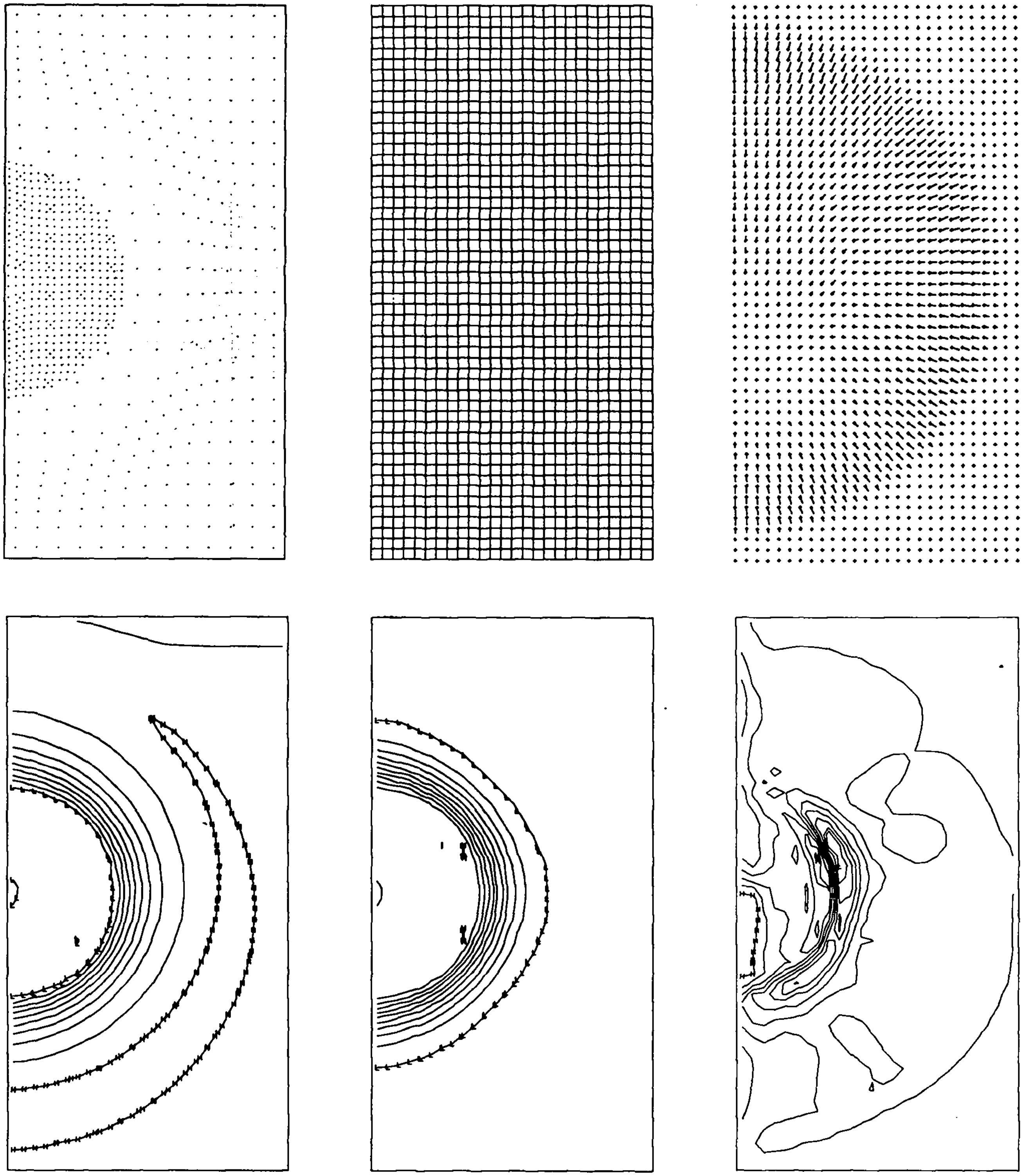


Fig. 21. An Eulerian calculation at t = 1 sec of the problem setup of Fig. 18.

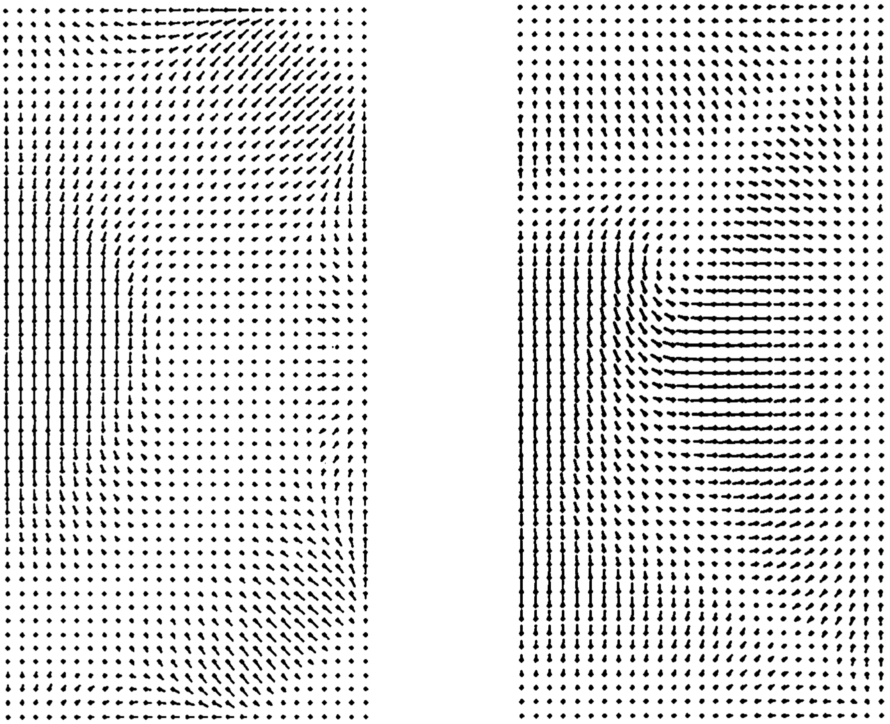


Fig. 22. Velocity-vector plots at t = 2 sec and t = 3 sec of the problem shown in Fig. 21, showing shock reflection from the boundaries.

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.

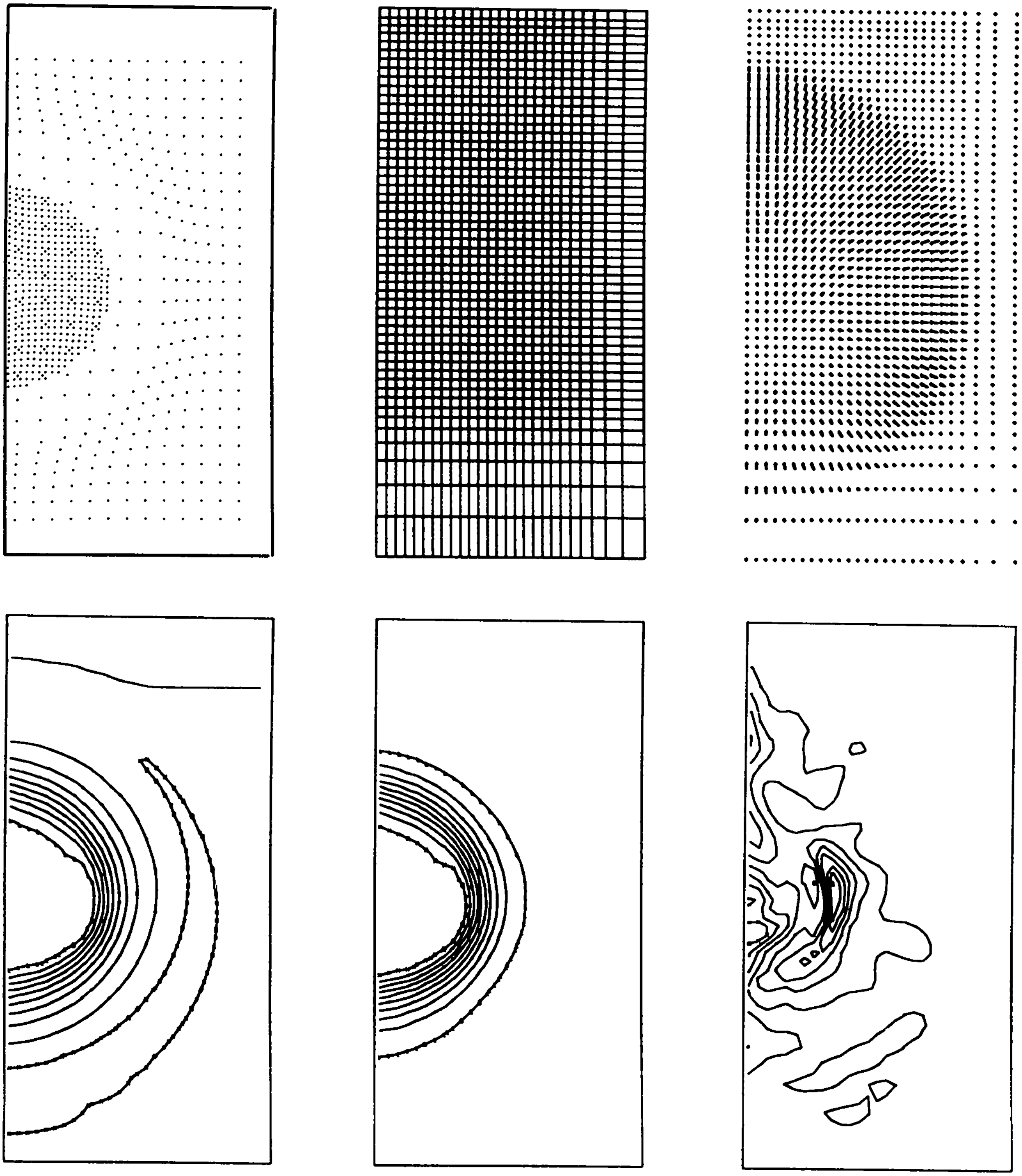


Fig. 23. A REZ0NE calculation at t = 1 sec of the problem setup of Fig. 18.

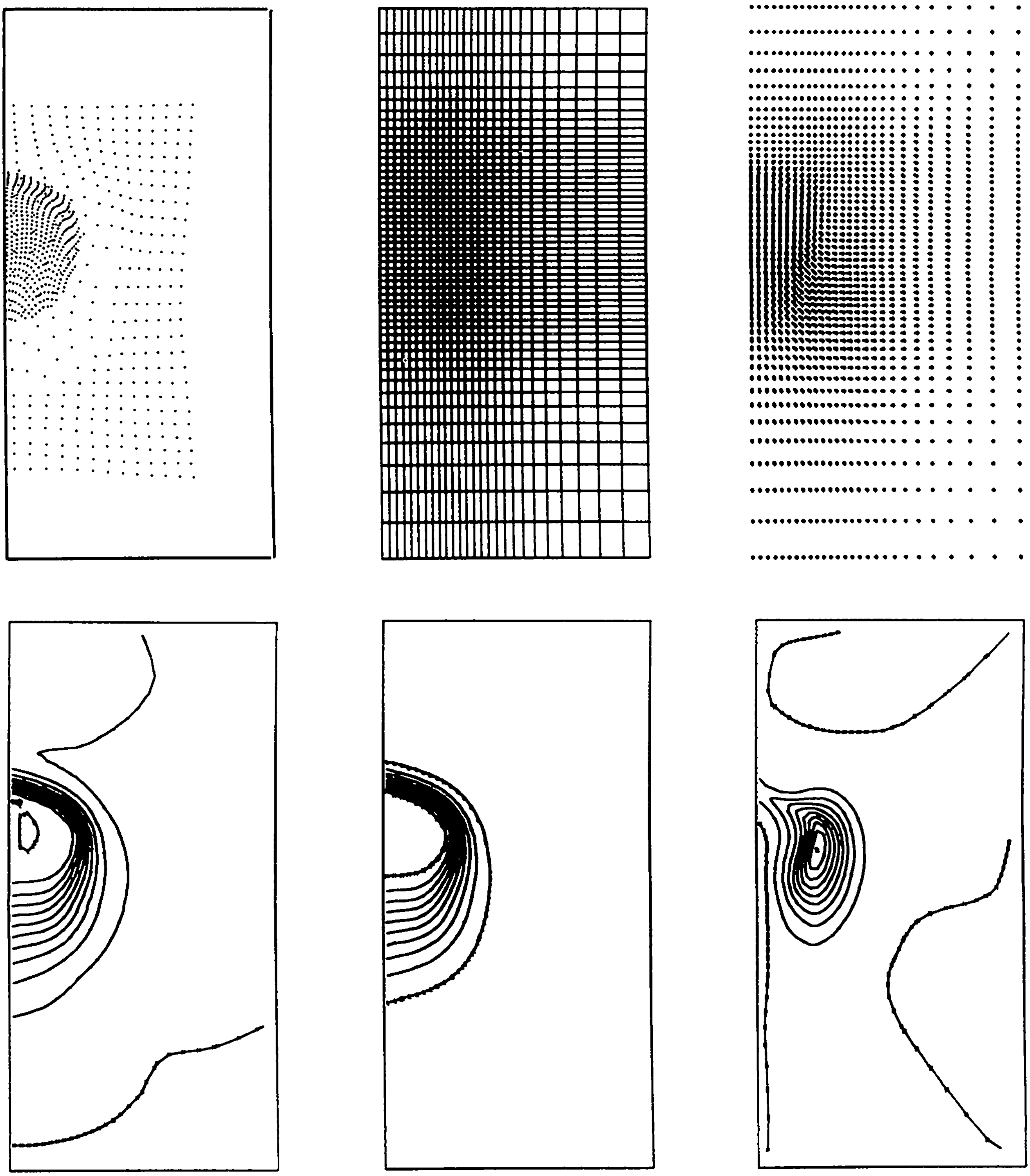


Fig. 24. The REZONE calculation of the problem of Figs. 18 and 23 at t = 5 sec.

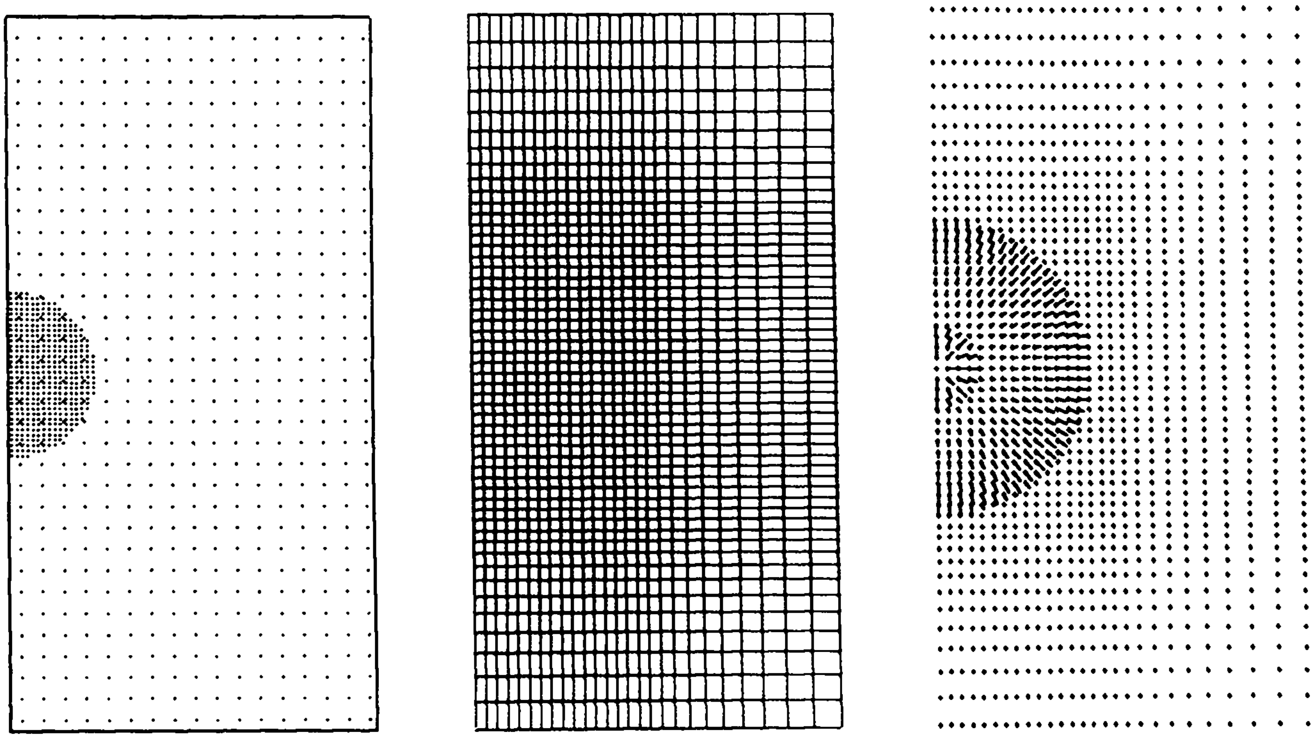


Fig. 25. A YAQUI setup with initial variable zoning for the problem shown in Fig. 18.

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, "Particulate 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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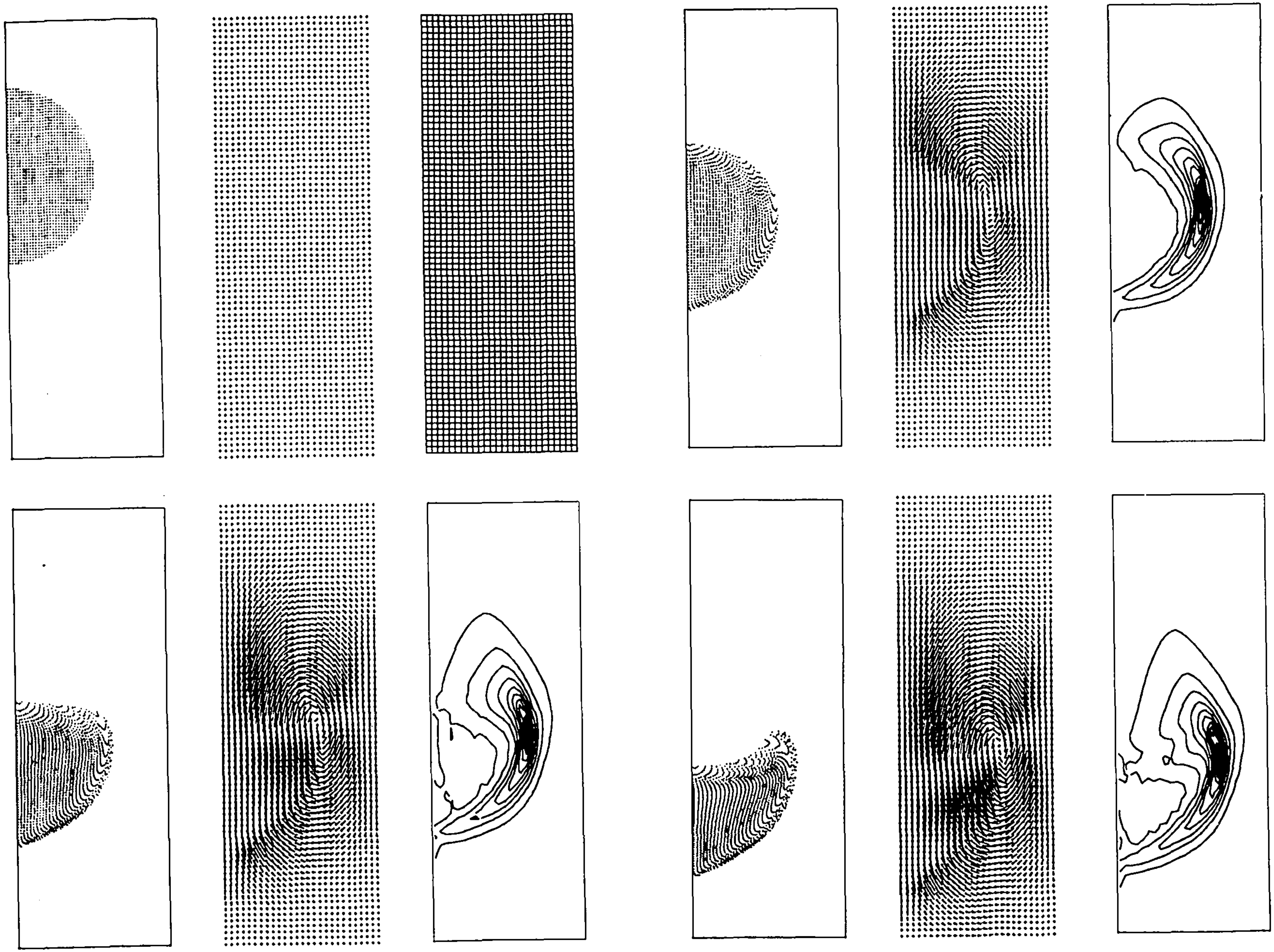


Fig. 26. YAQUI particle-fluid momentum-exchange calculation.

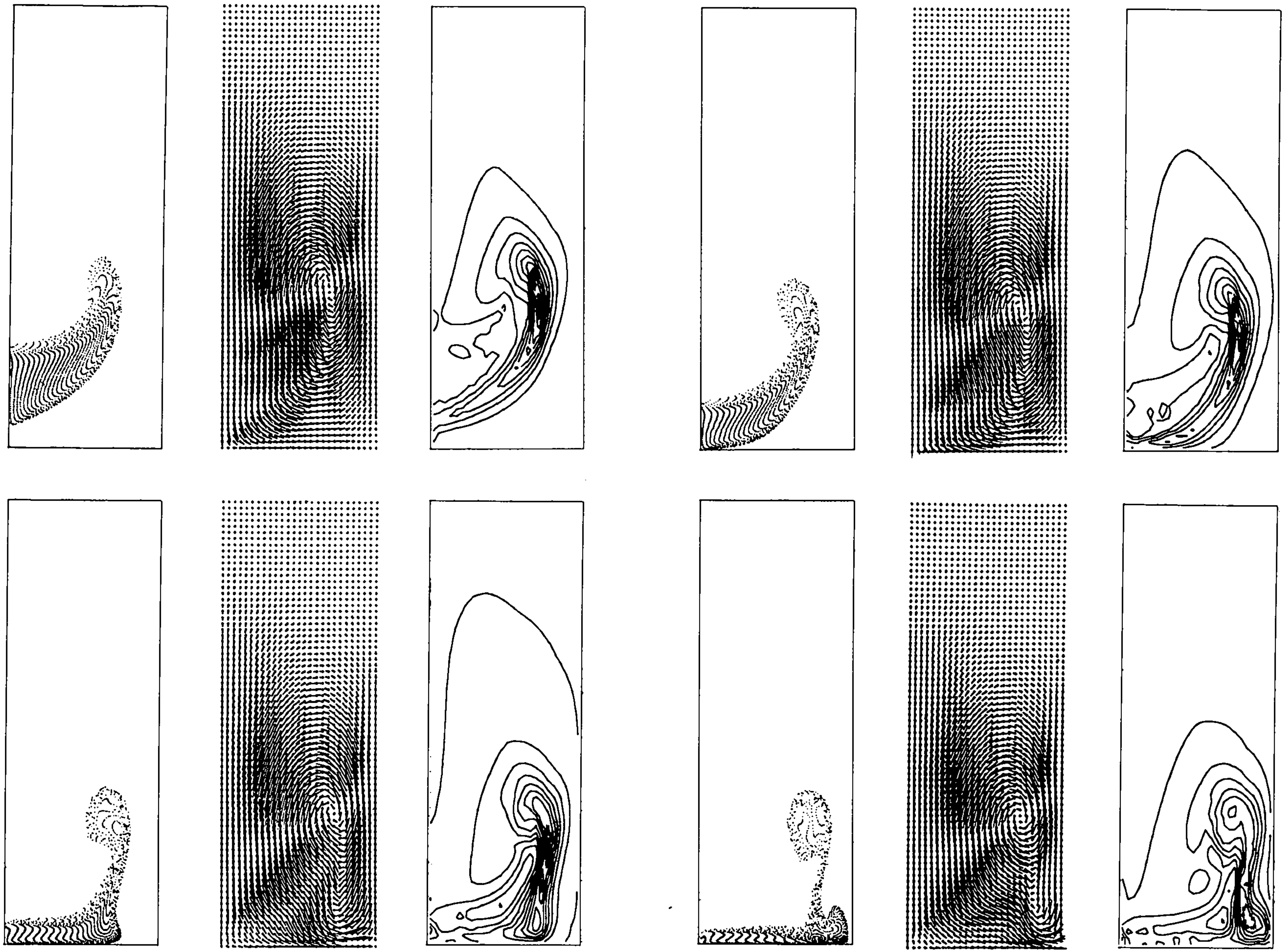
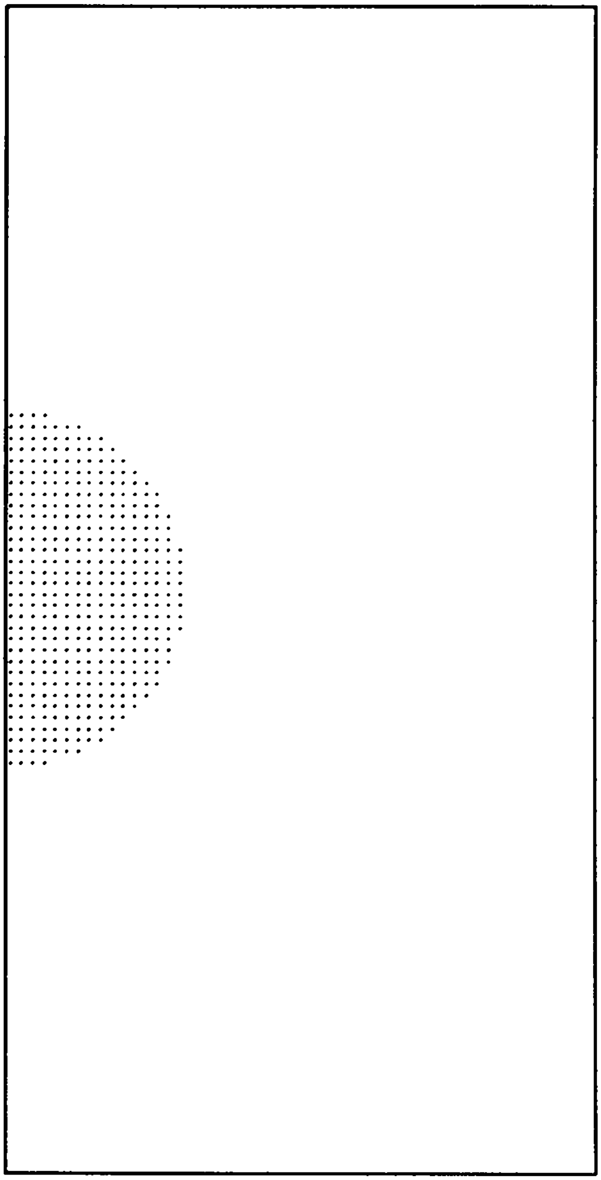


Fig. 26 (Contd)

```
YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3)      110872-1
  IBAR=  26
  JBAR=  52
  IUNF=  26
  JUNF=  52
  JCEN=  26
    DR= 1.00000E+00
    DZ= 1.00000E+00
   CYL= 1.00000E+00
GRDVEL= 0.
    A0= 7.50000E-01
   A0M= 7.50000E-01
    B0= 0.
   KXI= -1
    MU= 1.00000E+00
   LAM= 1.00000E+01
    OM= 1.00000E+00
   EPS= 1.00000E-04
    GR= 0.
    GZ= 0.
   ASQ= 1.00000E+02
   RON= 1.00000E+00
   GMI= 0.
  FREZ= 1.00000E+00
    YB= 0.
 REZY0= 0.
 REZUE= 0.
 REZVE= 0.
 REZVT= 0.
REZRON= 0.
REZSIE= 0.
   IBP=  26
   JBP=  52
   PDR= 1.00000E+00
   PDZ= 1.00000E+00
   PYB= 0.
   GZP=-1.00000E+00
 IMOMX= 1
     T= 0.
    DT= 1.00000E-01
 T20MD= 0.
 TLIMD= 0.
 TWFIN= 1.00000E+01
   LPR= 1
ICOLOR= 0
 DTO(1-10)= 1.00000E+00  -0.           -0.           -0.           -0.
           -0.           -0.           -0.           -0.           -0.
DTOC(1-10)= 1.00000E+02  -0.           -0.           -0.           -0.
           -0.           -0.           -0.           -0.           -0.
 DRPAR= 5.00000E-01  DZPAR= 5.00000E-01  XC= 0.            YC= 2.60000E+01  XD= 8.00000E+00
 YD= 0.           UPAR= 0.            VPAR= 0.           MTE= 2.50000E-01  DRAG= 1.00000E+00
      408 PARTICLES GENERATED, WITH TOTAL MASS= 3.46375E+02
 NB=  0  NR= 26  NT= 52  NL=  0  UI= 0.           VI= 0.           ROI= 1.00000E+00  SIEI= 1.00000E+00
```



```
PARTICLES
        PDR= 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)       110872-1   T= 0.          CYCLE=     0
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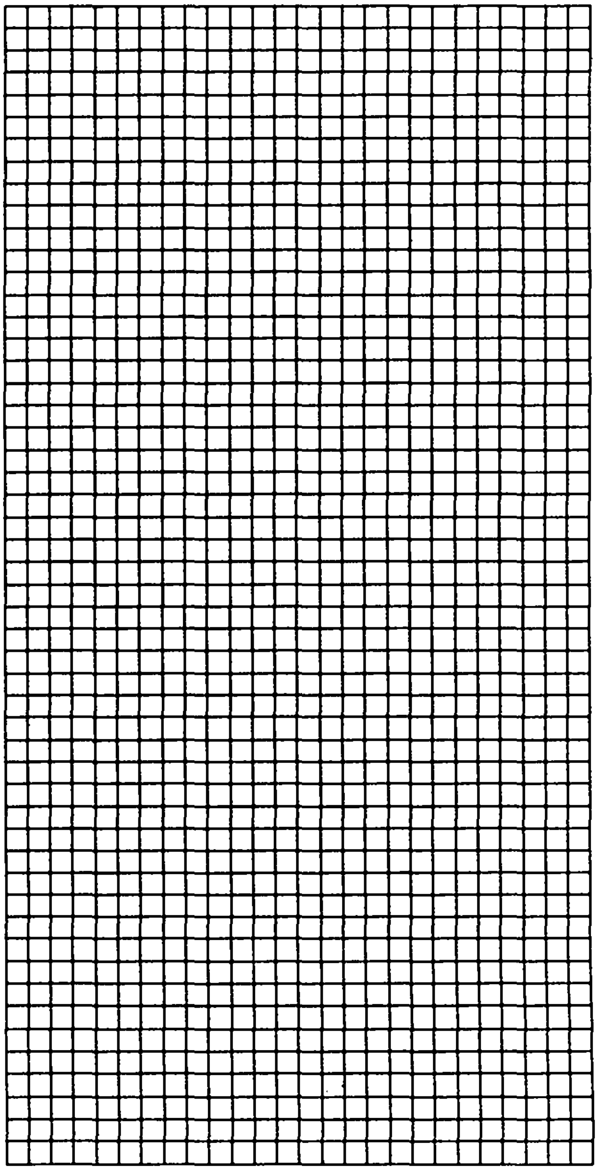

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ZONES
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    T3AAA  IBA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3)        110872-1   T= 0.            CYCLE=     0
```

```
   T3AAA  IBA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3)       110872-1   T= 0.          CYCLE=     0
I   J       X           Y           U           V           SIE         RHO         VOL         D           M           P
  8, 26  7.0000E+00  2.4000E+01  0.          0.          1.0000E+00  1.0000E+00  7.5000E+00  0.          7.0000E+00  0.
  9, 26  8.0000E+00  2.4000E+01  0.          0.          1.0000E+00  1.0000E+00  8.5000E+00  0.          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.
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 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.
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 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  0.
 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  0.
 25, 26  2.4000E+01  2.4000E+01  0.          0.          1.0000E+00  1.0000E+00  2.4500E+01  0.          2.4000E+01  0.
 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  0.
  1, 27  0.          2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  5.0000E-01  0.          2.5000E-01  0.
  2, 27  1.0000E+00  2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  1.5000E+00  0.          1.0000E+00  0.
  3, 27  2.0000E+00  2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  2.5000E+00  0.          2.0000E+00  0.
  4, 27  3.0000E+00  2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  3.5000E+00  0.          3.0000E+00  0.
  5, 27  4.0000E+00  2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  4.5000E+00  0.          4.0000E+00  0.
  6, 27  5.0000E+00  2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  5.5000E+00  0.          5.0000E+00  0.
  7, 27  6.0000E+00  2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  6.5000E+00  0.          6.0000E+00  0.
  8, 27  7.0000E+00  2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  7.5000E+00  0.          7.0000E+00  0.
  9, 27  8.0000E+00  2.5000E+01  0.          0.          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  0.
 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  0.
 25, 27  2.4000E+01  2.5000E+01  0.          0.          1.0000E+00  1.0000E+00  2.4500E+01  0.          2.4000E+01  0.
 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  0.
  1, 28  0.          2.6000E+01  0.          0.          1.0000E+00  1.0000E+00  5.0000E-01  0.          2.5000E-01  0.
  2, 28  1.0000E+00  2.6000E+01  0.          0.          1.0000E+00  1.0000E+00  1.5000E+00  0.          1.0000E+00  0.
  3, 28  2.0000E+00  2.6000E+01  0.          0.          1.0000E+00  1.0000E+00  2.5000E+00  0.          2.0000E+00  0.
  4, 28  3.0000E+00  2.6000E+01  0.          0.          1.0000E+00  1.0000E+00  3.5000E+00  0.          3.0000E+00  0.
  5, 28  4.0000E+00  2.6000E+01  0.          0.          1.0000E+00  1.0000E+00  4.5000E+00  0.          4.0000E+00  0.
  6, 28  5.0000E+00  2.6000E+01  0.          0.          1.0000E+00  1.0000E+00  5.5000E+00  0.          5.0000E+00  0.
  7, 28  6.0000E+00  2.6000E+01  0.          0.          1.0000E+00  1.0000E+00  6.5000E+00  0.          6.0000E+00  0.
  8, 28  7.0000E+00  2.6000E+01  0.          0.          1.0000E+00  1.0000E+00  7.5000E+00  0.          7.0000E+00  0.
  9, 28  8.0000E+00  2.6000E+01  0.          0.          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.
```

```
    T3AAA  IBA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3)       110872-1   T= 1.00000E-02 CYCLE=     1
 I   J       X           Y           U           V          SIE         RHO         VOL          D           M           P
  8, 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  5.0000E-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  5.0000E-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.
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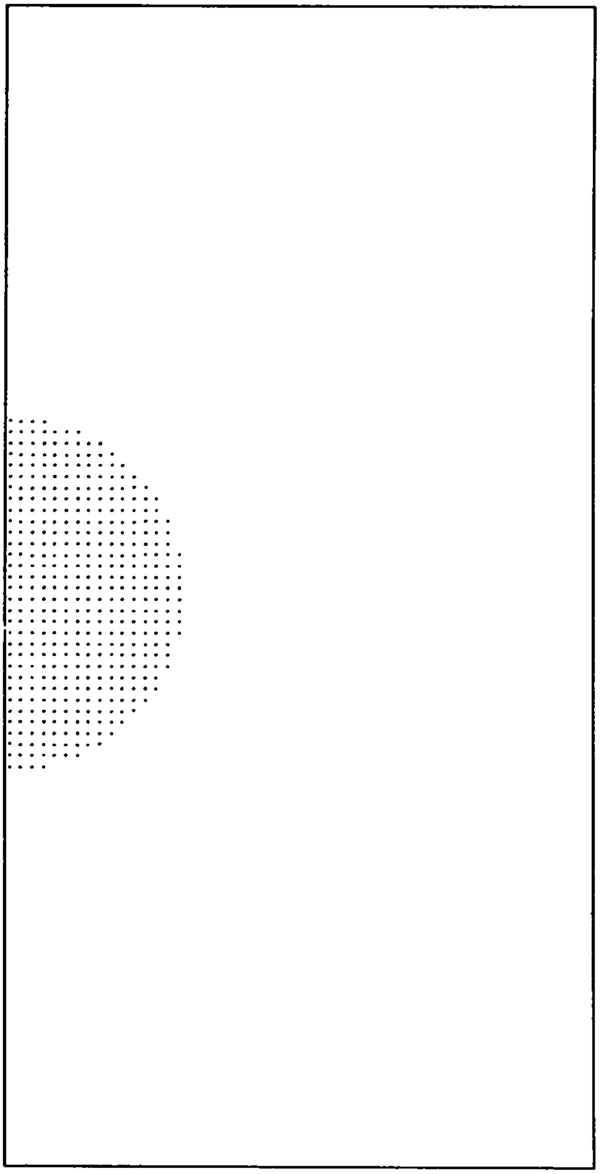

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PARTICLES
        PDR= 1.00000E+00 PDZ= 1.00000E+00 PXR= 2.60000E+01 PYB= 0.          PYT= 5.20000E+01
   T3AAA  IBA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAAIGB 032272-3)       110872-1    T= 1.00000E+00 CYCLE=     7
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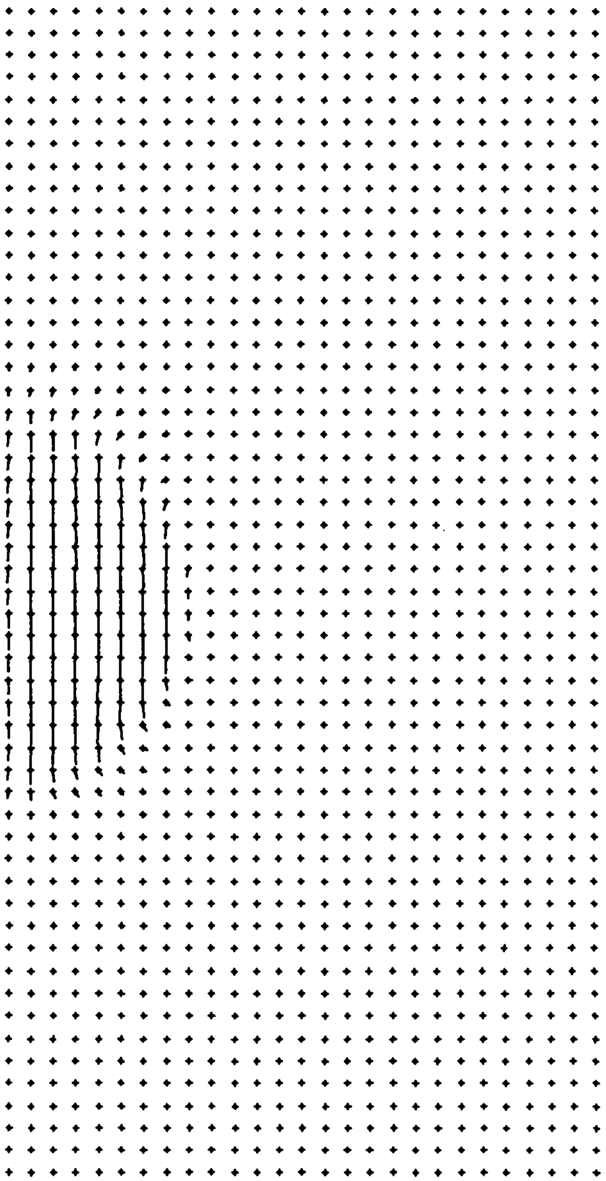
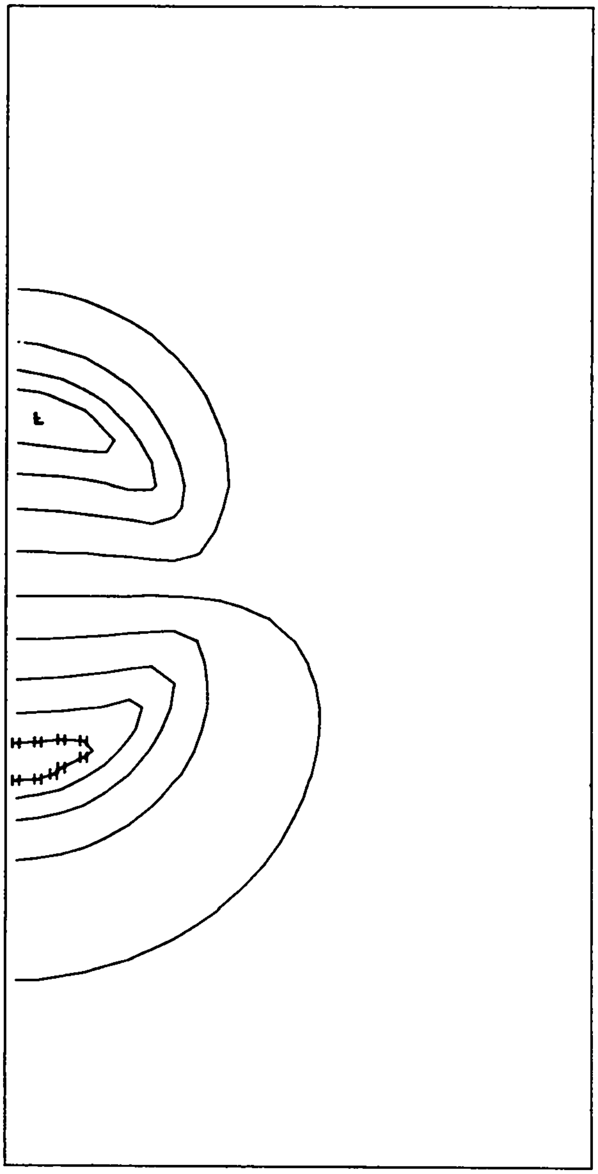


VELOCITY VECTORS

VMAX= 2.96442E-01

T3AAA 1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 1.00000E+00 CYCLE= 7



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ISOPYCNICS
          MIN= 9.90697E-01 MAX= 1.00900E+00 L= 9.90697E-01 H= 1.00807E+00 DQ= 1.93073E-03
   T3AAA  1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1G8 032272-3)       110872-1   T= 1.00000E+00 CYCLE=    7
```

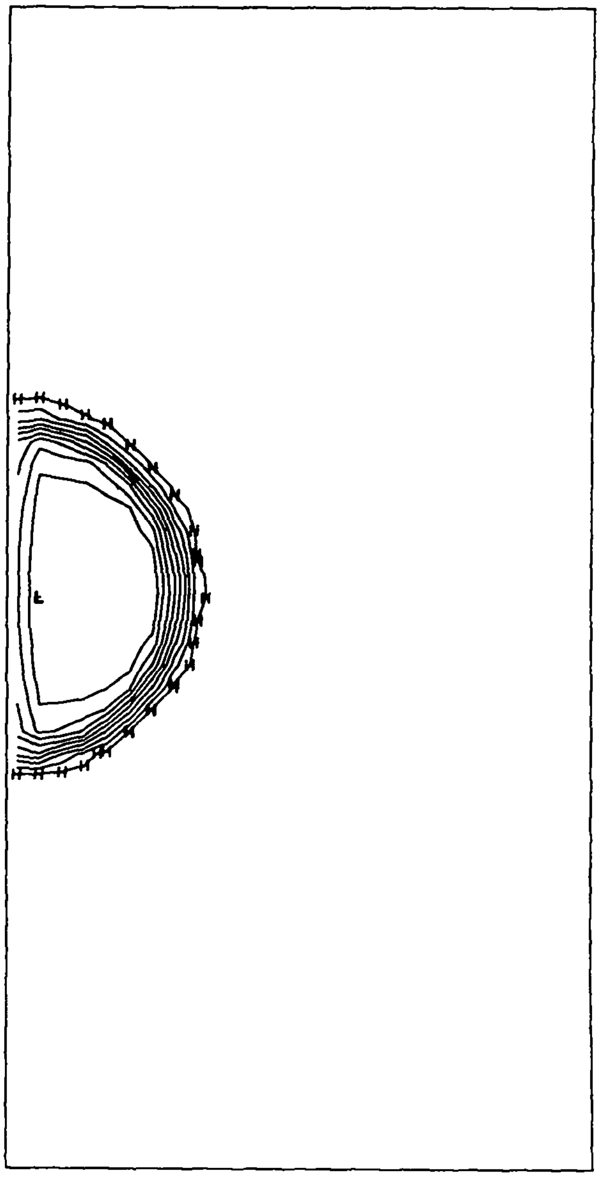

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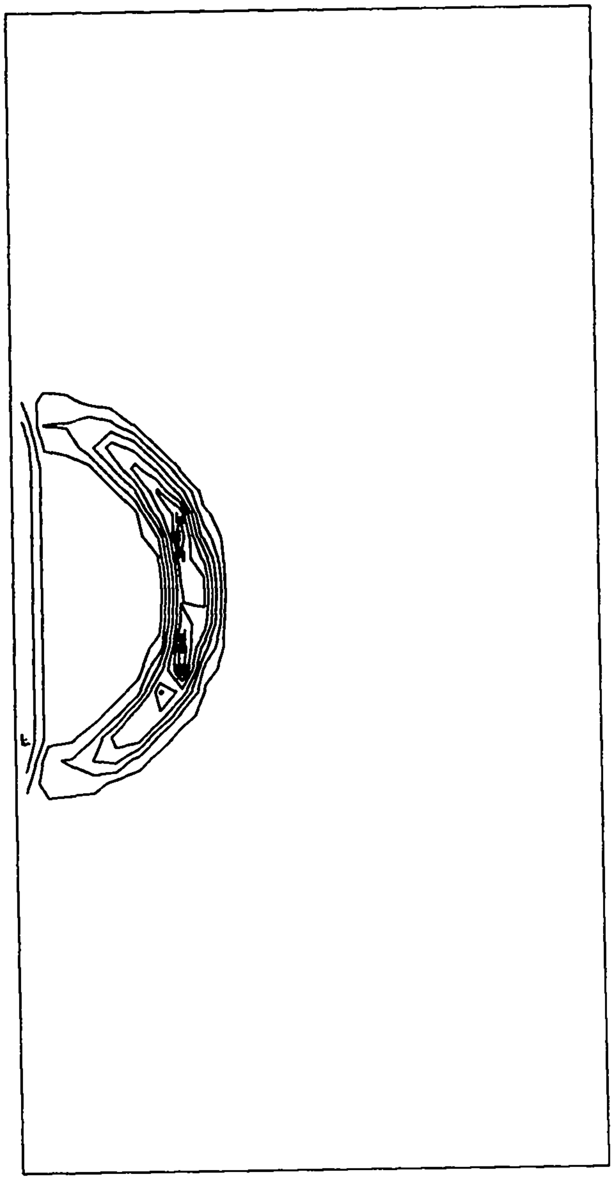
ISOTHERMS
          MIN= 9.72363E-01 MAX= 1.00004E+00 L= 9.72363E-01 H= 9.98169E-01 DQ= 2.86729E-03
    T3AAA  IBA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAAIGB 032272-3)        110872-1   T= 1.00000E+00 CYCLE=    7
```



VORTICITY

MIN=-7.34092E-02 MAX= 2.22235E-01 L=-7.34092E-02 H= 1.93570E-01 DQ= 2.96644E-02

T3AAA 18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 1.00000E+00 CYCLE= 7

```
   T3AAA  IBA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAAIGB 032272-3)      110872-1   T= 1.00000E+00 CYCLE=    7
 I   J      X           Y           U           V          SIE         RHO         VOL          D           M           P
  8, 26  7.0000E+00  2.4000E+01 -2.6115E-03 -2.7685E-01  9.8534E-01  1.0016E+00  7.5000E+00 -7.4401E-03  7.0153E+00  1.6220E-01
  9, 26  8.0000E+00  2.4000E+01  1.8472E-02 -9.1458E-02  9.9813E-01  1.0013E+00  8.5000E+00 -5.3887E-03  8.0160E+00  1.3420E-01
 10, 26  9.0000E+00  2.4000E+01  2.9641E-02  2.3379E-02  9.9983E-01  1.0009E+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-01  1.0006E+00  1.0500E+01 -1.2173E-03  1.0009E+01  5.6908E-02
 12, 26  1.1000E+01  2.4000E+01  1.0472E-02  9.8134E-03  9.9997E-01  1.0004E+00  1.1500E+01 -8.1243E-04  1.1007E+01  3.7067E-02
 13, 26  1.2000E+01  2.4000E+01  6.4399E-03  6.2071E-03  9.9999E-01  1.0003E+00  1.2500E+01 -5.6867E-04  1.2005E+01  2.5416E-02
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 23, 26  2.2000E+01  2.4000E+01  5.7160E-05  2.8970E-05  1.0000E+00  1.0000E+00  2.2500E+01 -4.8468E-05  2.2000E+01  8.2055E-04
 24, 26  2.3000E+01  2.4000E+01  6.2426E-06  6.1064E-06  1.0000E+00  1.0000E+00  2.3500E+01 -6.1081E-06  2.3000E+01  1.0341E-04
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 26, 26  2.5000E+01  2.4000E+01 -2.0318E-10  3.8627E-25  1.0000E+00  1.0000E+00  2.5500E+01  1.9920E-10  2.5000E+01 -2.8891E-09
 27, 26  2.6000E+01  2.4000E+01  0.         -9.5390E-25  0.          3.3769E-33  0.          0.          1.2750E+01  7.8431E-02
  1, 27  0.          2.5000E+01  1.4377E-05 -2.2500E-01  9.7828E-01  1.0004E+00  5.0000E-01 -7.4488E-04  2.5021E-01  3.5892E-02
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  7, 27  6.0000E+00  2.5000E+01 -2.7082E-03 -2.9012E-01  9.7308E-01  1.0004E+00  6.5000E+00 -8.7686E-04  6.0058E+00  4.1218E-02
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 13, 27  1.2000E+01  2.5000E+01  3.3904E-03  7.3901E-03  9.9999E-01  1.0001E+00  1.2500E+01 -1.5791E-04  1.2002E+01  7.2363E-03
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 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.         -8.2718E-25  0.          3.3769E-33  0.          0.          1.2750E+01  7.8431E-02
  1, 28  0.          2.6000E+01 -3.2053E-06 -2.2558E-01  9.7835E-01  9.9942E-01  5.0000E-01  1.1064E-03  2.4997E-01 -5.7697E-02
  2, 28  1.0000E+00  2.6000E+01  7.9745E-05 -2.9642E-01  9.7243E-01  9.9941E-01  1.5000E+00  1.0771E-03  9.9988E-01 -5.8950E-02
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  7, 28  6.0000E+00  2.6000E+01  7.6047E-04 -2.8947E-01  9.7334E-01  9.9921E-01  6.5000E+00  1.7076E-03  5.9989E+00 -7.9322E-02
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 13, 28  1.2000E+01  2.6000E+01 -1.9746E-04  7.8501E-03  9.9999E-01  9.9989E-01  1.2500E+01  2.2960E-04  1.2000E+01 -1.0550E-02
 14, 28  1.3000E+01  2.6000E+01 -7.7690E-05  4.8637E-03  1.0000E+00  9.9992E-01  1.3500E+01  1.5334E-04  1.3000E+01 -7.8319E-03
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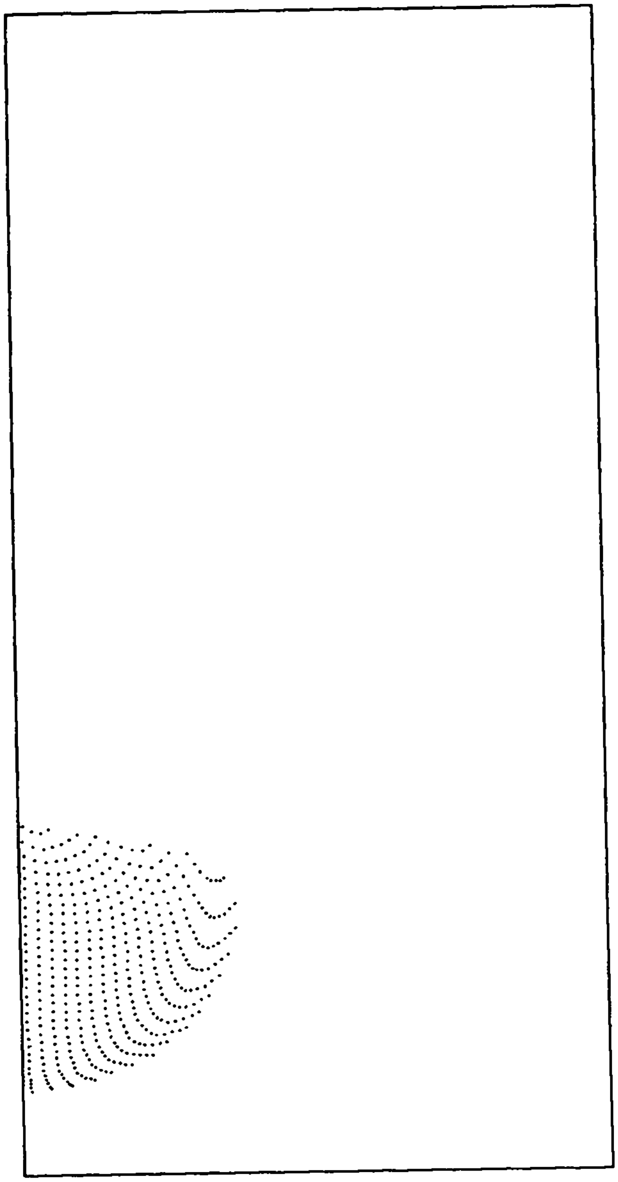

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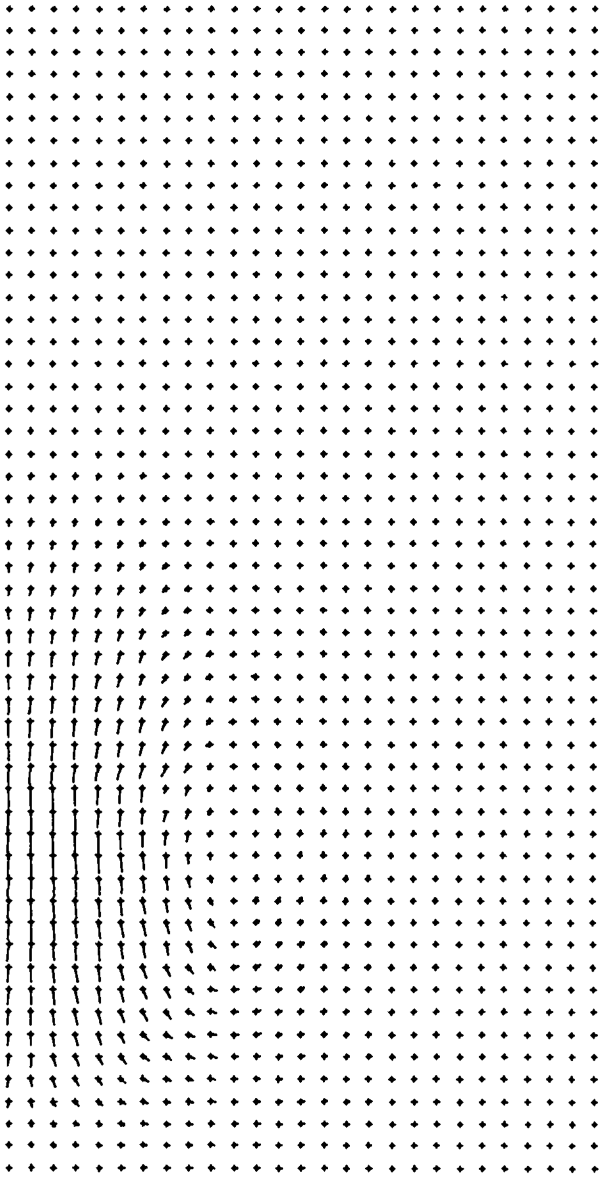

VELOCITY VECTORS
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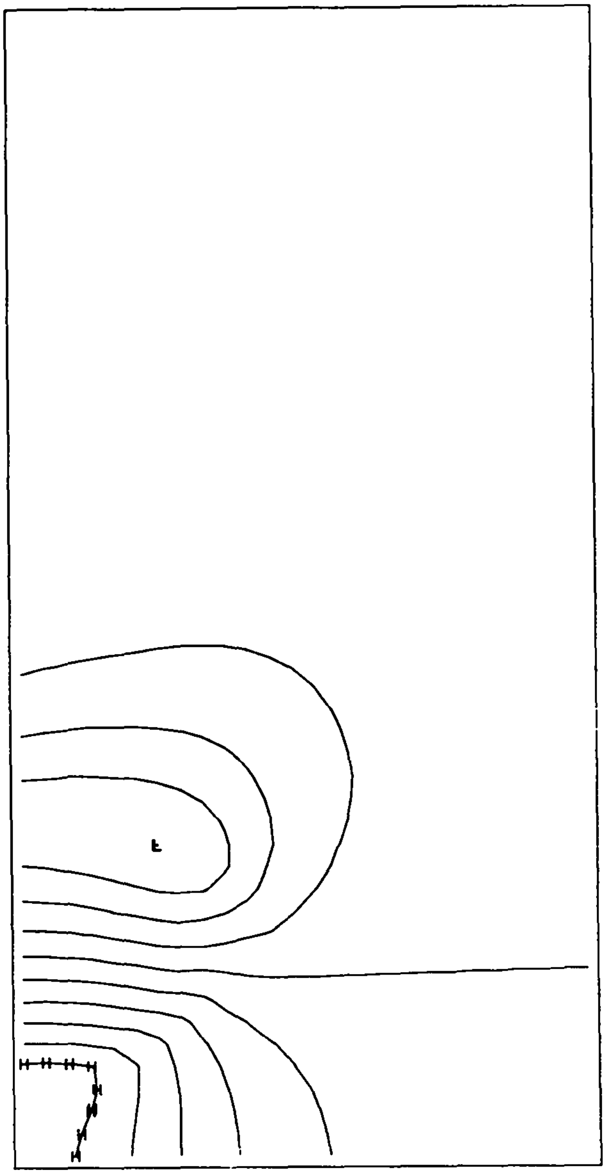

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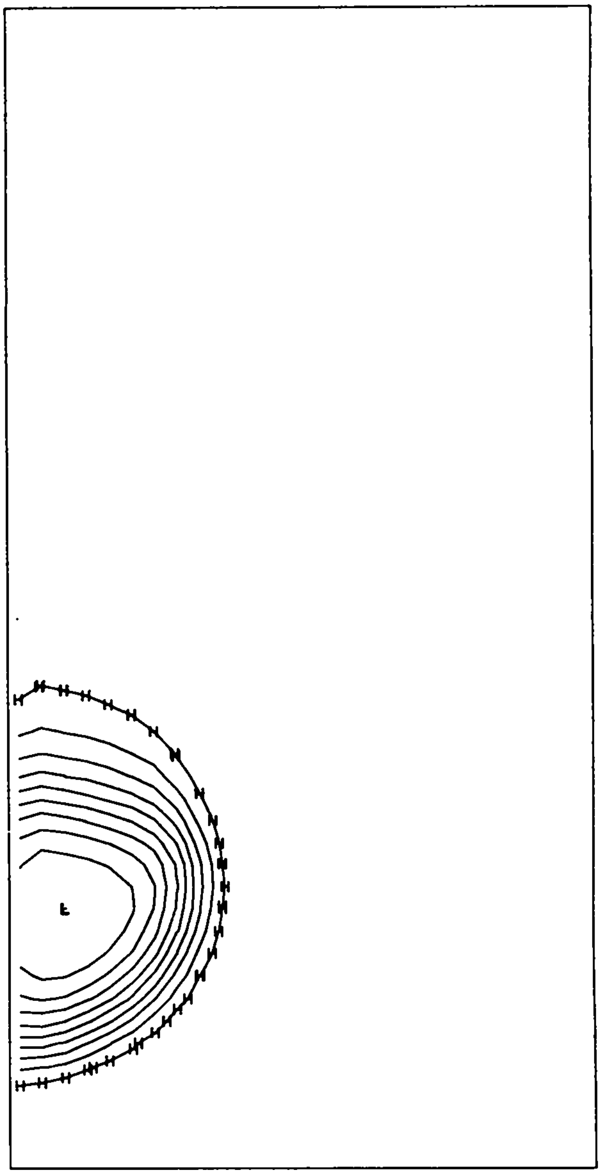

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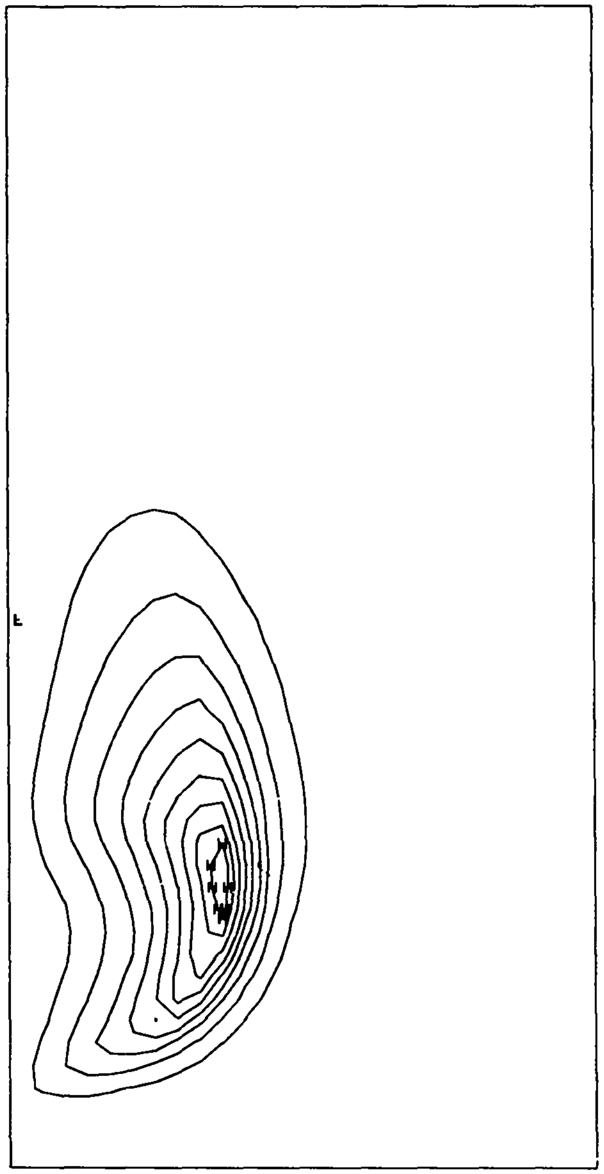

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VORTICITY
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    T3AAA  1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1G8 032272-3)      1:0872-1   T= 9.00000E+00 CYCLE=  232
```

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  T3AAA   18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1G8 032272-3)      110872-1    T= 9.00000E+00 CYCLE=  232
 I   J       X           Y           U           V          SIE         RHO          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  9.9680E-01  9.5000E+00 -2.3834E-03  8.9668E+00 -3.1973E-01
 11, 26  1.0000E+01  2.4000E+01 -4.9208E-01 -9.2084E-02  1.0145E+00  9.9680E-01  1.0500E+01 -2.1566E-03  9.9633E+00 -3.2023E-01
 12, 26  1.1000E+01  2.4000E+01 -4.4172E-01  4.0406E-02  1.0114E+00  9.9688E-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 -1.6101E-03  1.1959E+01 -3.0029E-01
 14, 26  1.3000E+01  2.4000E+01 -3.2845E-01  1.7186E-01  1.0057E+00  9.9717E-01  1.3500E+01 -1.3199E-03  1.2959E+01 -2.8300E-01
 15, 26  1.4000E+01  2.4000E+01 -2.7653E-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 -2.3053E-01  2.1089E-01  1.0028E+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  2.1669E-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
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 20, 26  1.9000E+01  2.4000E+01 -1.0426E-01  2.1746E-01  1.0008E+00  9.9826E-01  1.9500E+01 -1.9709E-04  1.8965E+01 -1.7440E-01
 21, 26  2.0000E+01  2.4000E+01 -8.3362E-02  2.1595E-01  1.0006E+00  9.9838E-01  2.0500E+01 -6.9868E-05  1.9967E+01 -1.6159E-01
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 27, 26  2.6000E+01  2.4000E+01  0.          2.0939E-01  0.         -1.8170E-07  0.          0.           1.2734E+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  5.9747E-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
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  7, 27  6.0000E+00  2.5000E+01 -4.5440E-01 -9.0021E-01  1.0452E+00  9.9835E-01  6.5000E+00 -2.2377E-03  5.9879E+00 -1.6497E-01
  8, 27  7.0000E+00  2.5000E+01 -4.9029E-01 -6.8854E-01  1.0466E+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 -4.6219E-01  1.0343E+00  9.9779E-01  8.5000E+00 -2.2432E-03  7.9796E+00 -2.2078E-01
 10, 27  9.0000E+00  2.5000E+01 -4.9601E-01 -2.5217E-01  1.0189E+00  9.9761E-01  9.5000E+00 -2.1057E-03  8.9754E+00 -2.3895E-01
 11, 27  1.0000E+01  2.5000E+01 -4.6399E-01 -8.9856E-02  1.0131E+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  1.0100E+00  9.9747E-01  1.1500E+01 -1.6979E-03  1.0969E+01 -2.5274E-01
 13, 27  1.2000E+01  2.5000E+01 -3.6642E-01  9.7761E-02  1.0070E+00  9.9751E-01  1.2500E+01 -1.4725E-03  1.1967E+01 -2.4987E-01
 14, 27  1.3000E+01  2.5000E+01 -3.1508E-01  1.4255E-01  1.0050E+00  9.9756E-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  1.0035E+00  9.9766E-01  1.4500E+01 -1.0447E-03  1.3964E+01 -2.3362E-01
 16, 27  1.5000E+01  2.5000E+01 -2.2482E-01  1.8379E-01  1.0024E+00  9.9777E-01  1.5500E+01 -8.3634E-04  1.4964E+01 -2.2262E-01
 17, 27  1.6000E+01  2.5000E+01 -1.8767E-01  1.9236E-01  1.0017E+00  9.9790E-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  1.0012E+00  9.9803E-01  1.7500E+01 -5.3876E-04  1.6964E+01 -1.9740E-01
 19, 27  1.8000E+01  2.5000E+01 -1.2828E-01  1.9945E-01  1.0009E+00  9.9814E-01  1.8500E+01 -4.4414E-04  1.7965E+01 -1.8562E-01
 20, 27  1.9000E+01  2.5000E+01 -1.0464E-01  2.0050E-01  1.0007E+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  1.0006E+00  9.9835E-01  2.0500E+01 -2.4078E-04  1.9966E+01 -1.6526E-01
 22, 27  2.1000E+01  2.5000E+01 -6.6169E-02  2.0061E-01  1.0005E+00  9.9842E-01  2.1500E+01 -1.7353E-04  2.0967E+01 -1.5751E-01
 23, 27  2.2000E+01  2.5000E+01 -5.0313E-02  2.0021E-01  1.0004E+00  9.9848E-01  2.2500E+01 -1.2993E-04  2.1967E+01 -1.5175E-01
 24, 27  2.3000E+01  2.5000E+01 -3.6075E-02  1.9977E-01  1.0004E+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  1.9932E-01  1.0004E+00  9.9855E-01  2.4500E+01 -8.9065E-05  2.3966E+01 -1.4468E-01
 26, 27  2.5000E+01  2.5000E+01 -1.1214E-02  1.9895E-01  1.0003E+00  9.9857E-01  2.5500E+01 -8.6277E-05  2.4965E+01 -1.4348E-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.         -1.2696E+00  1.2148E+00  1.0013E+00  5.0000E-01 -2.8902E-03  2.5024E-01  1.2918E-01
  2, 28  1.0000E+00  2.6000E+01 -8.5059E-02 -1.2895E+00  1.0890E+00  1.0009E+00  1.5000E+00 -1.4587E-03  1.0006E+00  8.7659E-02
  3, 28  2.0000E+00  2.6000E+01 -1.6812E-01 -1.2607E+00  1.0877E+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 -1.1924E+00  1.0699E+00  1.0002E+00  3.5000E+00 -1.6280E-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 -1.7367E-03  3.9984E+00 -1.5583E-02
  6, 28  5.0000E+00  2.6000E+01 -3.8003E-01 -9.5134E-01  1.0478E+00  9.9948E-01  5.5000E+00 -1.8330E-03  4.9962E+00 -5.1701E-02
  7, 28  6.0000E+00  2.6000E+01 -4.2866E-01 -7.8571E-01  1.0430E+00  9.9913E-01  6.5000E+00 -1.9022E-03  5.9934E+00 -8.7385E-02
  8, 28  7.0000E+00  2.6000E+01 -4.6076E-01 -5.9844E-01  1.0374E+00  9.9880E-01  7.5000E+00 -1.9755E-03  6.9900E+00 -1.2048E-01
  9, 28  8.0000E+00  2.6000E+01 -4.7278E-01 -4.0111E-01  1.0259E+00  9.9849E-01  8.5000E+00 -1.8973E-03  7.9862E+00 -1.5130E-01
 10, 28  9.0000E+00  2.6000E+01 -4.6220E-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 -4.3233E-01 -8.6694E-02  1.0118E+00  9.9808E-01  1.0500E+01 -1.6512E-03  9.9786E+00 -1.9242E-01
 12, 28  1.1000E+01  2.6000E+01 -3.9067E-01  1.0791E-02  1.0086E+00  9.9797E-01  1.1500E+01 -1.5047E-03  1.0975E+01 -2.0309E-01
 13, 28  1.2000E+01  2.6000E+01 -3.4426E-01  7.5636E-02  1.0060E+00  9.9791E-01  1.2500E+01 -1.3296E-03  1.1973E+01 -2.0893E-01
 14, 28  1.3000E+01  2.6000E+01 -2.9790E-01  1.1699E-01  1.0042E+00  9.9790E-01  1.3500E+01 -1.1759E-03  1.2970E+01 -2.0960E-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
```
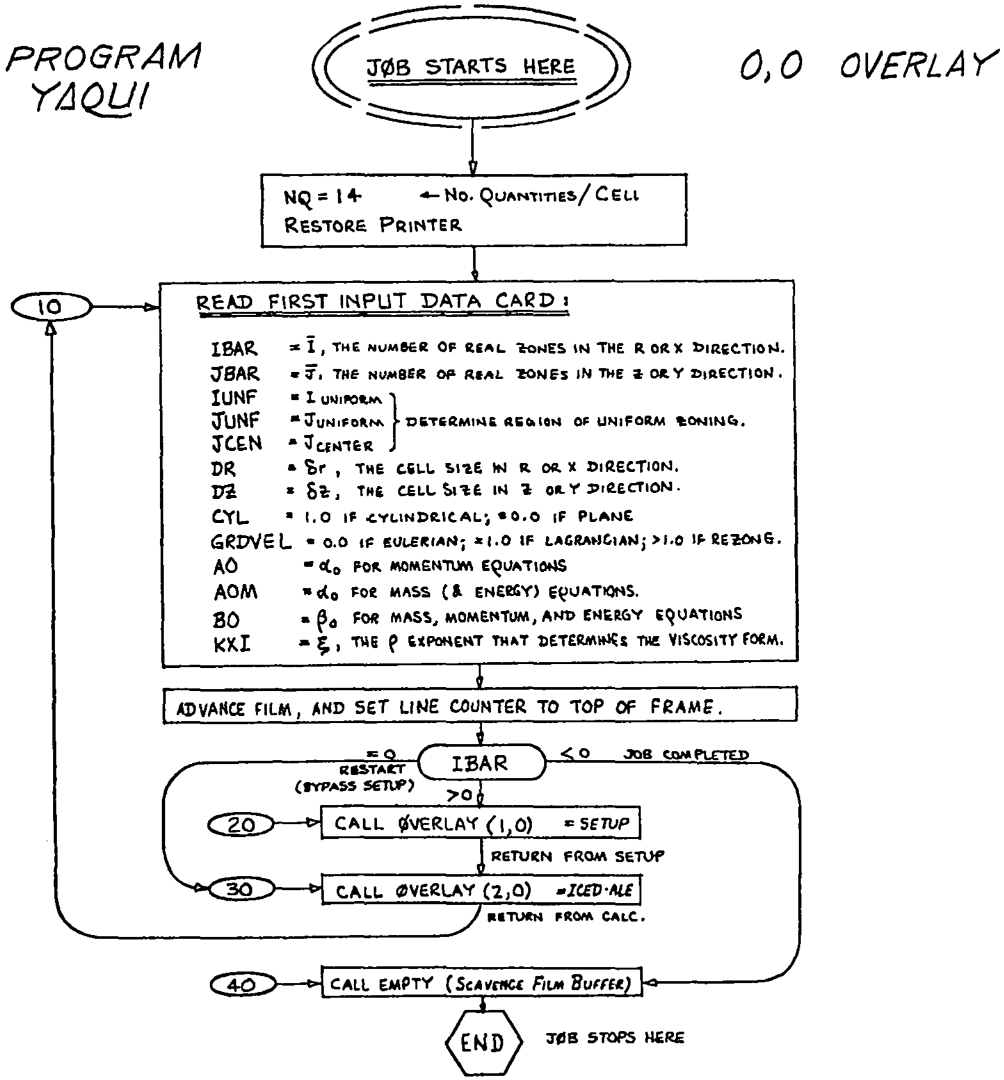

APPENDIX A

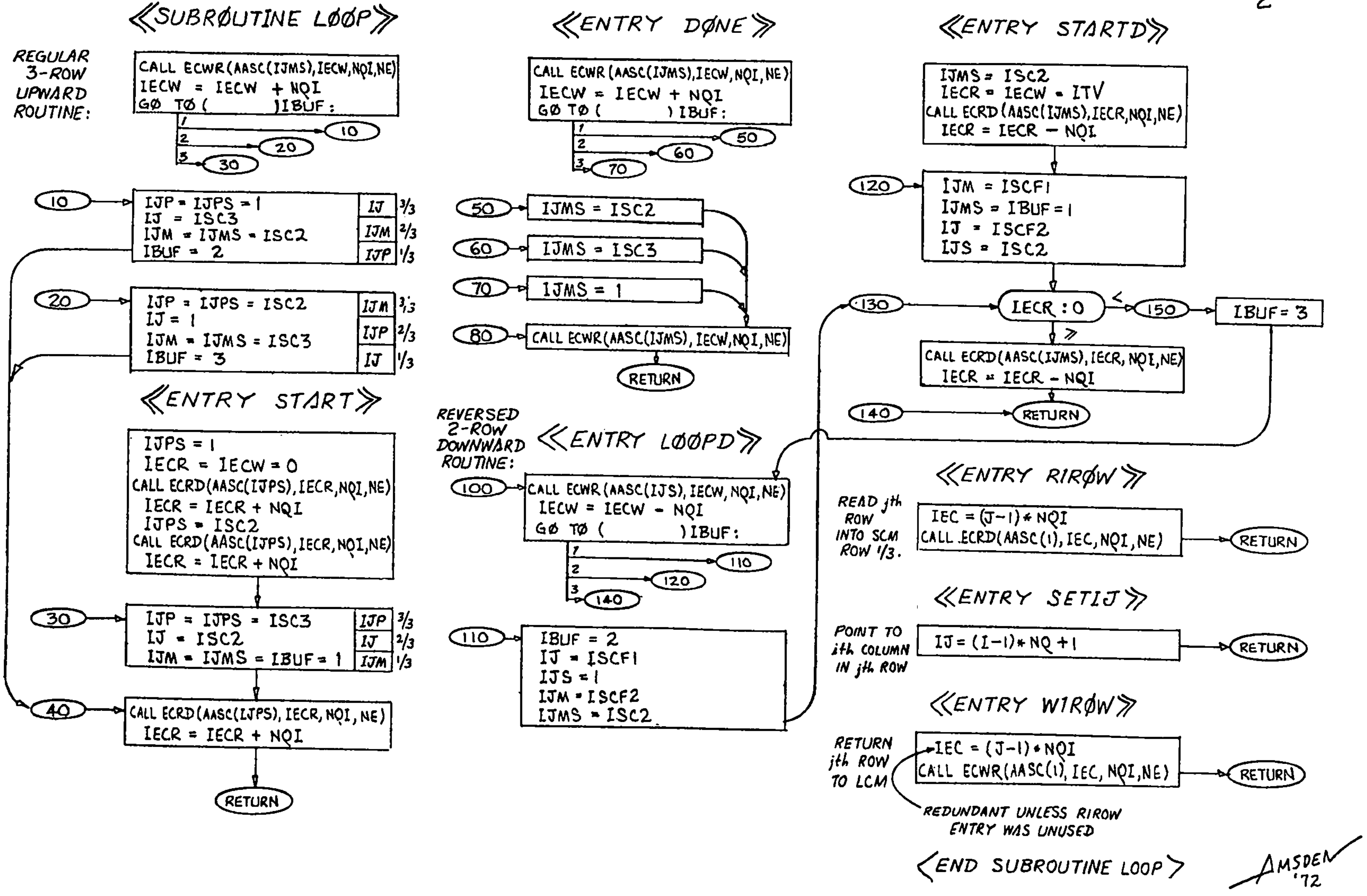
FLOW DIAGRAM FOR THE YAQUI PROGRAM


PROGRAM YAQUI
JØB STARTS HERE
0,0 OVERLAY
NQ = 14 ← No. QUANTITIES/CELL
RESTORE PRINTER
10
READ FIRST INPUT DATA CARD:
IBAR = Ī, THE NUMBER OF REAL ZONES IN THE R OR X DIRECTION.
JBAR = J̄, THE NUMBER OF REAL ZONES IN THE Z OR Y DIRECTION.
IUNF = I UNIFORM
JUNF = J UNIFORM
JCEN = J CENTER
DETERMINE REGION OF UNIFORM ZONING.
DR = δr, THE CELL SIZE IN R OR X DIRECTION.
DZ = δz, THE CELL SIZE IN Z OR Y DIRECTION.
CYL = 1.0 IF CYLINDRICAL; = 0.0 IF PLANE
GRDVEL = 0.0 IF EULERIAN; = 1.0 IF LAGRANGIAN; > 1.0 IF REZONE.
AO = α₀ FOR MOMENTUM EQUATIONS
AOM = α₀ FOR MASS (& ENERGY) EQUATIONS.
BO = β₀ FOR MASS, MOMENTUM, AND ENERGY EQUATIONS
KXI = ξ, THE ρ EXPONENT THAT DETERMINES THE VISCOSITY FORM.
ADVANCE FILM, AND SET LINE COUNTER TO TOP OF FRAME.
IBAR
= 0 RESTART (BYPASS SETUP)
< 0 JOB COMPLETED
> 0
20
CALL ØVERLAY (1,0) = SETUP
RETURN FROM SETUP
30
CALL ØVERLAY (2,0) = ICED-ALE
RETURN FROM CALC.
40
CALL EMPTY (Scavenge Film Buffer)
END
JØB STOPS HERE

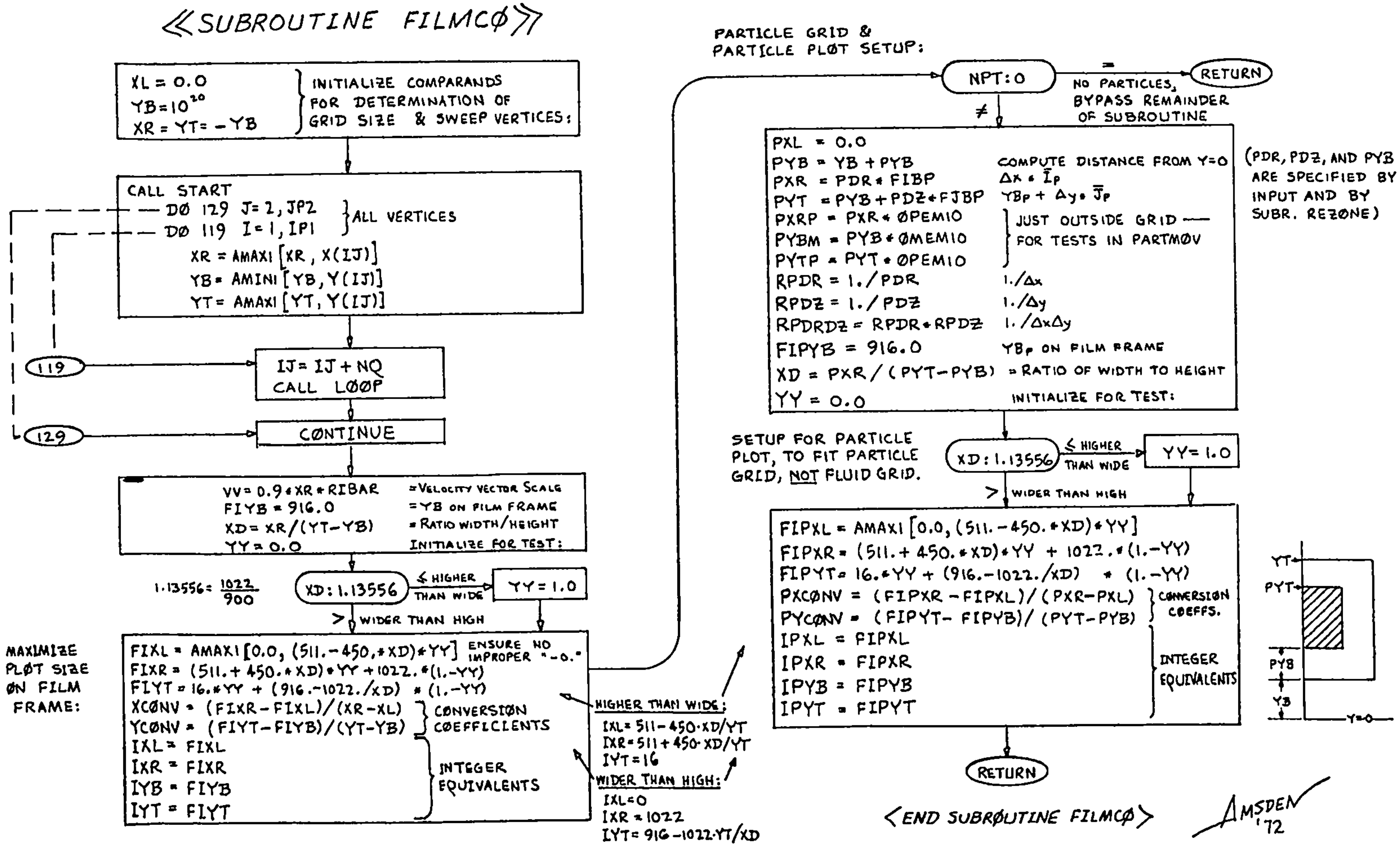
AMSDEN '72

0,0 SUBROUTINES — SCM/LCM 3-ROW BUFFERING:

2

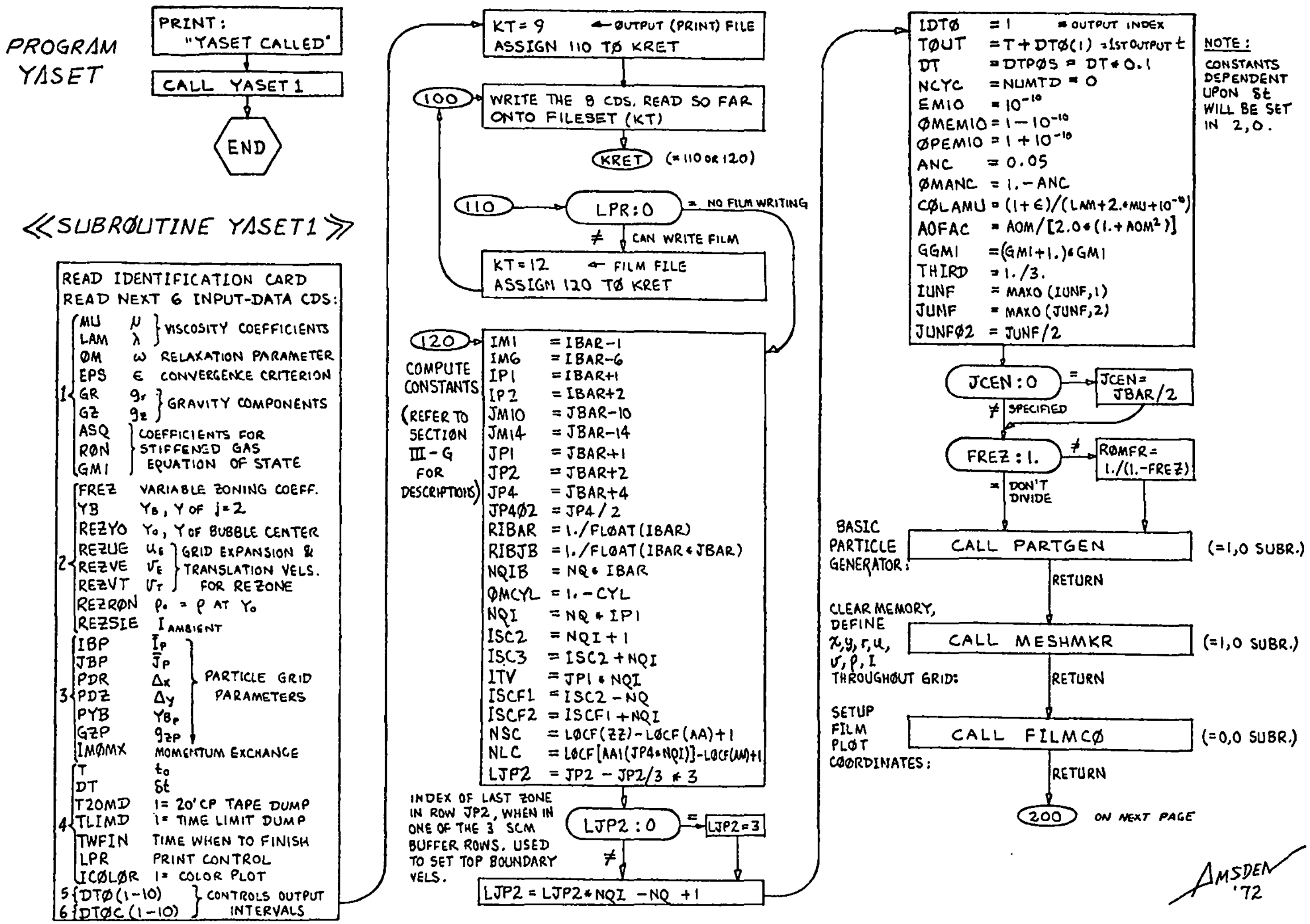


0,0 SUBROUTINES - SETUP PLOTS & PARTICLE GRID:



AMSDEN '72

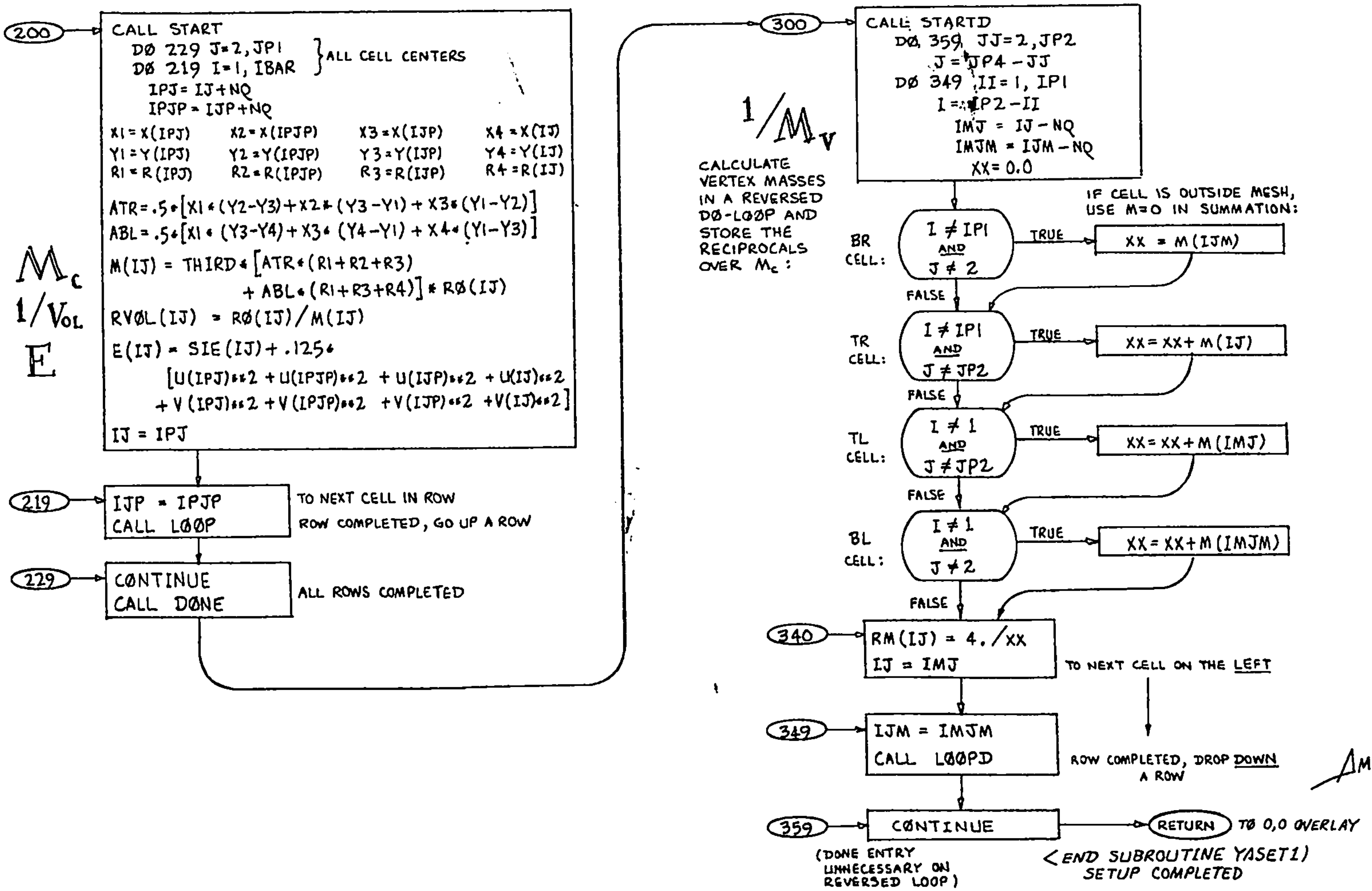
1,0 OVERLAY - THE PROBLEM SETUP:



AMSDEN '72

1,0 SUBROUTINES – THE PROBLEM SETUP:

«SUBROUTINE YASET1» CONTINUED:



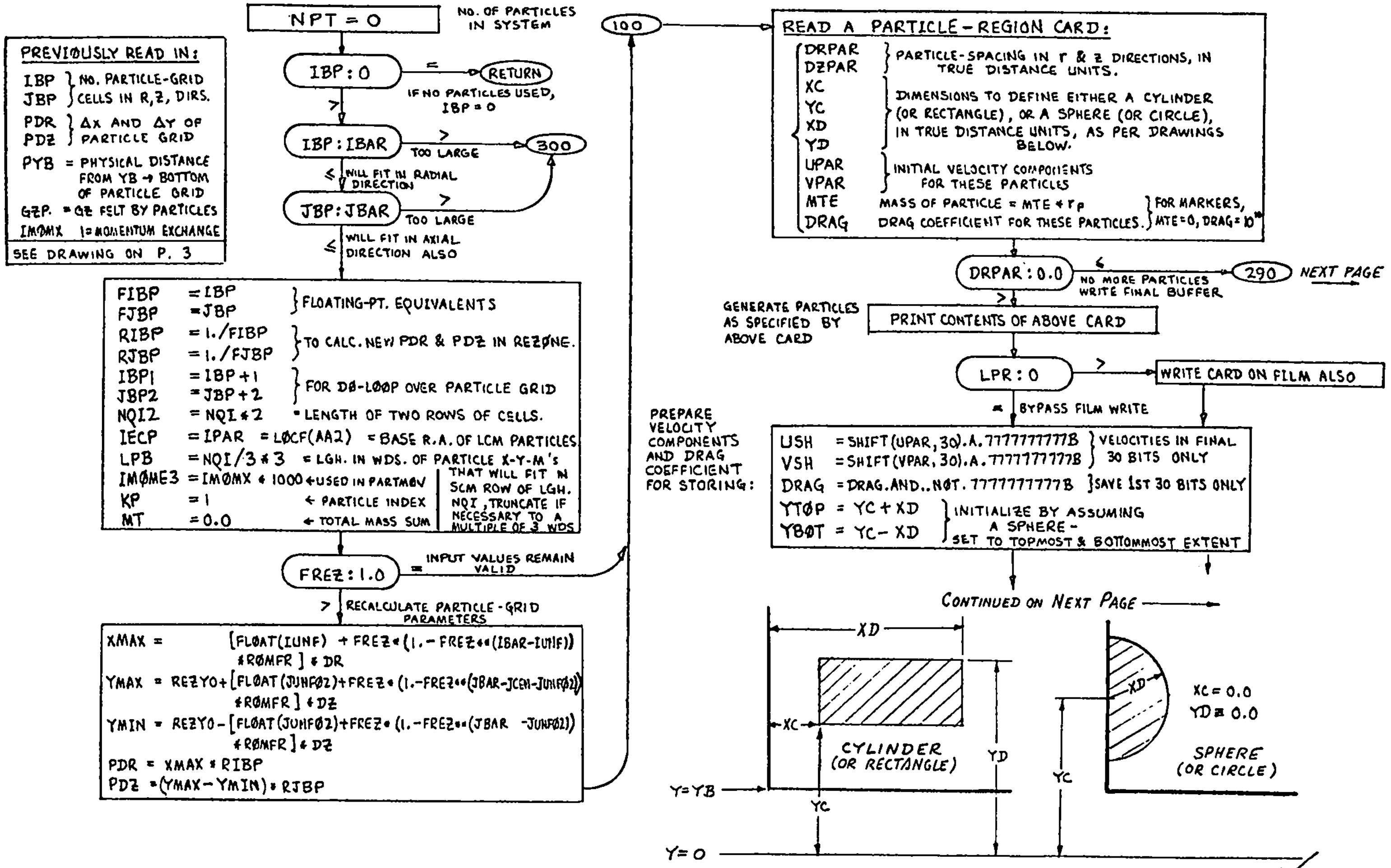
```
200  CALL START
       DØ 229 J=2,JP1
       DØ 219 I=1,IBAR
         IPJ= IJ+NQ
         IPJP = IJP+NQ
     X1 = X(IPJ)      X2 = X(IPJP)      X3 = X(IJP)      X4 = X(IJ)
     Y1 = Y(IPJ)      Y2 = Y(IPJP)      Y3 = Y(IJP)      Y4 = Y(IJ)
     R1 = R(IPJ)      R2 = R(IPJP)      R3 = R(IJP)      R4 = R(IJ)
     ATR=.5*[X1*(Y2-Y3)+X2*(Y3-Y1) + X3*(Y1-Y2)]
     ABL=.5*[X1*(Y3-Y4)+X3*(Y4-Y1) + X4*(Y1-Y3)]
     M(IJ) = THIRD*[ATR*(R1+R2+R3)
                   + ABL*(R1+R3+R4)]*RØ(IJ)
     RVØL(IJ) = RØ(IJ)/M(IJ)
     E(IJ) = SIE(IJ)+.125*
          [U(IPJ)**2 +U(IPJP)**2 +U(IJP)**2 +U(IJ)**2
         +V(IPJ)**2 +V(IPJP)**2 +V(IJP)**2 +V(IJ)**2]
     IJ = IPJ

219  IJP = IPJP
     CALL LØØP

229  CØNTINUE
     CALL DØNE
```

```
300  CALL STARTD
       DØ 359 JJ=2,JP2
         J = JP4 - JJ
       DØ 349 II=1,IP1
           I = IP2-II
             IMJ = IJ - NQ
             IMJM = IJM - NQ
              XX= 0.0

     I ≠ IP1 AND J ≠ 2     TRUE:  XX = M(IJM)
     I ≠ IP1 AND J ≠ JP2   TRUE:  XX= XX+ M(IJ)
     I ≠ 1 AND J ≠ JP2     TRUE:  XX= XX+M(IMJ)
     I ≠ 1 AND J ≠ 2       TRUE:  XX= XX+M(IMJM)

340  RM(IJ) = 4./XX
     IJ = IMJ

349  IJM = IMJM
     CALL LØØPD

359  CØNTINUE
```

AMSDEN '72

1.0 SUBROUTINES - PARTICLE GENERATOR :

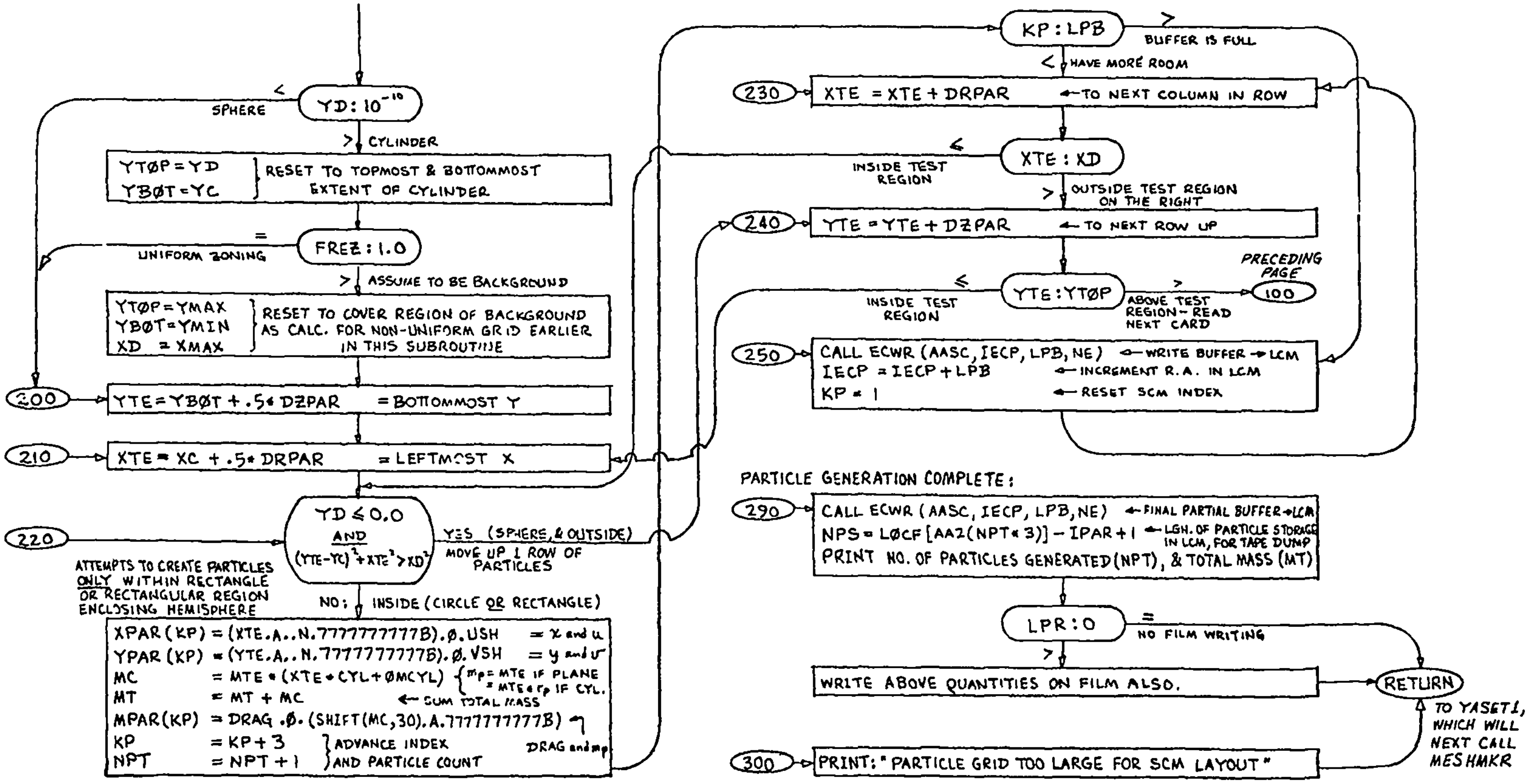
«SUBROUTINE PARTGEN»



AMSDEN '72

1.0 SUBROUTINES - PARTICLE GENERATOR (CONT'D):

«SUBROUTINE PARTGEN» CONTINUED:

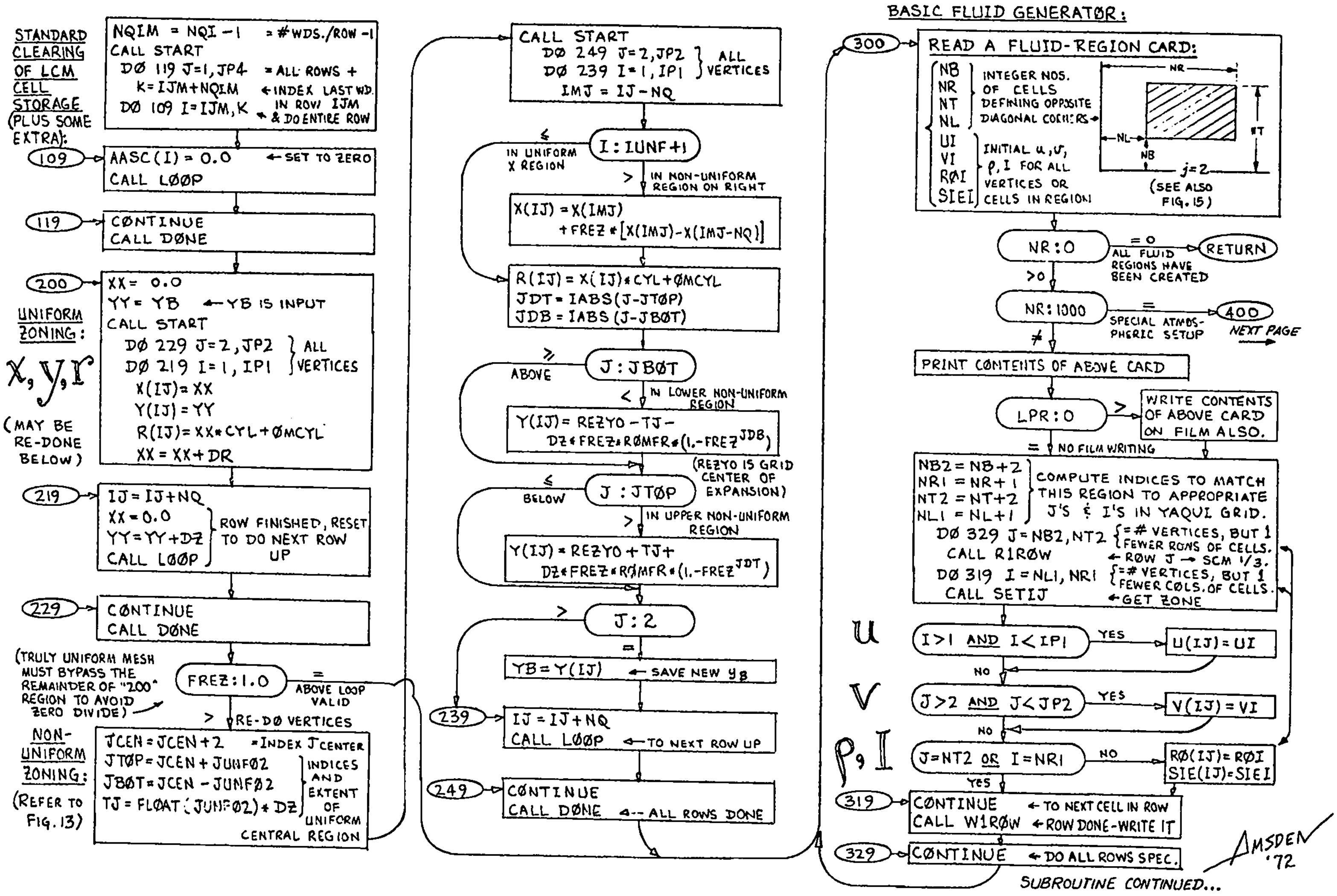


<END SUBROUTINE PARTGEN>

AMSDEN '72

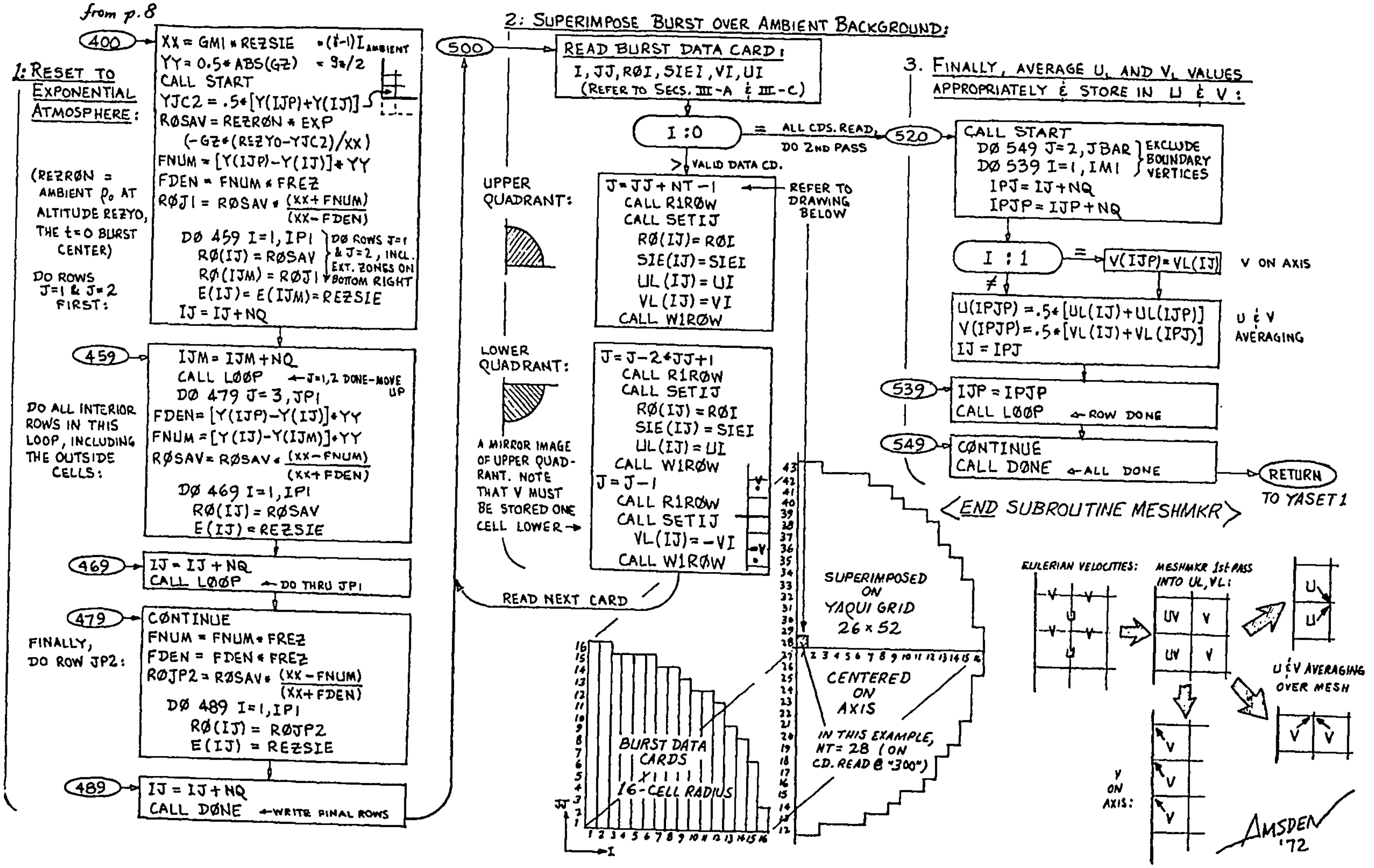
1.0 SUBROUTINES - MESH & FLUID GENERATOR:

≪SUBROUTINE MESHMKR≫



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

≪SUBROUTINE MESHMKR≫ CONTINUED:



from p.8

1: RESET TO EXPONENTIAL ATMOSPHERE:

(REZRØN = AMBIENT ρ_0 AT ALTITUDE REZYO, THE t=0 BURST CENTER)

DO ROWS J=1 & J=2 FIRST:

```
400  XX = GMI * REZSIE        = (γ-1)I AMBIENT
     YY = 0.5*ABS(GZ)         = gz/2
     CALL START
     YJC2 = .5*[Y(IJP)+Y(IJ)]
     RØSAV = REZRØN * EXP
        (-GZ*(REZYO-YJC2)/XX)
     FNUM = [Y(IJP)-Y(IJ)]*YY
     FDEN = FNUM * FREZ
     RØJ1 = RØSAV * (XX+FNUM)/(XX-FDEN)
       DØ 459 I=1,IP1          } DØ ROWS J=1 & J=2, INCL.
         RØ(IJ) = RØSAV        } EXT. ZONES ON BOTTOM RIGHT
         RØ(IJM) = RØJ1
         E(IJ)= E(IJM)=REZSIE
       IJ = IJ+NQ
```

DO ALL INTERIOR ROWS IN THIS LOOP, INCLUDING THE OUTSIDE CELLS:

```
459  IJM = IJM+NQ
     CALL LØØP              <- J=1,2 DONE-MOVE UP
     DØ 479 J=3,JP1
     FDEN= [Y(IJP)-Y(IJ)]*YY
     FNUM =[Y(IJ)-Y(IJM)]*YY
     RØSAV= RØSAV * (XX-FNUM)/(XX+FDEN)
       DØ 469 I=1,IP1
         RØ(IJ) = RØSAV
         E(IJ) = REZSIE
469  IJ = IJ + NQ
     CALL LØØP              <- DO THRU JP1
```

FINALLY, DO ROW JP2:

```
479  CØNTINUE
     FNUM = FNUM * FREZ
     FDEN = FDEN * FREZ
     RØJP2 = RØSAV * (XX-FNUM)/(XX+FDEN)
       DØ 489 I=1,IP1
         RØ(IJ) = RØJP2
         E(IJ) = REZSIE
489  IJ = IJ+NQ
     CALL DØNE              <- WRITE FINAL ROWS
```

2: SUPERIMPOSE BURST OVER AMBIENT BACKGROUND:

```
500  READ BURST DATA CARD:
     I,JJ,RØI,SIEI,VI,UI
     (REFER TO SECS. III-A & III-C)
     I : 0     = ALL CDS. READ, DO 2ND PASS (-> 520)
               > VALID DATA CD.
```

UPPER QUADRANT:

```
     J = JJ + NT - 1         <- REFER TO DRAWING BELOW
       CALL R1RØW
       CALL SETIJ
         RØ(IJ)= RØI
         SIE(IJ)=SIEI
         UL (IJ) = UI
         VL (IJ) = VI
       CALL W1RØW
```

LOWER QUADRANT: A MIRROR IMAGE OF UPPER QUADRANT. NOTE THAT V MUST BE STORED ONE CELL LOWER →

```
     J = J-2*JJ+1
       CALL R1RØW
       CALL SETIJ
         RØ(IJ) = RØI
         SIE (IJ) = SIEI
         UL(IJ) = UI
       CALL W1RØW
     J = J-1
       CALL R1RØW
       CALL SETIJ
         VL(IJ)= -VI
       CALL W1RØW
     READ NEXT CARD (-> 500)
```

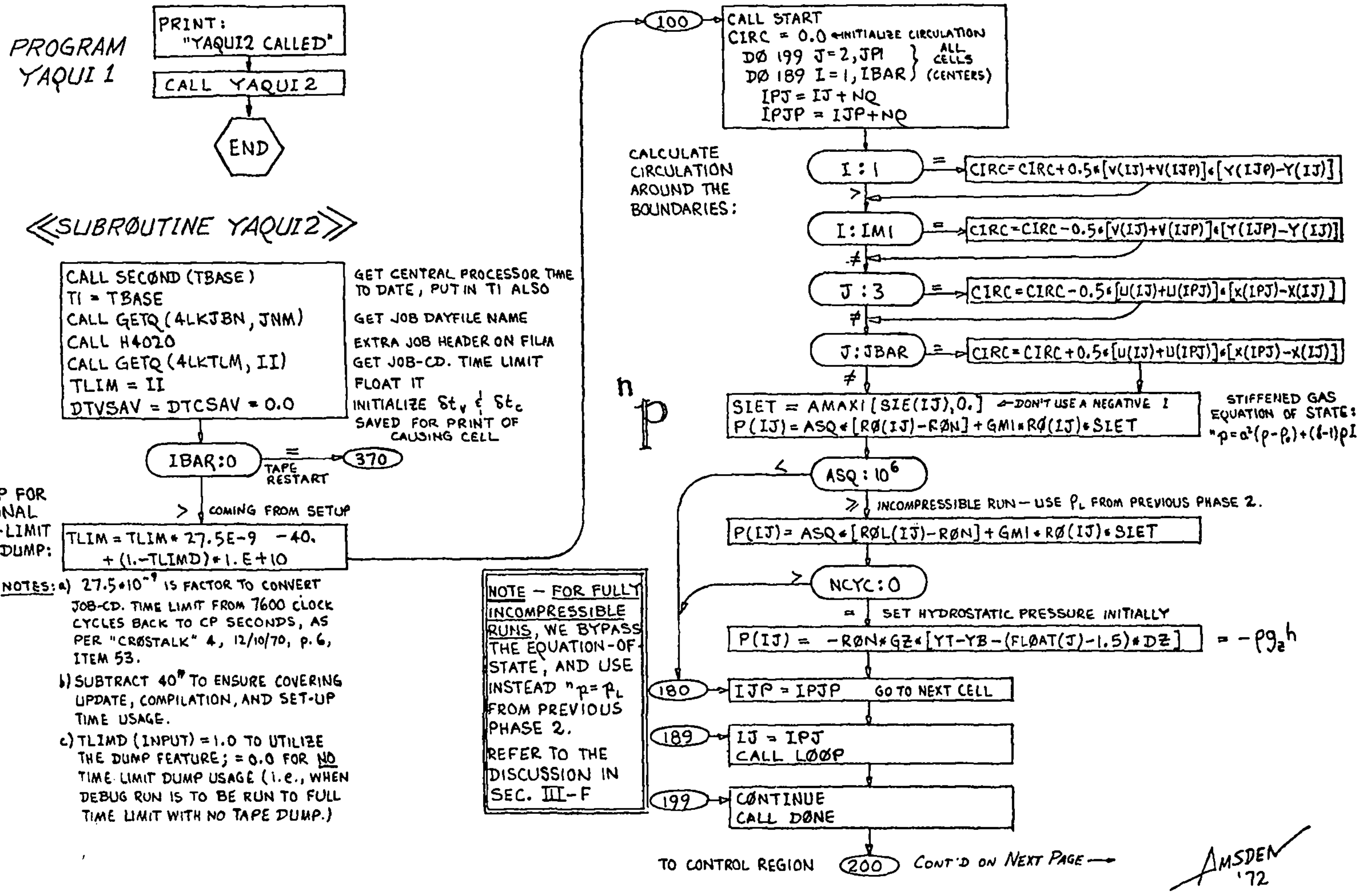
3. FINALLY, AVERAGE U_L AND V_L VALUES APPROPRIATELY & STORE IN U & V:

```
520  CALL START
      DØ 549 J=2,JBAR   } EXCLUDE
      DØ 539 I=1,IM1    } BOUNDARY VERTICES
       IPJ= IJ+NQ
       IPJP= IJP+NQ
     I : 1     =  V(IJP)=VL(IJ)          V ON AXIS
               ≠
     U(IPJP) =.5*[UL(IJ)+UL(IJP)]        U & V AVERAGING
     V(IPJP)=.5*[VL(IJ)+VL(IPJ)]
     IJ = IPJ
539  IJP = IPJP
     CALL LØØP              <- ROW DONE
549  CØNTINUE
     CALL DØNE              <- ALL DONE
     RETURN TO YASET1
```

<END SUBROUTINE MESHMKR>

AMSDEN '72

2,0 OVERLAY – 3-PHASE ICED-ALE:



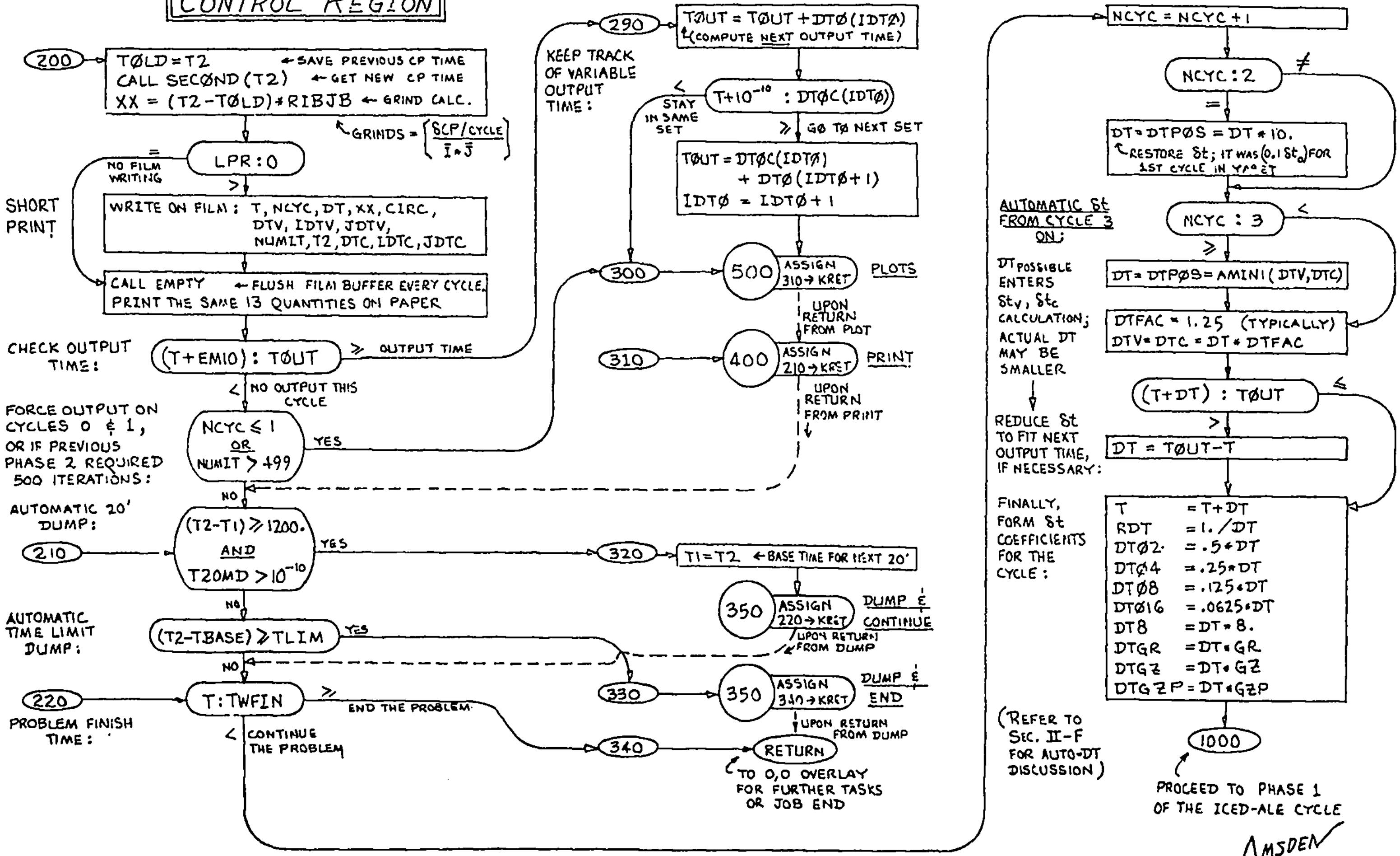
NOTES:
a) $27.5 \cdot 10^{-9}$ IS FACTOR TO CONVERT JOB-CD. TIME LIMIT FROM 7600 CLOCK CYCLES BACK TO CP SECONDS, AS PER "CROSTALK" 4, 12/10/70, p. 6, ITEM 53.
b) SUBTRACT 40" TO ENSURE COVERING UPDATE, COMPILATION, AND SET-UP TIME USAGE.
c) TLIMD (INPUT) = 1.0 TO UTILIZE THE DUMP FEATURE; = 0.0 FOR NO TIME LIMIT DUMP USAGE (i.e., WHEN DEBUG RUN IS TO BE RUN TO FULL TIME LIMIT WITH NO TAPE DUMP.)

NOTE – FOR FULLY INCOMPRESSIBLE RUNS, WE BYPASS THE EQUATION-OF-STATE, AND USE INSTEAD $^n p = p_L$ FROM PREVIOUS PHASE 2.

REFER TO THE DISCUSSION IN SEC. III-F

≪SUBROUTINE YAQUI2≫ CONTINUED:

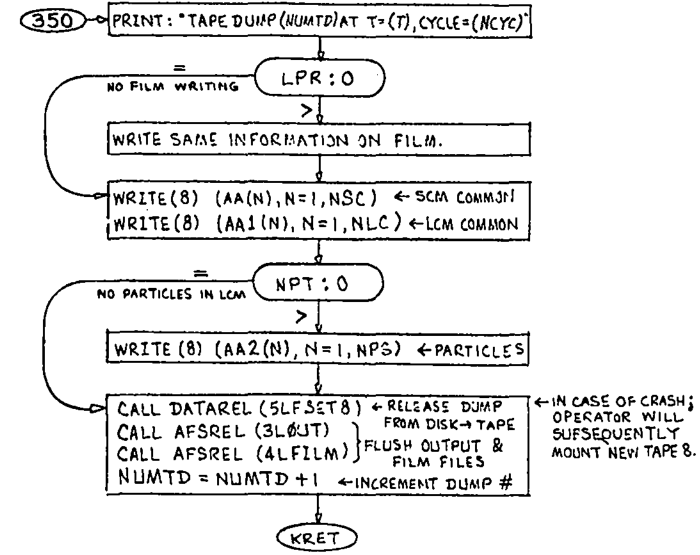
CONTROL REGION



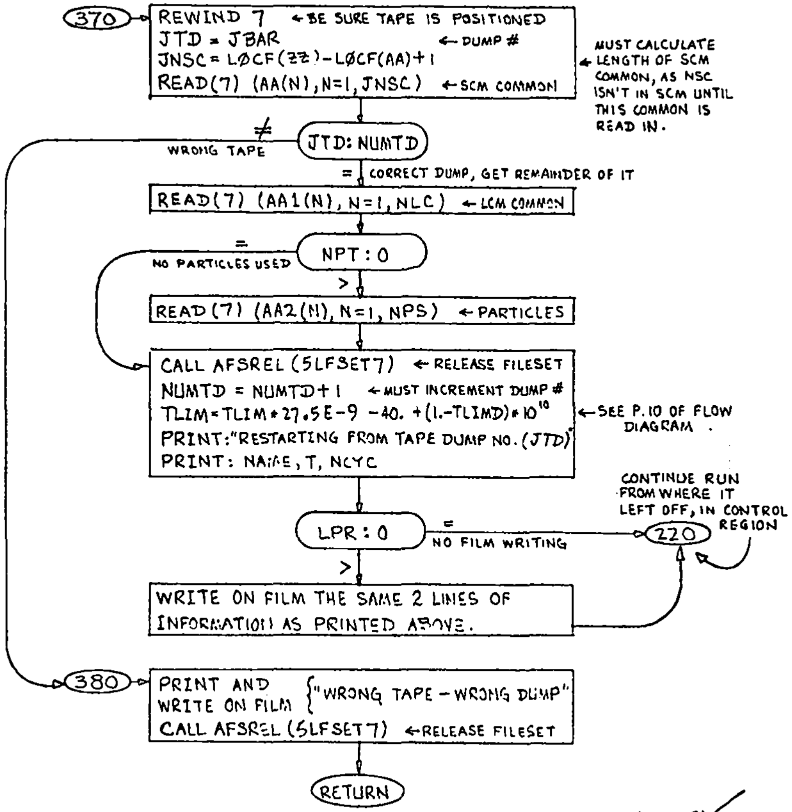
AMSDEN '72

«SUBROUTINE YAQUI2» CONTINUED:

TAPE DUMP



TAPE RESTART



NOTES:

NSC = LENGTH OF SCM COMMON 'YSC2, = LOCF(ZZ) - LOCF(AA)+1

NLC = LENGTH OF LCM CELL STORAGE, = LOCF(AA1(JP4*NQI))-LOCF(AA1)+1

NPS = LENGTH OF LCM PARTICLE STORAGE, = $\underbrace{\text{LOCF(AA2(NPT*3)) - IPAR+1}}_{\text{LWA. - FWA. +1}}$

↑ THESE 3 PARAMETERS ARE STORED IN THE SCM COMMON YSC2.
NSC & NLC ARE CALCULATED IN YASET1 IN STATEMENT #120
NPS IS CALCULATED AT THE END OF PARTGEN IN STATEMENT #290.

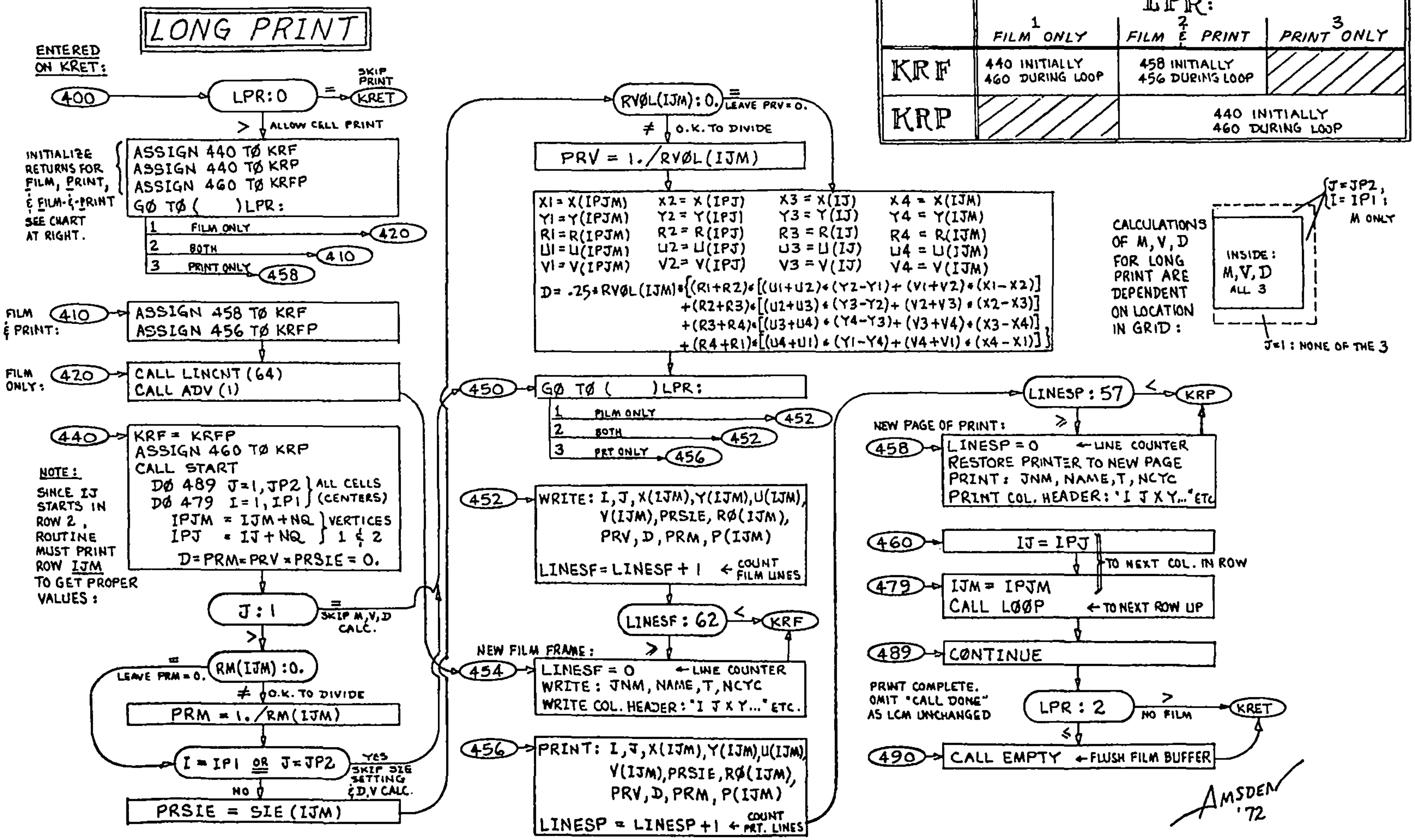
USE OF JP4 IN NLC ENSURES THAT CAREFULLY-CLEARED LCM WILL BE USED, TO AVOID TROUBLE ON RESTART.
NPT IS THE TOTAL NO. OF PARTICLES IN THE SYSTEM.

AMSDEN '72

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

≪SUBROUTINE YAQUI2≫ CONTINUED:

LONG PRINT



	LPR: 1 FILM ONLY	2 FILM & PRINT	3 PRINT ONLY
KRF	440 INITIALLY 460 DURING LOOP	458 INITIALLY 456 DURING LOOP	▨
KRP	▨	440 INITIALLY 460 DURING LOOP	

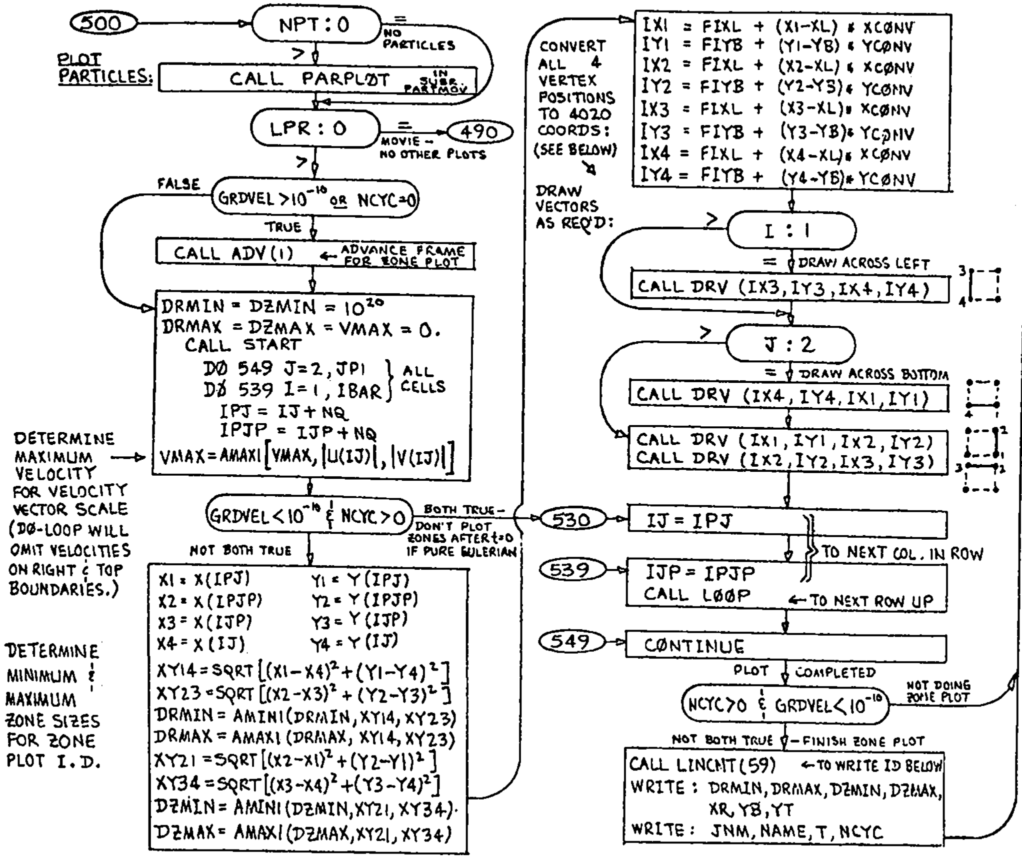
AMSDEN '72

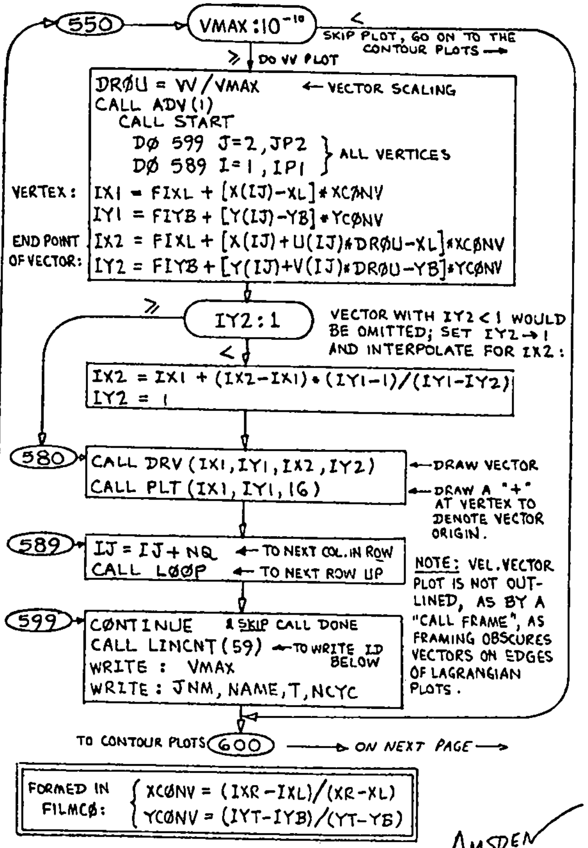
2,0 SUBROUTINES – 3-PHASE ICED-ALE (CONT'D):

«SUBROUTINE YAQUI2» CONTINUED:

ZONE PLOT

VELOCITY VECTOR PLOT

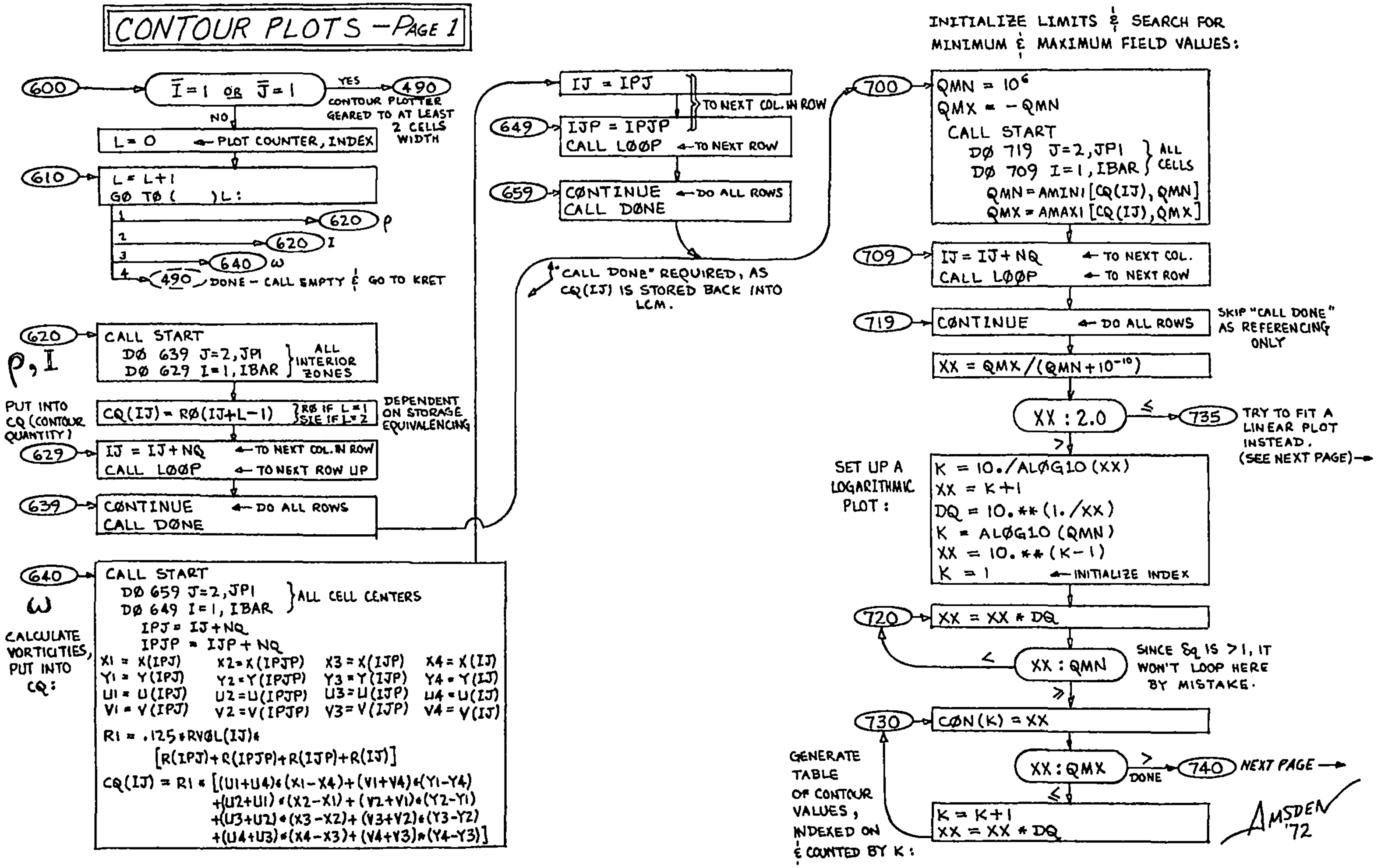




AMSDEN '72

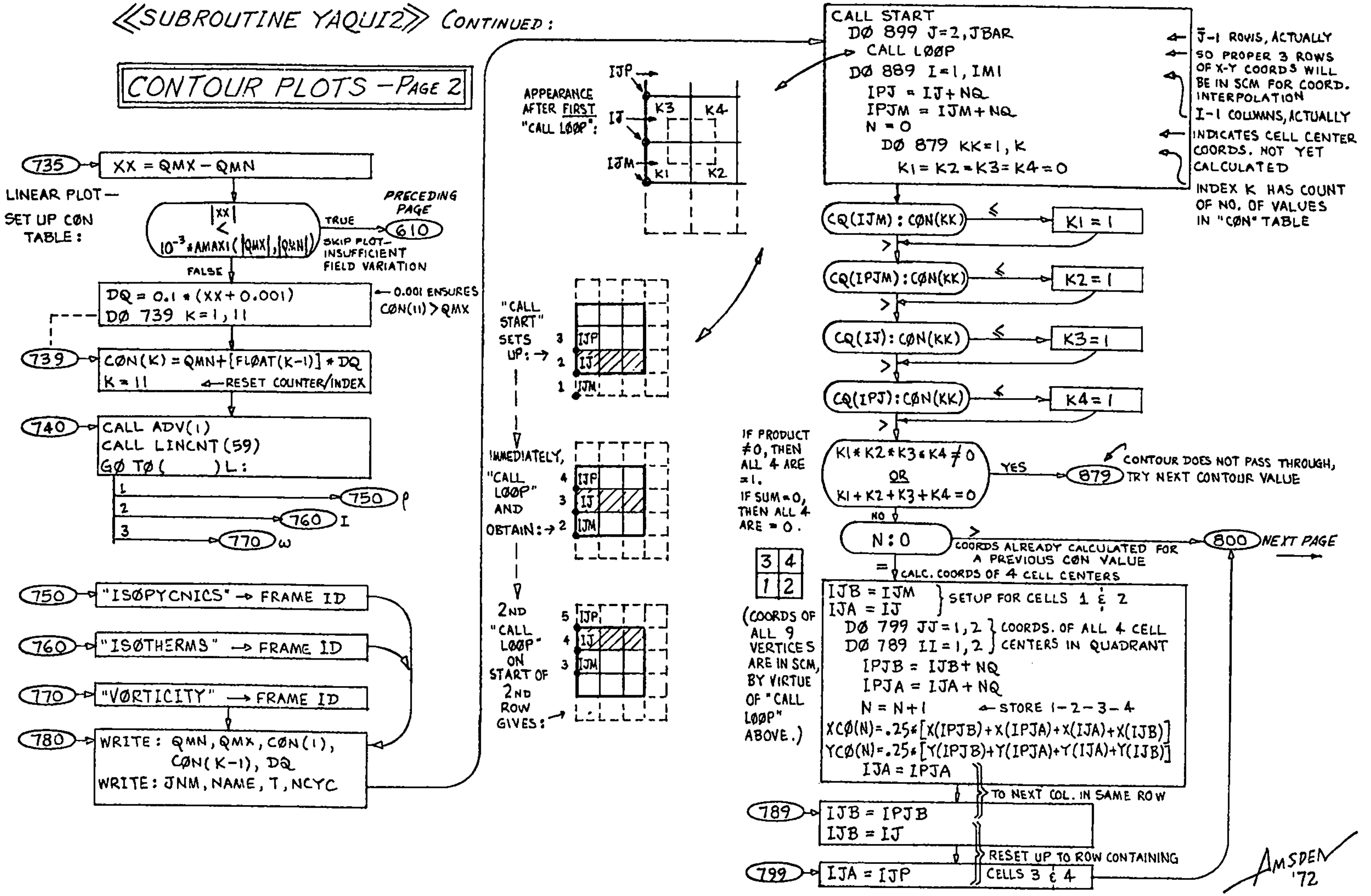
2,0 SUBROUTINES – 3-PHASE ICED-ALE (CONT'D):

«SUBROUTINE YAQUI2» CONTINUED:



«SUBROUTINE YAQUI2» CONTINUED:

CONTOUR PLOTS – PAGE 2



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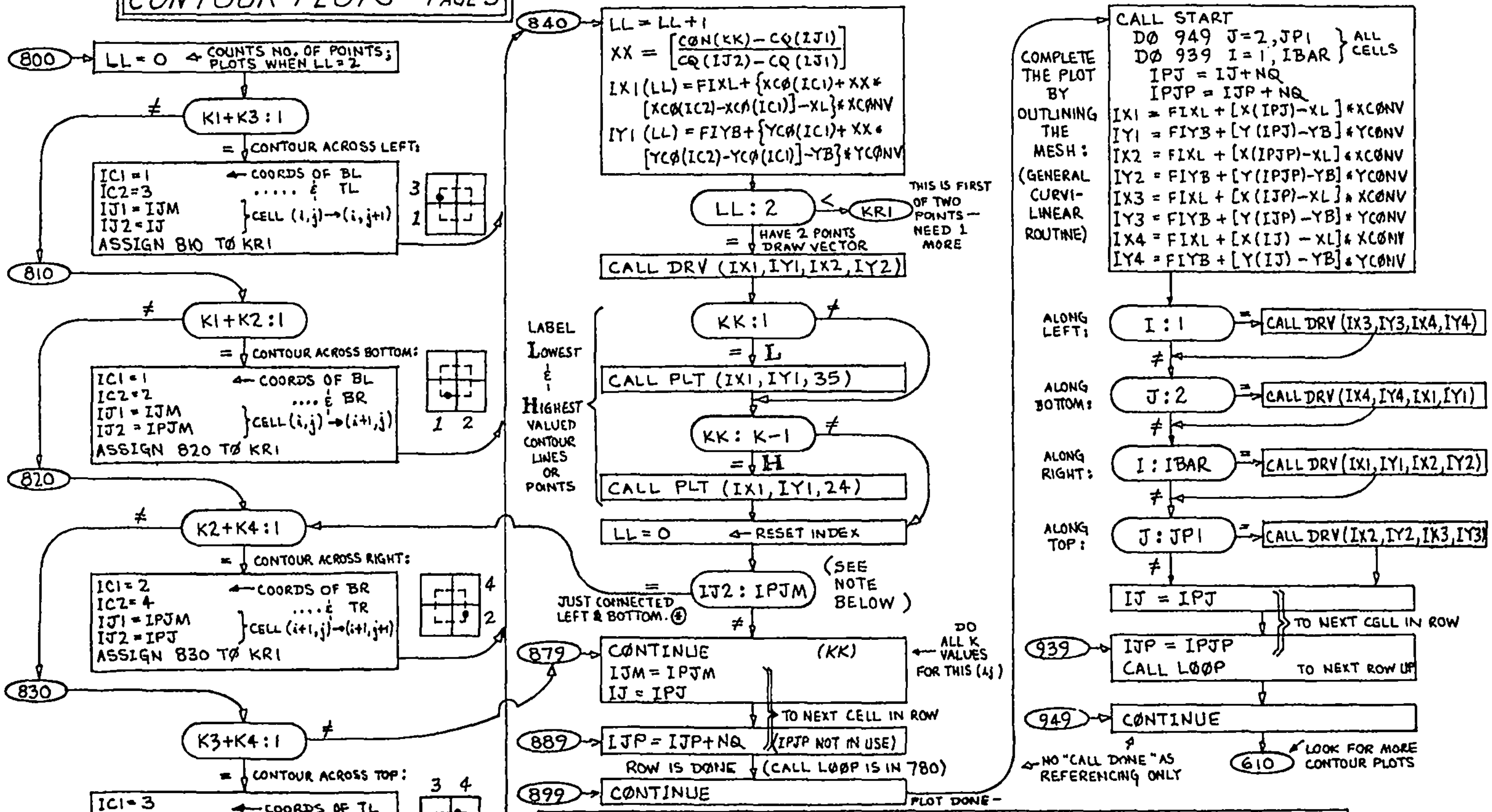
≪SUBROUTINE YAQUI2≫ CONTINUED:

CONTOUR PLOTS – PAGE 3



✱NOTE: IF A CONTOUR VALUE CROSSES ALL 4 SIDES, THE PLOT ROUTINE SHOULD CONNECT EITHER (L→B AND R→T) OR (B→R AND T→L). TO DETERMINE WHICH CHOICE IS CORRECT WOULD, HOWEVER, REQUIRE FOLLOWING THE PATH OF THE CONTOUR THROUGH MORE THAN THE 4 ZONES USED. (GENERALLY, GRADIENTS ARE WELL ENOUGH SPREAD OUT TO AVOID THIS PROBLEM.) THE ABOVE ROUTINE AVOIDS THE MORE COMPLICATED LOGIC, AND SIMPLY CONNECTS (L→B AND R→T) TO CLOSE CONTOUR LINES.

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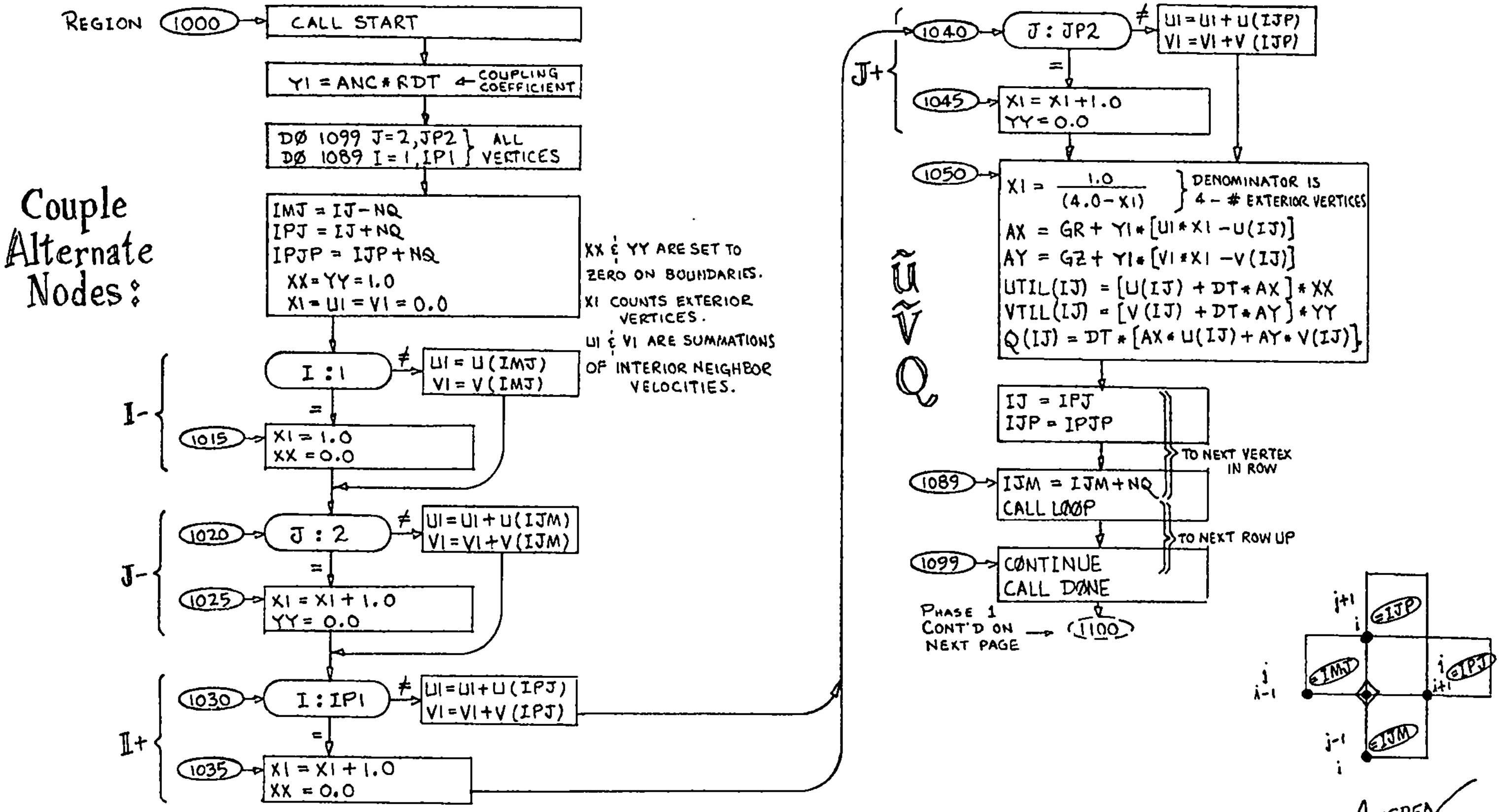
«SUBROUTINE YAQUI2» CONTINUED:

PHASE-1 CALCULATION – PAGE 1

INITIALIZE VERTEX VALUES OF $\tilde{u}$, $\tilde{v}$, Q:



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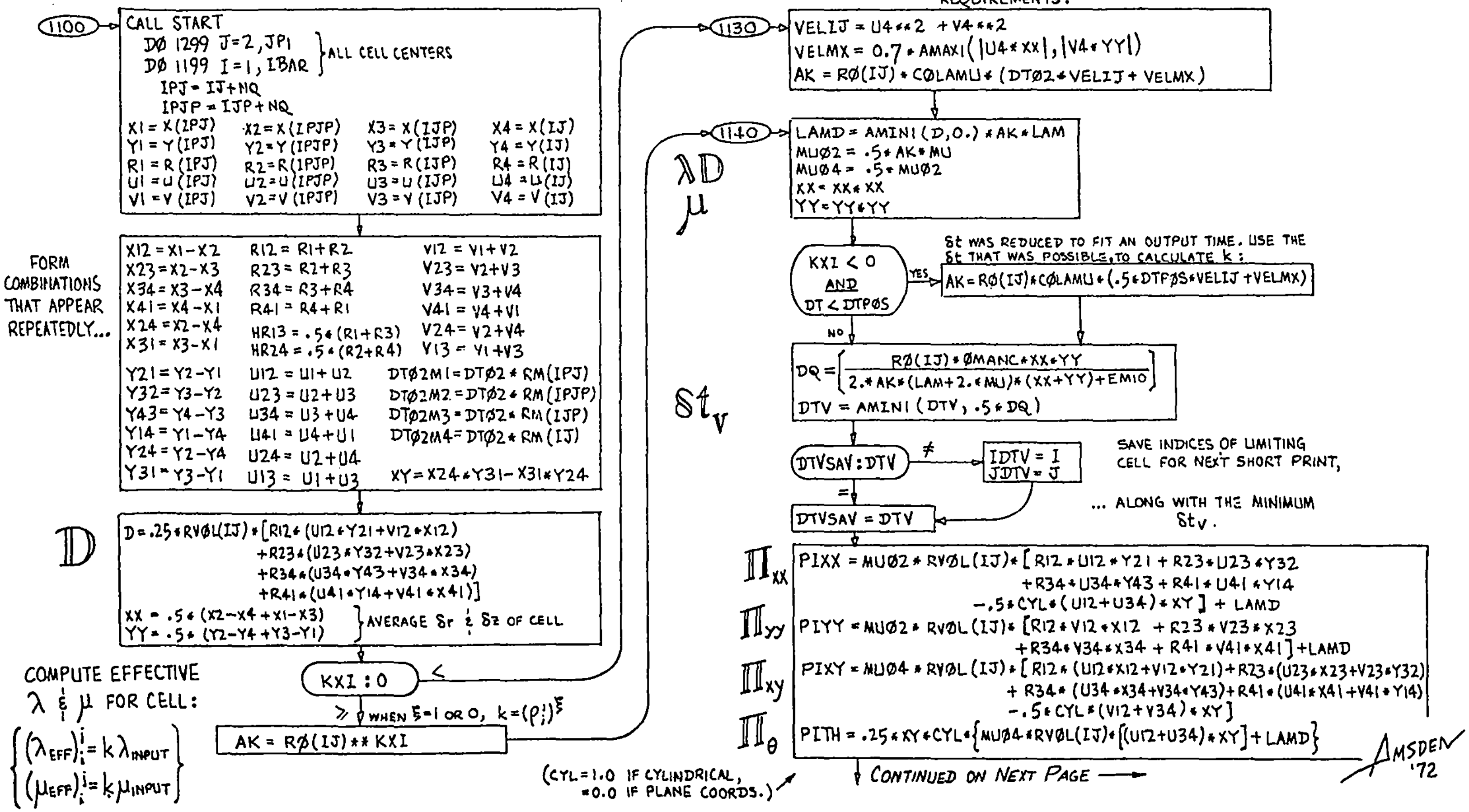
⟪SUBROUTINE YAQUI2⟫ CONTINUED:

PHASE-1 CALCULATION - PAGE 2

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



```
1100  CALL START
        DØ 1299 J=2,JP1   }ALL CELL CENTERS
        DØ 1199 I=1,IBAR  }
          IPJ = IJ+NQ
          IPJP = IJP+NQ
      X1 = X(IPJ)    X2 = X(IPJP)    X3 = X(IJP)    X4 = X(IJ)
      Y1 = Y(IPJ)    Y2 = Y(IPJP)    Y3 = Y(IJP)    Y4 = Y(IJ)
      R1 = R(IPJ)    R2 = R(IPJP)    R3 = R(IJP)    R4 = R(IJ)
      U1 = U(IPJ)    U2 = U(IPJP)    U3 = U(IJP)    U4 = U(IJ)
      V1 = V(IPJ)    V2 = V(IPJP)    V3 = V(IJP)    V4 = V(IJ)
```

FORM COMBINATIONS THAT APPEAR REPEATEDLY...

```
      X12 = X1-X2    R12 = R1+R2              V12 = V1+V2
      X23 = X2-X3    R23 = R2+R3              V23 = V2+V3
      X34 = X3-X4    R34 = R3+R4              V34 = V3+V4
      X41 = X4-X1    R41 = R4+R1              V41 = V4+V1
      X24 = X2-X4    HR13 = .5*(R1+R3)        V24 = V2+V4
      X31 = X3-X1    HR24 = .5*(R2+R4)        V13 = V1+V3
      Y21 = Y2-Y1    U12 = U1+U2    DTØ2M1 = DTØ2*RM(IPJ)
      Y32 = Y3-Y2    U23 = U2+U3    DTØ2M2 = DTØ2*RM(IPJP)
      Y43 = Y4-Y3    U34 = U3+U4    DTØ2M3 = DTØ2*RM(IJP)
      Y14 = Y1-Y4    U41 = U4+U1    DTØ2M4 = DTØ2*RM(IJ)
      Y24 = Y2-Y4    U24 = U2+U4
      Y31 = Y3-Y1    U13 = U1+U3    XY = X24*Y31-X31*Y24
```

$\mathbb{D}$

```
      D = .25*RVØL(IJ)*[R12*(U12*Y21+V12*X12)
                       +R23*(U23*Y32+V23*X23)
                       +R34*(U34*Y43+V34*X34)
                       +R41*(U41*Y14+V41*X41)]
      XX = .5*(X2-X4+X1-X3)  }AVERAGE δr & δz OF CELL
      YY = .5*(Y2-Y4+Y3-Y1)  }

      KXI : 0
        <  → 1130
        ≥  WHEN ξ=1 OR 0, k=(ρ_i)^ξ
      AK = RØ(IJ)**KXI   → 1140
```

COMPUTE EFFECTIVE λ & μ FOR CELL:

$$\left\{\begin{array}{l}(\lambda_{EFF})^i_i = k\,\lambda_{INPUT}\\ (\mu_{EFF})^i_i = k\,\mu_{INPUT}\end{array}\right\}$$

WHEN ξ = -1, BASE k UPON THE NUMERICAL STABILITY REQUIREMENTS.

```
1130  VELIJ = U4**2 + V4**2
      VELMX = 0.7*AMAX1(|U4*XX|,|V4*YY|)
      AK = RØ(IJ)*CØLAMU*(DTØ2*VELIJ + VELMX)
```

$\lambda \mathbb{D}$ μ

```
1140  LAMD = AMIN1(D,0.)*AK*LAM
      MUØ2 = .5*AK*MU
      MUØ4 = .5*MUØ2
      XX = XX*XX
      YY = YY*YY

      KXI < 0 AND DT < DTPØS
        YES: AK = RØ(IJ)*CØLAMU*(.5*DTPØS*VELIJ +VELMX)
        NO
```

δt WAS REDUCED TO FIT AN OUTPUT TIME. USE THE δt THAT WAS POSSIBLE, TO CALCULATE k:

δt_V

```
      DQ = [ RØ(IJ)*ØMANC*XX*YY / (2.*AK*(LAM+2.*MU)*(XX+YY)+EM10) ]
      DTV = AMIN1(DTV,.5*DQ)

      DTVSAV : DTV
        ≠  IDTV = I
           JDTV = J
        =
      DTVSAV = DTV
```

SAVE INDICES OF LIMITING CELL FOR NEXT SHORT PRINT, ... ALONG WITH THE MINIMUM δt_V.

Π_{xx} Π_{yy} Π_{xy} Π_θ

```
      PIXX = MUØ2*RVØL(IJ)*[R12*U12*Y21 + R23*U23*Y32
                           +R34*U34*Y43 + R41*U41*Y14
                      -.5*CYL*(U12+U34)*XY] + LAMD
      PIYY = MUØ2*RVØL(IJ)*[R12*V12*X12 + R23*V23*X23
                           +R34*V34*X34 + R41*V41*X41]+LAMD
      PIXY = MUØ4*RVØL(IJ)*[R12*(U12*X12+V12*Y21)+R23*(U23*X23+V23*Y32)
                           + R34*(U34*X34+V34*Y43)+R41*(U41*X41+V41*Y14)
                           -.5*CYL*(V12+V34)*XY]
      PITH = .25*XY*CYL*{MUØ4*RVØL(IJ)*[(U12+U34)*XY]+LAMD}
```

(CYL=1.0 IF CYLINDRICAL, =0.0 IF PLANE COORDS.)

CONTINUED ON NEXT PAGE →

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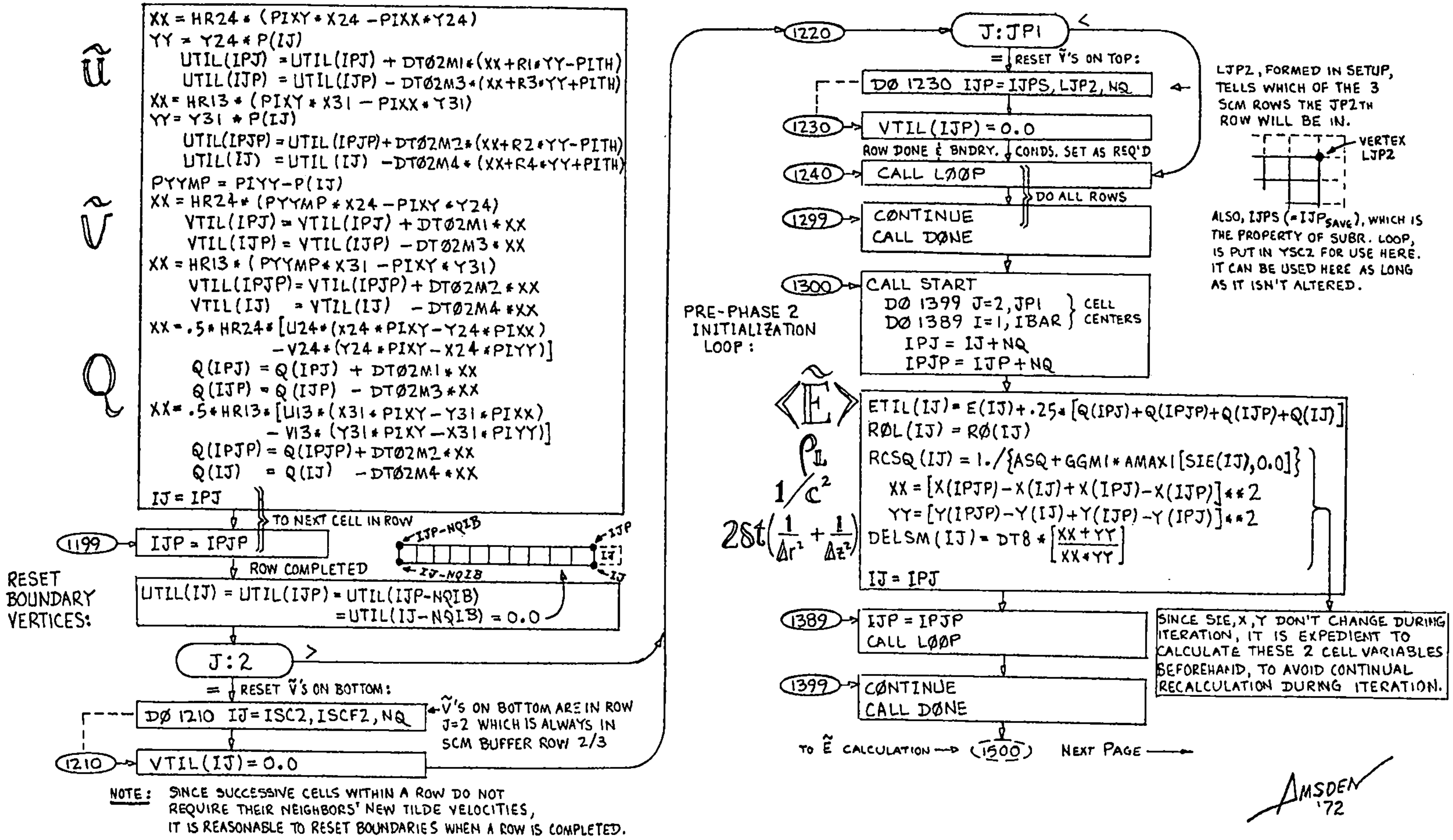
«SUBROUTINE YAQUI2» CONTINUED:

PHASE-1 CALCULATION – PAGE 3

UPDATING THE VERTICES:



$\tilde{u}$

```
XX = HR24 * (PIXY * X24 - PIXX * Y24)
YY = Y24 * P(IJ)
   UTIL(IPJ)  = UTIL(IPJ) + DTØ2M1 * (XX + R1 * YY - PITH)
   UTIL(IJP)  = UTIL(IJP) - DTØ2M3 * (XX + R3 * YY + PITH)
XX = HR13 * (PIXY * X31 - PIXX * Y31)
YY = Y31 * P(IJ)
   UTIL(IPJP) = UTIL(IPJP) + DTØ2M2 * (XX + R2 * YY - PITH)
   UTIL(IJ)   = UTIL(IJ) - DTØ2M4 * (XX + R4 * YY + PITH)
```

$\tilde{v}$

```
PYYMP = PIYY - P(IJ)
XX = HR24 * (PYYMP * X24 - PIXY * Y24)
   VTIL(IPJ) = VTIL(IPJ) + DTØ2M1 * XX
   VTIL(IJP) = VTIL(IJP) - DTØ2M3 * XX
XX = HR13 * (PYYMP * X31 - PIXY * Y31)
   VTIL(IPJP) = VTIL(IPJP) + DTØ2M2 * XX
   VTIL(IJ)   = VTIL(IJ) - DTØ2M4 * XX
```

Q

```
XX = .5 * HR24 * [U24 * (X24 * PIXY - Y24 * PIXX)
                 - V24 * (Y24 * PIXY - X24 * PIYY)]
   Q(IPJ) = Q(IPJ) + DTØ2M1 * XX
   Q(IJP) = Q(IJP) - DTØ2M3 * XX
XX = .5 * HR13 * [U13 * (X31 * PIXY - Y31 * PIXX)
                 - V13 * (Y31 * PIXY - X31 * PIYY)]
   Q(IPJP) = Q(IPJP) + DTØ2M2 * XX
   Q(IJ)   = Q(IJ) - DTØ2M4 * XX
IJ = IPJ
```

TO NEXT CELL IN ROW

```
1199  IJP = IPJP
```

ROW COMPLETED

RESET BOUNDARY VERTICES:

```
UTIL(IJ) = UTIL(IJP) = UTIL(IJP-NQIB)
         = UTIL(IJ-NQIB) = 0.0
```

```
J:2   >
```

= RESET $\tilde{V}$'S ON BOTTOM:

```
      DØ 1210 IJ=ISC2,ISCF2,NQ
1210  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.

```
1220  J:JP1   <
```

= RESET $\tilde{V}$'S ON TOP:

```
      DØ 1230 IJP=IJPS,LJP2,NQ
1230  VTIL(IJP)=0.0
```

ROW DONE & BNDRY. CONDS. SET AS REQ'D

```
1240  CALL LØØP
```

DO ALL ROWS

```
1299  CØNTINUE
      CALL DØNE
```

LJP2, FORMED IN SETUP, TELLS WHICH OF THE 3 SCM ROWS THE JP2TH ROW WILL BE IN.

ALSO, IJPS (= IJP_{SAVE}), WHICH IS THE PROPERTY OF SUBR. LOOP, IS PUT IN YSC2 FOR USE HERE. IT CAN BE USED HERE AS LONG AS IT ISN'T ALTERED.

PRE-PHASE 2 INITIALIZATION LOOP:

```
1300  CALL START
        DØ 1399 J=2,JP1      } CELL
        DØ 1389 I=1,IBAR     } CENTERS
          IPJ = IJ+NQ
          IPJP = IJP+NQ
```

$\langle\tilde{E}\rangle$ ρ_L $1/c^2$ $2\delta t\left(\frac{1}{\Delta r^2}+\frac{1}{\Delta z^2}\right)$

```
ETIL(IJ) = E(IJ) + .25 * [Q(IPJ) + Q(IPJP) + Q(IJP) + Q(IJ)]
RØL(IJ) = RØ(IJ)
RCSQ(IJ) = 1./{ASQ + GGM1 * AMAX1[SIE(IJ),0.0]}
  XX = [X(IPJP) - X(IJ) + X(IPJ) - X(IJP)]**2
  YY = [Y(IPJP) - Y(IJ) + Y(IJP) - Y(IPJ)]**2
DELSM(IJ) = DT8 * [(XX + YY)/(XX * YY)]
IJ = IPJ
```

SINCE SIE,X,Y DON'T CHANGE DURING ITERATION, IT IS EXPEDIENT TO CALCULATE THESE 2 CELL VARIABLES BEFOREHAND, TO AVOID CONTINUAL RECALCULATION DURING ITERATION.

```
1389  IJP = IPJP
      CALL LØØP
1399  CØNTINUE
      CALL DØNE
```

TO $\tilde{E}$ CALCULATION ⟶ (1500) NEXT PAGE ⟶

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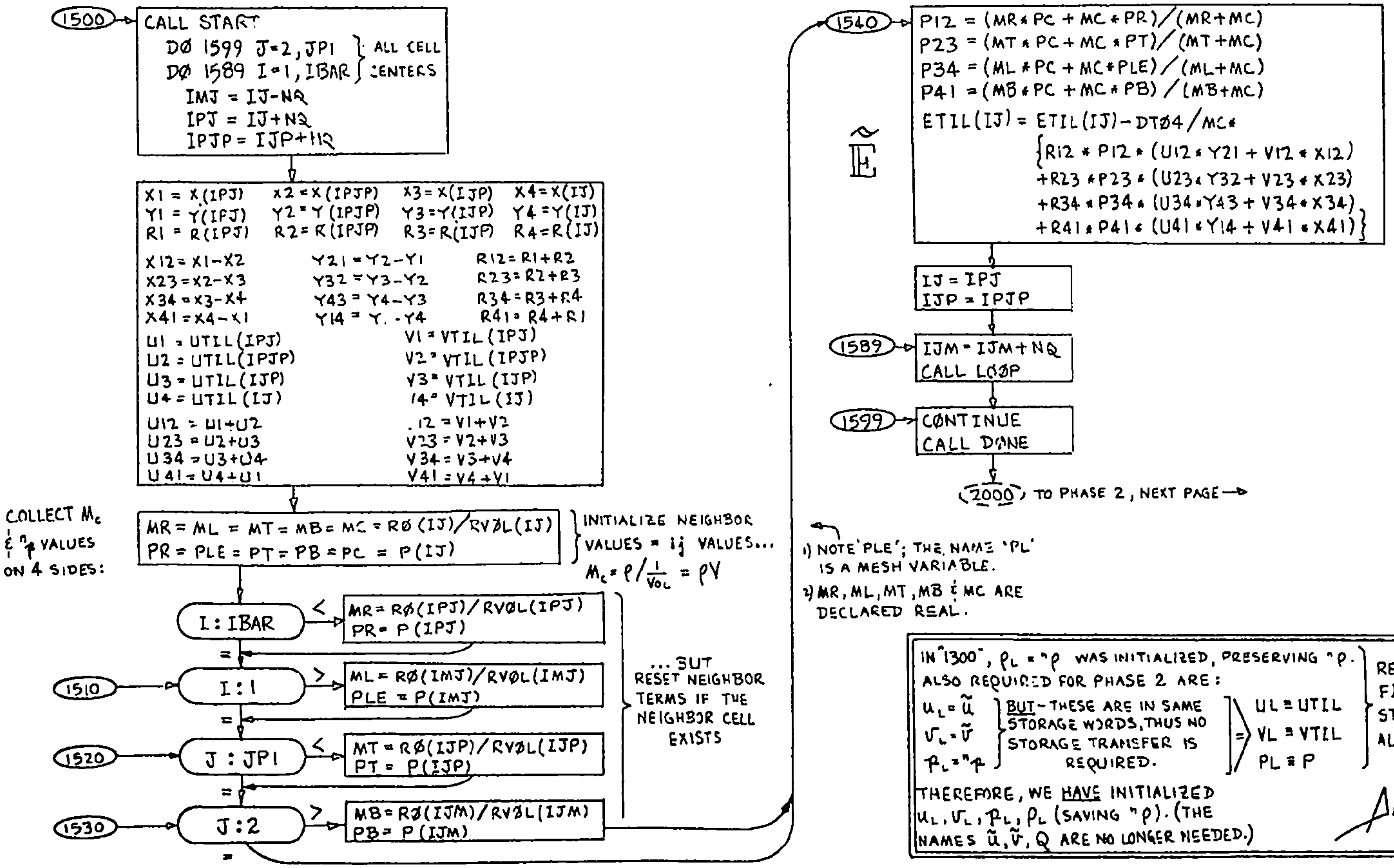
«SUBROUTINE YAQUI2» CONTINUED:

PHASE-1 CALCULATION - PAGE 4

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



```
(1500) CALL START
         DO 1599 J=2,JP1    } ALL CELL
         DO 1589 I=1,IBAR   } CENTERS
           IMJ = IJ-NQ
           IPJ = IJ+NQ
           IPJP = IJP+NQ

X1 = X(IPJ)    X2 = X(IPJP)   X3 = X(IJP)   X4 = X(IJ)
Y1 = Y(IPJ)    Y2 = Y(IPJP)   Y3 = Y(IJP)   Y4 = Y(IJ)
R1 = R(IPJ)    R2 = R(IPJP)   R3 = R(IJP)   R4 = R(IJ)

X12 = X1-X2         Y21 = Y2-Y1        R12 = R1+R2
X23 = X2-X3         Y32 = Y3-Y2        R23 = R2+R3
X34 = X3-X4         Y43 = Y4-Y3        R34 = R3+R4
X41 = X4-X1         Y14 = Y1-Y4        R41 = R4+R1
U1 = UTIL(IPJ)                  V1 = VTIL(IPJ)
U2 = UTIL(IPJP)                 V2 = VTIL(IPJP)
U3 = UTIL(IJP)                  V3 = VTIL(IJP)
U4 = UTIL(IJ)                   V4 = VTIL(IJ)
U12 = U1+U2                     V12 = V1+V2
U23 = U2+U3                     V23 = V2+V3
U34 = U3+U4                     V34 = V3+V4
U41 = U4+U1                     V41 = V4+V1

MR = ML = MT = MB = MC = RO(IJ)/RVOL(IJ)
PR = PLE = PT = PB = PC = P(IJ)

       I : IBAR   <  MR = RO(IPJ)/RVOL(IPJ)
                     PR = P(IPJ)
          =
(1510) I : 1      >  ML = RO(IMJ)/RVOL(IMJ)
                     PLE = P(IMJ)
          =
(1520) J : JP1    <  MT = RO(IJP)/RVOL(IJP)
                     PT = P(IJP)
          =
(1530) J : 2      >  MB = RO(IJM)/RVOL(IJM)
                     PB = P(IJM)
          =

(1540) P12 = (MR*PC + MC*PR)/(MR+MC)
       P23 = (MT*PC + MC*PT)/(MT+MC)
       P34 = (ML*PC + MC*PLE)/(ML+MC)
       P41 = (MB*PC + MC*PB)/(MB+MC)
       ETIL(IJ) = ETIL(IJ)-DTO4/MC*
                  {R12*P12*(U12*Y21 + V12*X12)
                  +R23*P23*(U23*Y32 + V23*X23)
                  +R34*P34*(U34*Y43 + V34*X34)
                  +R41*P41*(U41*Y14 + V41*X41)}

       IJ = IPJ
       IJP = IPJP

(1589) IJM = IJM+NQ
       CALL LOOP

(1599) CONTINUE
       CALL DONE

(2000) TO PHASE 2, NEXT PAGE →
```

COLLECT M_c & $^n p$ VALUES ON 4 SIDES:

INITIALIZE NEIGHBOR VALUES = ij VALUES...

$M_c = \rho / \frac{1}{Vol} = \rho V$

...BUT RESET NEIGHBOR TERMS IF THE NEIGHBOR CELL EXISTS

$\tilde{\mathbb{E}}$

1) NOTE 'PLE'; THE NAME 'PL' IS A MESH VARIABLE.

2) MR, ML, MT, MB & MC ARE DECLARED REAL.

IN "1300", $\rho_L = {}^n\rho$ WAS INITIALIZED, PRESERVING $^n\rho$. ALSO REQUIRED FOR PHASE 2 ARE: } REFER TO FIG. 9 — STORAGE ALLOCATION

$u_L = \tilde{u}$
$v_L = \tilde{v}$
$p_L = {}^n p$ } BUT - THESE ARE IN SAME STORAGE WORDS, THUS NO STORAGE TRANSFER IS REQUIRED. => UL ≡ UTIL, VL ≡ VTIL, PL ≡ P

THEREFORE, WE HAVE INITIALIZED u_L, v_L, p_L, ρ_L (SAVING $^n\rho$). (THE NAMES $\tilde{u}, \tilde{v}$, Q ARE NO LONGER NEEDED.)

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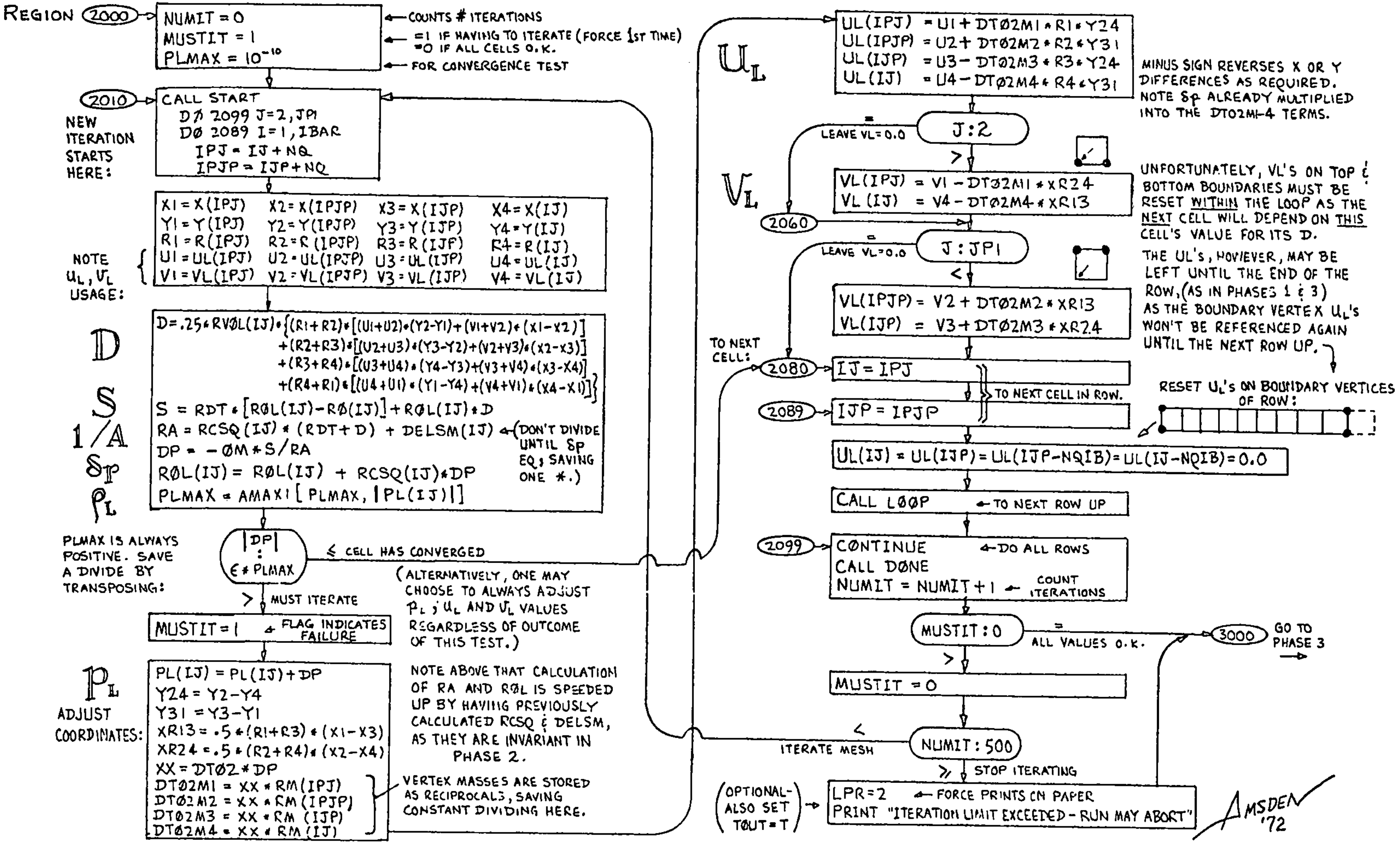
«SUBROUTINE YAQUI2» CONTINUED:

PHASE 2 : ITERATION



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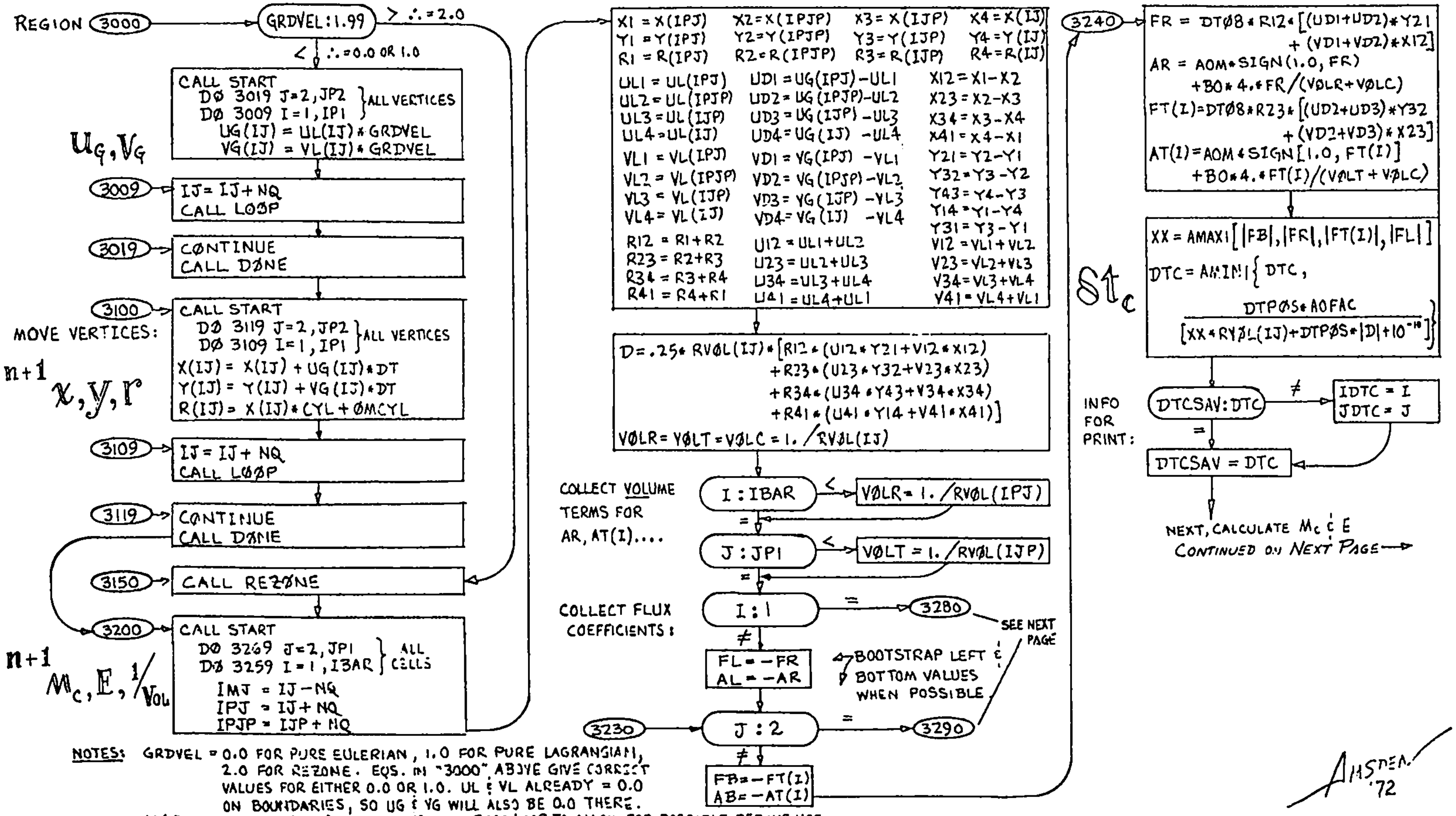
2.0 SUBROUTINES - 3-PHASE ICED-ALE (CONT'D):

«SUBROUTINE YAQUI2» CONTINUED:

PHASE-3 CALCULATION - PAGE 1

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



NOTES: GRDVEL = 0.0 FOR PURE EULERIAN, 1.0 FOR PURE LAGRANGIAN, 2.0 FOR REZONE. EQS. IN "3000" ABOVE GIVE CORRECT VALUES FOR EITHER 0.0 OR 1.0. UL & VL ALREADY = 0.0 ON BOUNDARIES, SO UG & VG WILL ALSO BE 0.0 THERE.
X,Y,R VERTEX LOOP (3100) IS SEPARATE FROM 3000 LOOP TO ALLOW FOR POSSIBLE REZONE USE.

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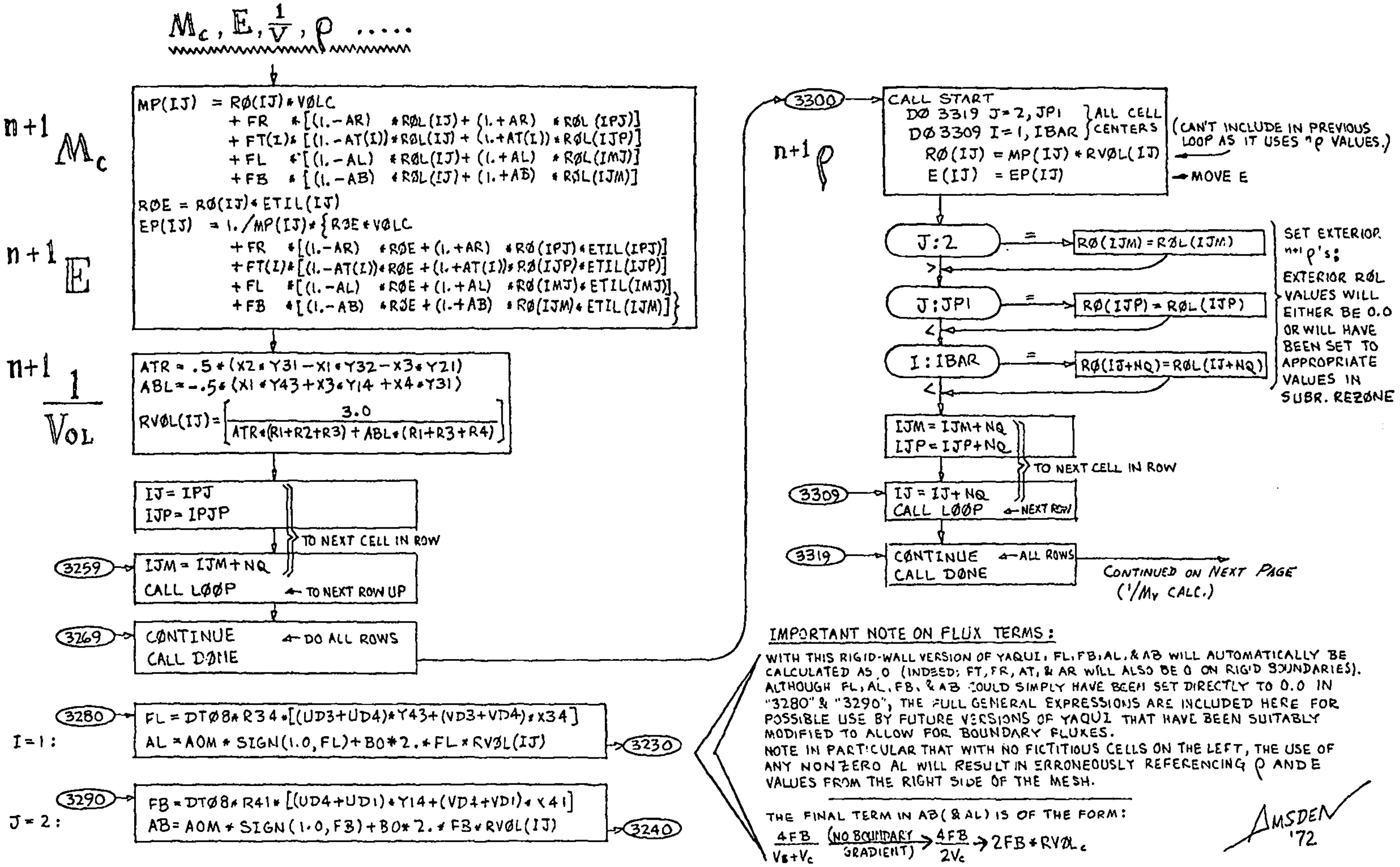
«SUBROUTINE YAQUI2» CONTINUED:

PHASE-3 CALCULATION - PAGE 2



```
MP(IJ)  = RØ(IJ)*VØLC
          + FR    *[(1.-AR)    *RØL(IJ)+ (1.+AR)    *RØL (IPJ)]
          + FT(I)* [(1.-AT(I))*RØL(IJ) + (1.+AT(I))*RØL(IJP)]
          + FL    *[(1.-AL)    *RØL(IJ)+ (1.+AL)    *RØL(IMJ)]
          + FB    *[(1.-AB)    *RØL(IJ)+ (1.+AB)    *RØL(IJM)]
RØE = RØ(IJ)*ETIL(IJ)
EP(IJ)  = 1./MP(IJ)*{RØE*VØLC
          + FR    *[(1.-AR)    *RØE + (1.+AR)    *RØ(IPJ)*ETIL(IPJ)]
          + FT(I)*[(1.-AT(I))*RØE + (1.+AT(I))*RØ(IJP)*ETIL(IJP)]
          + FL    *[(1.-AL)    *RØE + (1.+AL)    *RØ(IMJ)*ETIL(IMJ)]
          + FB    *[(1.-AB)    *RØE + (1.+AB)    *RØ(IJM)*ETIL(IJM)]}

ATR = .5*(X2*Y31-X1*Y32-X3*Y21)
ABL=-.5*(X1*Y43+X3*Y14+X4*Y31)
RVØL(IJ)=[3.0/(ATR*(R1+R2+R3)+ABL*(R1+R3+R4))]

IJ= IPJ
IJP= IPJP
3259  IJM = IJM+NQ
      CALL LØØP
3269  CØNTINUE
      CALL DØNE

3280  FL = DTØ8*R34*[(UD3+UD4)*Y43+(VD3+VD4)*X34]
      AL = AOM*SIGN(1.0,FL)+BO*2.*FL*RVØL(IJ)       3230
3290  FB = DTØ8*R41*[(UD4+UD1)*Y14+(VD4+VD1)*X41]
      AB= AOM*SIGN(1.0,FB)+BO*2.*FB*RVØL(IJ)        3240

3300  CALL START
      DØ 3319 J=2,JP1
      DØ 3309 I=1,IBAR
      RØ(IJ) = MP(IJ)*RVØL(IJ)
      E(IJ)  = EP(IJ)

J:2     =  RØ(IJM)=RØL(IJM)
J:JP1   =  RØ(IJP)=RØL(IJP)
I:IBAR  =  RØ(IJ+NQ)=RØL(IJ+NQ)

      IJM= IJM+NQ
      IJP= IJP+NQ
3309  IJ = IJ+NQ
      CALL LØØP
3319  CØNTINUE
      CALL DØNE
```

CONTINUED ON NEXT PAGE (1/M_V CALC.)

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 ρ AND E VALUES FROM THE RIGHT SIDE OF THE MESH.

THE FINAL TERM IN AB (& AL) IS OF THE FORM:

$$\frac{4FB}{V_B+V_C} \xrightarrow[\text{GRADIENT)}]{\text{(NO BOUNDARY}} \frac{4FB}{2V_C} \rightarrow 2FB*RV\emptyset L_C$$

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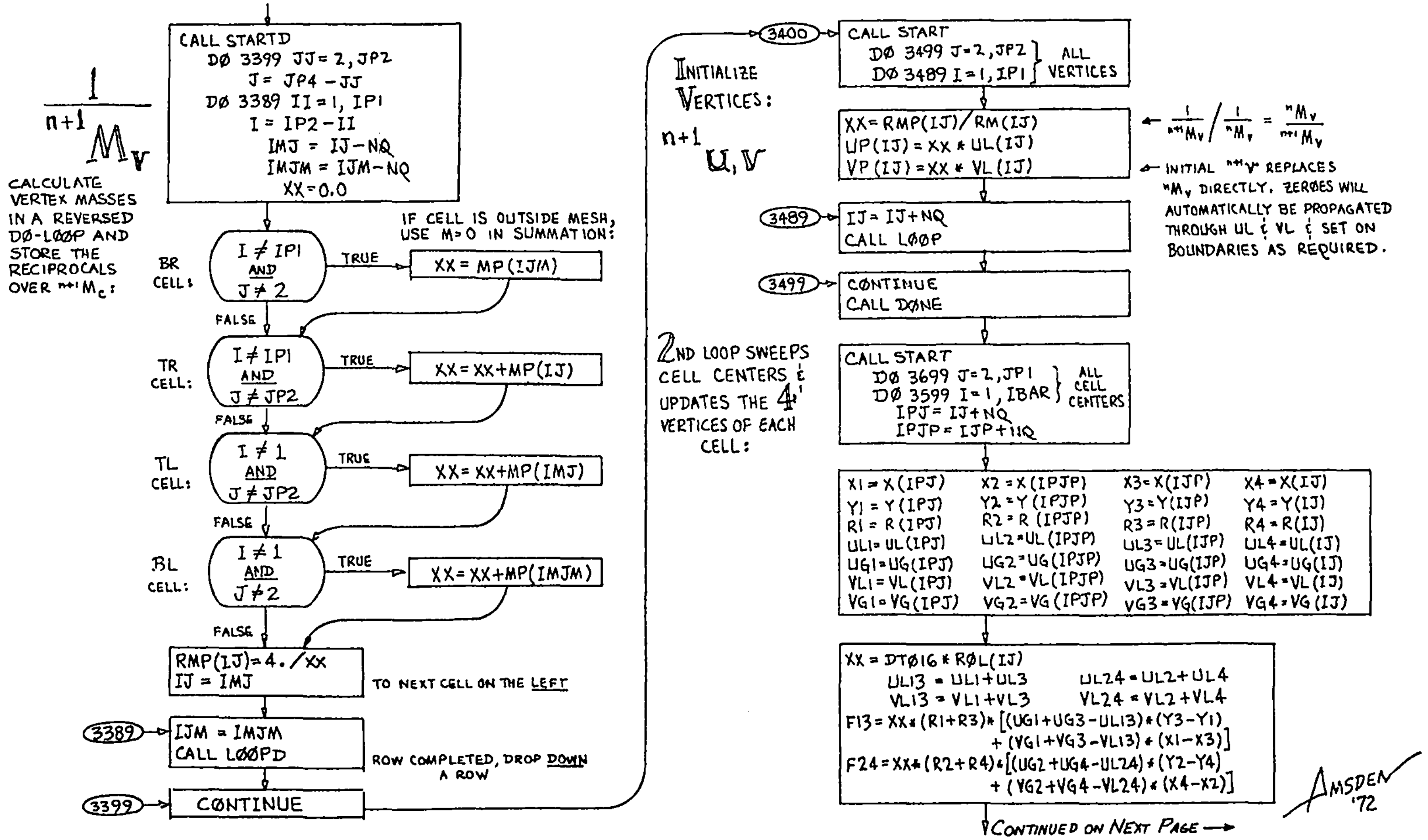
⟪SUBROUTINE YAQUI2⟫ CONTINUED:

PHASE-3 CALCULATION - PAGE 3

CALCULATE "n+1" VALUES OF $\frac{1}{M_V}$, u, v



$\frac{1}{^{n+1}M_V}$

CALCULATE VERTEX MASSES IN A REVERSED DO-LOOP AND STORE THE RECIPROCALS OVER $^{n+1}M_c$:

```
      CALL STARTD
        DO 3399 JJ = 2,JP2
           J = JP4 - JJ
        DO 3389 II = 1, IP1
           I = IP2 - II
            IMJ = IJ-NQ
            IMJM = IJM-NQ
             XX = 0.0
```

IF CELL IS OUTSIDE MESH, USE M=0 IN SUMMATION:

```
XX = MP(IJM)
```

```
XX = XX+MP(IJ)
```

```
XX = XX+MP(IMJ)
```

```
XX = XX+MP(IMJM)
```

```
      RMP(IJ)=4./XX
      IJ = IMJ
```

TO NEXT CELL ON THE LEFT

```
3389  IJM = IMJM
      CALL LOOPD
```

ROW COMPLETED, DROP DOWN A ROW

```
3399  CONTINUE
```

INITIALIZE VERTICES: $^{n+1}$u, v

```
3400  CALL START
        DO 3499 J=2,JP2
        DO 3489 I=1,IP1
```

ALL VERTICES

```
      XX= RMP(IJ)/RM(IJ)
      UP(IJ) = XX * UL(IJ)
      VP(IJ) = XX * VL(IJ)
```

$\leftarrow \frac{1}{^{n+1}M_v} / \frac{1}{^{n}M_v} = \frac{^{n}M_v}{^{n+1}M_v}$

← INITIAL "$^{n+1}$V" REPLACES $^{n}M_v$ DIRECTLY. ZEROES WILL AUTOMATICALLY BE PROPAGATED THROUGH UL & VL & SET ON BOUNDARIES AS REQUIRED.

```
3489  IJ= IJ+NQ
      CALL LOOP
3499  CONTINUE
      CALL DONE
```

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

```
      CALL START
        DO 3699 J=2,JP1
        DO 3599 I=1,IBAR
          IPJ= IJ+NQ
          IPJP= IJP+NQ
```

ALL CELL CENTERS

```
X1 = X(IPJ)      X2 = X(IPJP)     X3 = X(IJP)     X4 = X(IJ)
Y1 = Y(IPJ)      Y2 = Y(IPJP)     Y3 = Y(IJP)     Y4 = Y(IJ)
R1 = R(IPJ)      R2 = R(IPJP)     R3 = R(IJP)     R4 = R(IJ)
UL1 = UL(IPJ)    UL2 = UL(IPJP)   UL3 = UL(IJP)   UL4 = UL(IJ)
UG1 = UG(IPJ)    UG2 = UG(IPJP)   UG3 = UG(IJP)   UG4 = UG(IJ)
VL1 = VL(IPJ)    VL2 = VL(IPJP)   VL3 = VL(IJP)   VL4 = VL(IJ)
VG1 = VG(IPJ)    VG2 = VG(IPJP)   VG3 = VG(IJP)   VG4 = VG(IJ)
```

```
XX = DTO16 * ROL(IJ)
     UL13 = UL1+UL3          UL24 = UL2+UL4
     VL13 = VL1+VL3          VL24 = VL2+VL4
F13 = XX*(R1+R3)*[(UG1+UG3-UL13)*(Y3-Y1)
                + (VG1+VG3-VL13)*(X1-X3)]
F24 = XX*(R2+R4)*[(UG2+UG4-UL24)*(Y2-Y4)
                + (VG2+VG4-VL24)*(X4-X2)]
```

CONTINUED ON NEXT PAGE →

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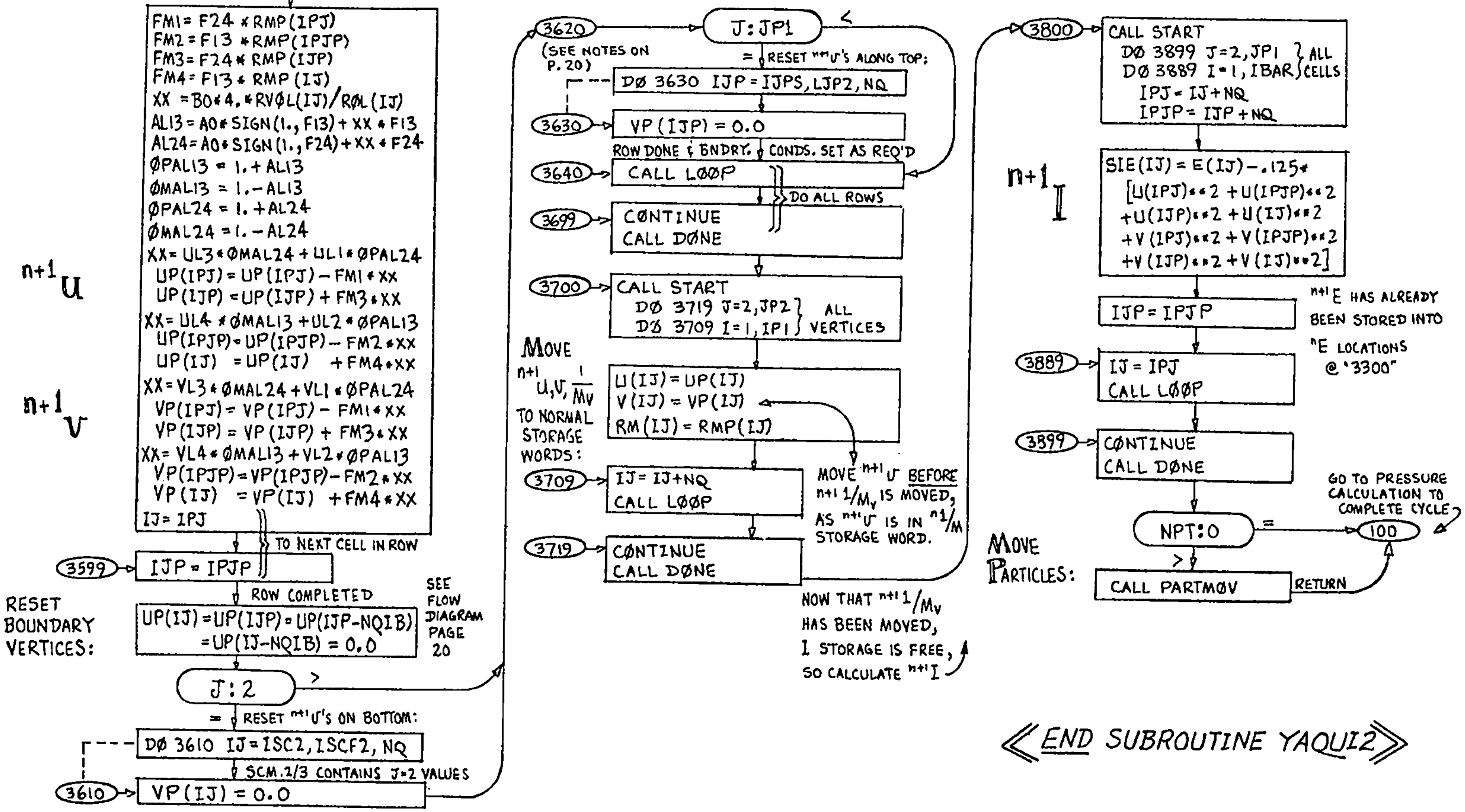
《SUBROUTINE YAQUI2》 CONTINUED:

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 (IJ)
      XX =B0*4.*RVØL(IJ)/RØL(IJ)
      AL13 = A0*SIGN(1., F13) + XX * F13
      AL24= A0*SIGN (1., F24)+XX * F24
      ØPAL13 = 1.+AL13
      ØMAL13 = 1.-AL13
      ØPAL24 = 1.+AL24
      ØMAL24 =1.-AL24
      XX= UL3*ØMAL24 + UL1*ØPAL24
       UP(IPJ) = UP(IPJ) - FM1*XX
       UP(IJP) =UP(IJP) + FM3*XX
      XX= UL4 *ØMAL13 +UL2*ØPAL13
       UP(IPJP)=UP(IPJP) - FM2*XX
       UP(IJ)  =UP(IJ)   +FM4*XX
      XX=VL3*ØMAL24 +VL1*ØPAL24
       VP(IPJ)= VP(IPJ) - FM1*XX
       VP(IJP) = VP(IJP) + FM3*XX
      XX= VL4*ØMAL13 +VL2*ØPAL13
       VP(IPJP)=VP(IPJP)-FM2*XX
       VP(IJ)  =VP(IJ)   +FM4*XX
      IJ= IPJ
3599  IJP = IPJP
      UP(IJ) =UP(IJP) = UP(IJP-NQIB)
         =UP(IJ-NQIB) = 0.0
      J:2
      DØ 3610 IJ=ISC2,ISCF2, NQ
3610  VP(IJ) = 0.0
3620  J:JP1
      DØ 3630 IJP=IJPS,LJP2,NQ
3630  VP (IJP) = 0.0
3640  CALL LØØP
3699  CØNTINUE
      CALL DØNE
3700  CALL START
        DØ 3719 J=2,JP2
        DØ 3709 I=1,IP1
      U(IJ)=UP(IJ)
      V(IJ) = VP(IJ)
      RM(IJ)= RMP(IJ)
3709  IJ= IJ+NQ
      CALL LØØP
3719  CØNTINUE
      CALL DØNE
3800  CALL START
        DØ 3899 J=2,JP1
        DØ 3889 I=1,IBAR
          IPJ = IJ+NQ
          IPJP= IJP+NQ
      SIE(IJ) = E(IJ)-.125*
        [U(IPJ)**2 +U(IPJP)**2
        +U(IJP)**2 +U(IJ)**2
        +V (IPJ)**2 +V(IPJP)**2
        +V (IJP)**2 +V(IJ)**2]
      IJP= IPJP
3889  IJ = IPJ
      CALL LØØP
3899  CØNTINUE
      CALL DØNE
      NPT:0
      CALL PARTMØV
```

《END SUBROUTINE YAQUI2》

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.

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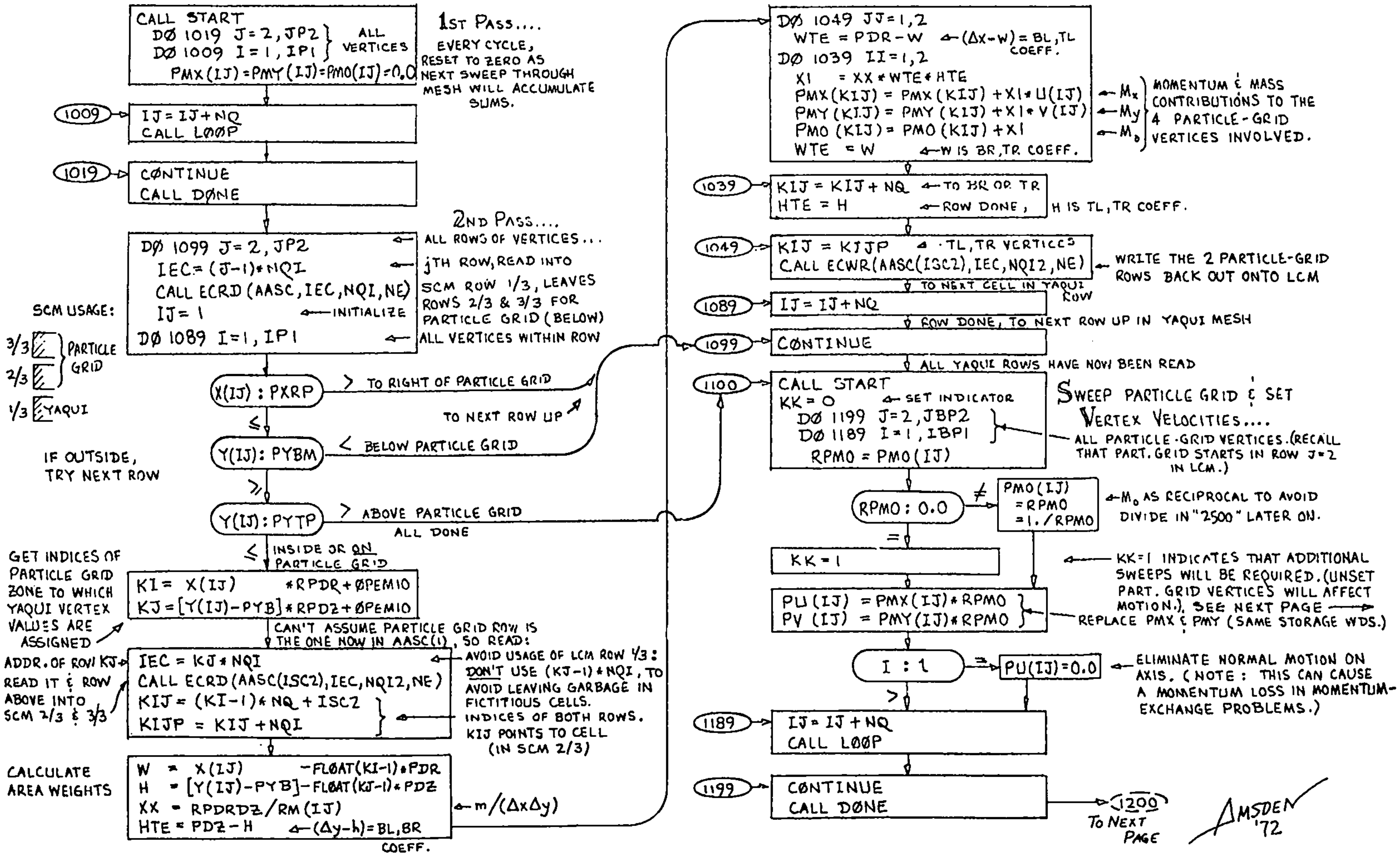
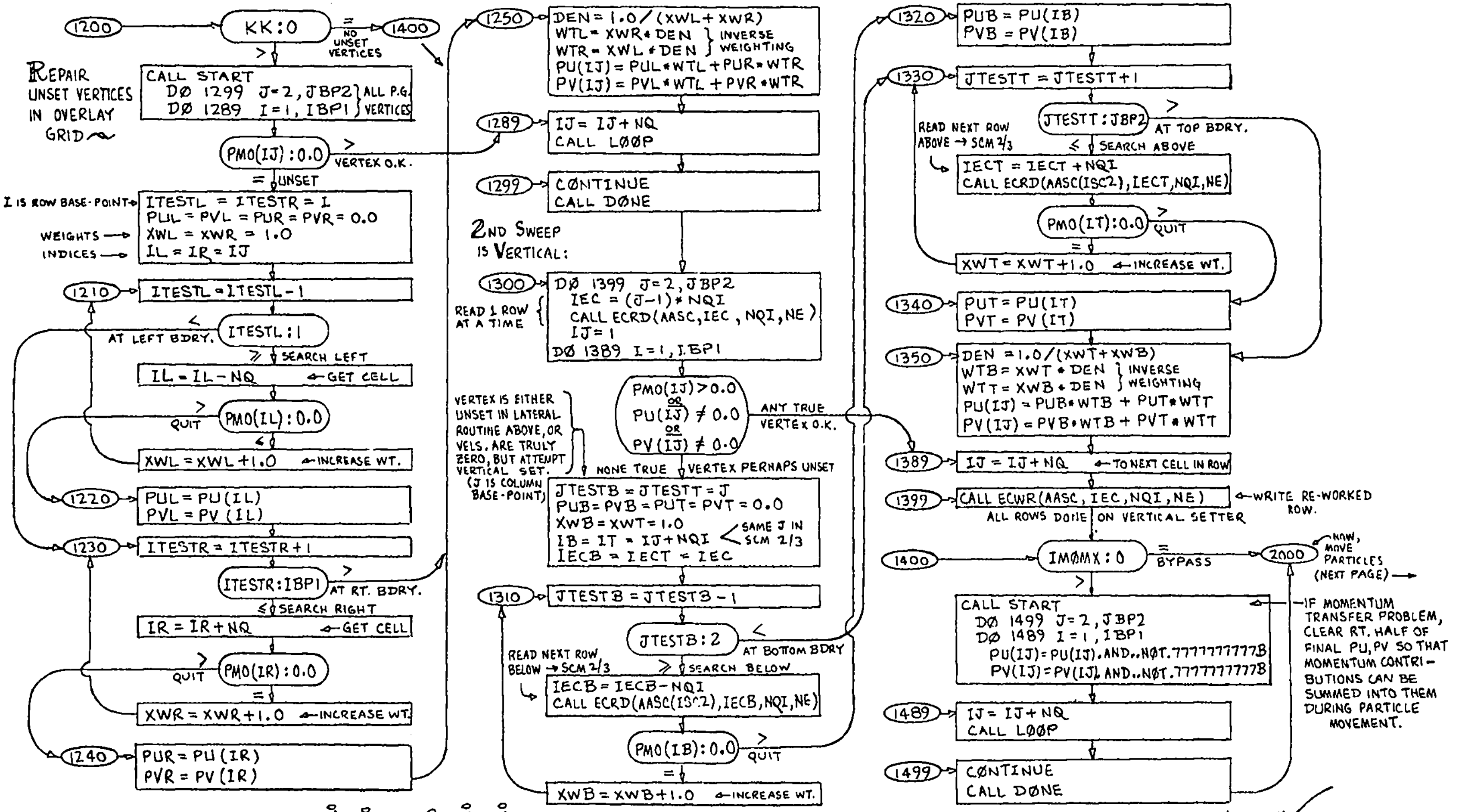
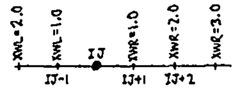
«SUBROUTINE PARTMØV»



⟪SUBROUTINE PARTMØV⟫ - PAGE 2



LINEAR WEIGHTING EXAMPLE:



FOR NONZERO MASSES AT IJ-1 & IJ+1, WEIGHTING WOULD BE 1/2 L + 1/2 R
FOR NONZERO MASSES AT IJ-1 & IJ+2, WEIGHTING WOULD BE 2/3 L + 1/3 R

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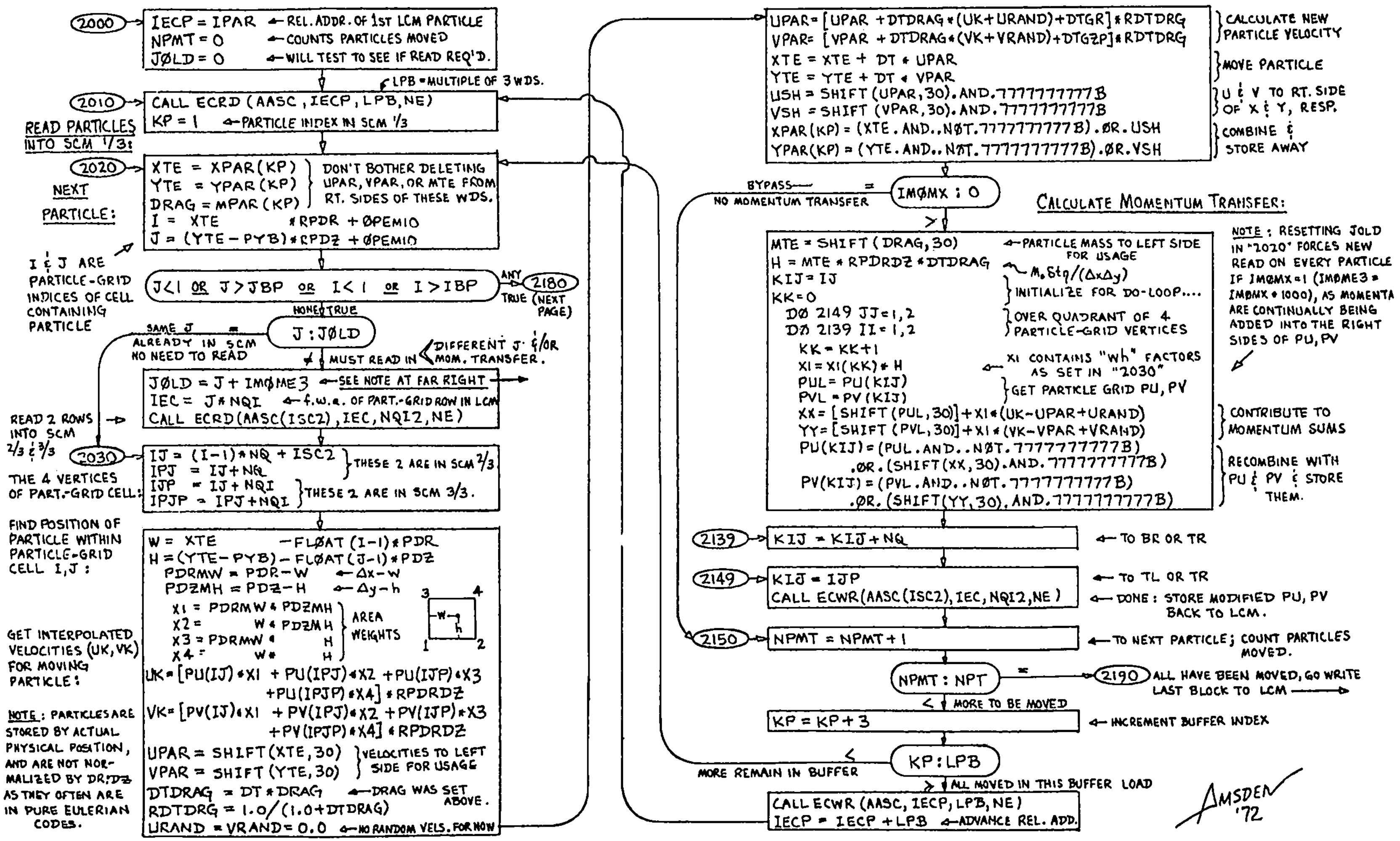
2.0 SUBROUTINES – PARTICLE MOVER (CONT'D):

≪SUBROUTINE PARTMØV≫ - PAGE 3

MOVE PARTICLES IN RELATION TO OVERLAY GRID



READ PARTICLES INTO SCM 1/3:

```
2000  IECP = IPAR      ← REL. ADDR. OF 1ST LCM PARTICLE
      NPMT = 0         ← COUNTS PARTICLES MOVED
      JØLD = 0         ← WILL TEST TO SEE IF READ REQ'D.
                                 LPB = MULTIPLE OF 3 WDS.
2010  CALL ECRD (AASC, IECP, LPB, NE)
      KP = 1           ← PARTICLE INDEX IN SCM 1/3
```

NEXT PARTICLE:

```
2020  XTE = XPAR(KP)   } DON'T BOTHER DELETING
      YTE = YPAR(KP)   } UPAR, VPAR, OR MTE FROM
      DRAG = MPAR(KP)  } RT. SIDES OF THESE WDS.
      I = XTE            *RPDR + ØPEMIO
      J = (YTE - PYB)*RPDZ + ØPEMIO
```

I & J ARE PARTICLE-GRID INDICES OF CELL CONTAINING PARTICLE

```
      J<1 OR J>JBP OR I<1 OR I>IBP
          ANY TRUE → 2180 (NEXT PAGE)
          NONE TRUE ↓
      J : JØLD
          =  SAME J ALREADY IN SCM, NO NEED TO READ → 2030
          ≠  MUST READ IN ≪ DIFFERENT J &/OR MOM. TRANSFER.
      JØLD = J + IMØME3     ← SEE NOTE AT FAR RIGHT →
      IEC = J*NQI           ← f.w.a. OF PART.-GRID ROW IN LCM
      CALL ECRD(AASC(ISC2), IEC, NQI2, NE)
```

READ 2 ROWS INTO SCM 2/3 & 3/3

THE 4 VERTICES OF PART.-GRID CELL:

```
2030  IJ = (I-1)*NQ + ISC2  } THESE 2 ARE IN SCM 2/3
      IPJ = IJ+NQ           }
      IJP = IJ + NQI        } THESE 2 ARE IN SCM 3/3.
      IPJP = IPJ+NQI        }
```

FIND POSITION OF PARTICLE WITHIN PARTICLE-GRID CELL I,J:

```
      W = XTE         - FLØAT(I-1)*PDR
      H = (YTE - PYB) - FLØAT(J-1)*PDZ
        PDRMW = PDR-W     ← Δx-w
        PDZMH = PDZ-H     ← Δy-h
          X1 = PDRMW * PDZMH  }
          X2 =     W * PDZMH  } AREA
          X3 = PDRMW *     H  } WEIGHTS
          X4 =     W *     H  }
```

GET INTERPOLATED VELOCITIES (UK, VK) FOR MOVING PARTICLE:

```
      UK = [PU(IJ)*X1 + PU(IPJ)*X2 + PU(IJP)*X3
                 +PU(IPJP)*X4]*RPDRDZ
      VK = [PV(IJ)*X1 + PV(IPJ)*X2 + PV(IJP)*X3
                 +PV(IPJP)*X4]*RPDRDZ
      UPAR = SHIFT(XTE,30)  } VELOCITIES TO LEFT
      VPAR = SHIFT(YTE,30)  } SIDE FOR USAGE
      DTDRAG = DT*DRAG         ← DRAG WAS SET ABOVE.
      RDTDRG = 1.0/(1.0+DTDRAG)
      URAND = VRAND = 0.0      ← NO RANDOM VELS. FOR NOW
```

NOTE: PARTICLES ARE STORED BY ACTUAL PHYSICAL POSITION, AND ARE NOT NORMALIZED BY DR;DZ AS THEY OFTEN ARE IN PURE EULERIAN CODES.

```
      UPAR = [UPAR + DTDRAG*(UK+URAND)+DTGR]*RDTDRG    } CALCULATE NEW
      VPAR = [VPAR + DTDRAG*(VK+VRAND)+DTGZP]*RDTDRG   } PARTICLE VELOCITY
      XTE = XTE + DT*UPAR                              } MOVE PARTICLE
      YTE = YTE + DT*VPAR                              }
      USH = SHIFT(UPAR,30).AND.7777777777B             } U & V TO RT. SIDE
      VSH = SHIFT(VPAR,30).AND.7777777777B             } OF X & Y, RESP.
      XPAR(KP) = (XTE.AND..NØT.7777777777B).ØR.USH     } COMBINE &
      YPAR(KP) = (YTE.AND..NØT.7777777777B).ØR.VSH     } STORE AWAY
      IMØMX : 0
          =  BYPASS — NO MOMENTUM TRANSFER → 2150
          >  ↓
```

CALCULATE MOMENTUM TRANSFER:

```
      MTE = SHIFT(DRAG,30)          ← PARTICLE MASS TO LEFT SIDE FOR USAGE
      H = MTE*RPDRDZ*DTDRAG         ← M_p δt η/(ΔxΔy)
      KIJ = IJ                      } INITIALIZE FOR DO-LOOP....
      KK = 0                        }
        DØ 2149 JJ=1,2              } OVER QUADRANT OF 4
        DØ 2139 II=1,2              } PARTICLE-GRID VERTICES
          KK = KK+1
          XI = XI(KK)*H             ← XI CONTAINS "wh" FACTORS AS SET IN "2030"
          PUL = PU(KIJ)             } GET PARTICLE GRID PU, PV
          PVL = PV(KIJ)             }
          XX = [SHIFT(PUL,30)]+XI*(UK-UPAR+URAND)   } CONTRIBUTE TO
          YY = [SHIFT(PVL,30)]+XI*(VK-VPAR+VRAND)   } MOMENTUM SUMS
          PU(KIJ) = (PUL.AND..NØT.7777777777B)      }
               .ØR.(SHIFT(XX,30).AND.7777777777B)   } RECOMBINE WITH
          PV(KIJ) = (PVL.AND..NØT.7777777777B)      } PU & PV & STORE
               .ØR.(SHIFT(YY,30).AND.7777777777B)   } THEM.
2139  KIJ = KIJ+NQ                  ← TO BR OR TR
2149  KIJ = IJP                     ← TO TL OR TR
      CALL ECWR(AASC(ISC2),IEC,NQI2,NE)   ← DONE: STORE MODIFIED PU, PV BACK TO LCM.
2150  NPMT = NPMT+1                 ← TO NEXT PARTICLE; COUNT PARTICLES MOVED.
      NPMT : NPT
          =  → 2190  ALL HAVE BEEN MOVED, GO WRITE LAST BLOCK TO LCM →
          <  ↓ MORE TO BE MOVED
      KP = KP+3                     ← INCREMENT BUFFER INDEX
      KP : LPB
          <  MORE REMAIN IN BUFFER → 2020
          >  ↓ ALL MOVED IN THIS BUFFER LOAD
      CALL ECWR (AASC, IECP, LPB, NE)
      IECP = IECP + LPB             ← ADVANCE REL. ADD.    → 2010
```

NOTE: RESETTING JOLD IN "2020" FORCES NEW READ ON EVERY PARTICLE IF IMØMX=1 (IMØME3 = IMØMX*1000), AS MOMENTA ARE CONTINUALLY BEING ADDED INTO THE RIGHT SIDES OF PU, PV

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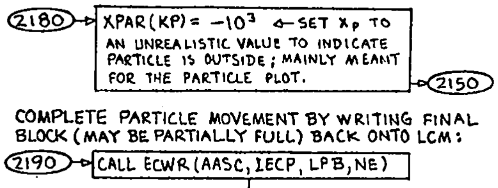
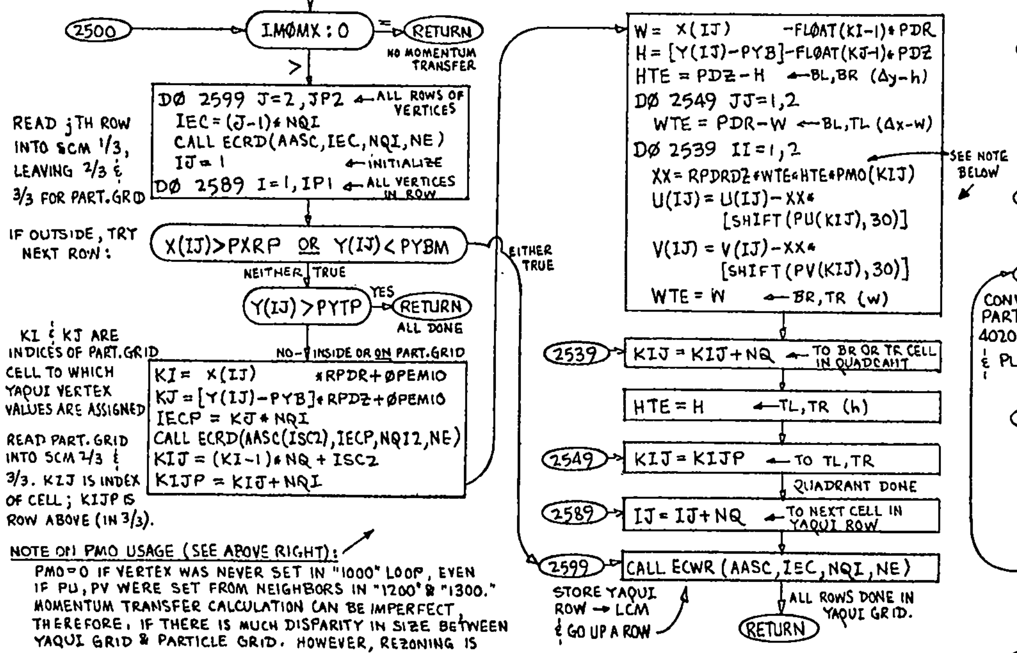
«SUBROUTINE PARTMØV» - PAGE 4



MOMENTUM TRANSFER BACK ONTO YAQUI GRID:

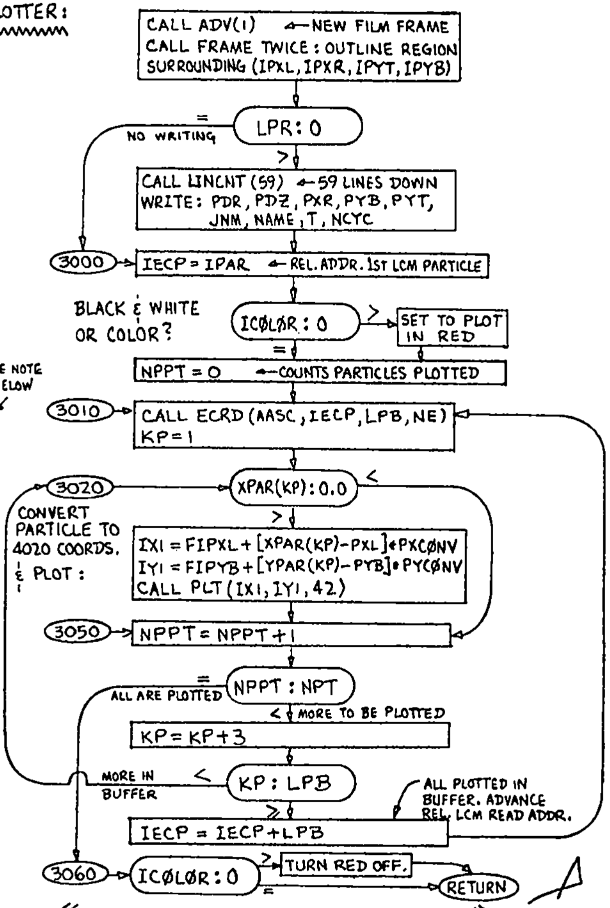


NOTE ON PMO USAGE (SEE ABOVE RIGHT):

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 YAQUI 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.

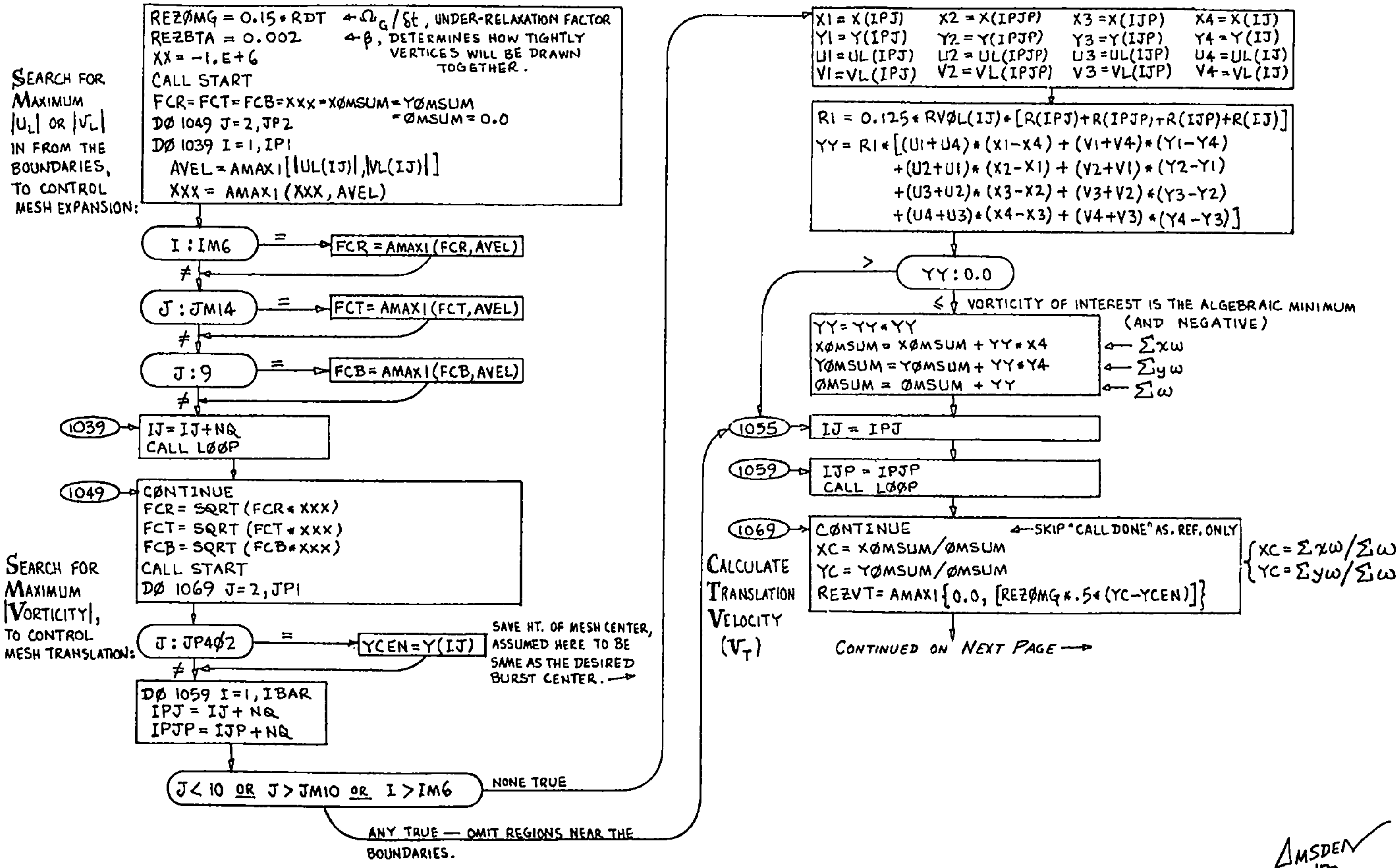
«ENTRY PARPLOT»

PARTICLE PLOTTER:



«END SUBROUTINE PARTMOV»

«SUBROUTINE REZONE»



```
      REZØMG = 0.15*RDT
      REZBTA = 0.002
      XX = -1.E+6
      CALL START
      FCR=FCT=FCB=XXX=XØMSUM=YØMSUM=ØMSUM=0.0
      DØ 1049 J=2,JP2
      DØ 1039 I=1,IP1
        AVEL = AMAX1[|UL(IJ)|,|VL(IJ)|]
        XXX = AMAX1(XXX,AVEL)

      FCR = AMAX1(FCR,AVEL)
      FCT= AMAX1(FCT,AVEL)
      FCB= AMAX1(FCB,AVEL)

1039  IJ= IJ+NQ
      CALL LØØP

1049  CØNTINUE
      FCR= SQRT(FCR*XXX)
      FCT= SQRT (FCT*XXX)
      FCB= SQRT (FCB*XXX)
      CALL START
      DØ 1069 J=2,JP1

      YCEN=Y(IJ)

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

      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)

      R1 = 0.125*RVØL(IJ)*[R(IPJ)+R(IPJP)+R(IJP)+R(IJ)]
      YY = R1*[(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=YY*YY
      XØMSUM = XØMSUM + YY*X4
      YØMSUM = YØMSUM + YY*Y4
      ØMSUM = ØMSUM + YY

1055  IJ = IPJ

1059  IJP = IPJP
      CALL LØØP

1069  CØNTINUE
      XC = XØMSUM/ØMSUM
      YC = YØMSUM/ØMSUM
      REZVT= AMAX1{0.0, [REZØMG*.5*(YC-YCEN)]}
```

CONTINUED ON NEXT PAGE →

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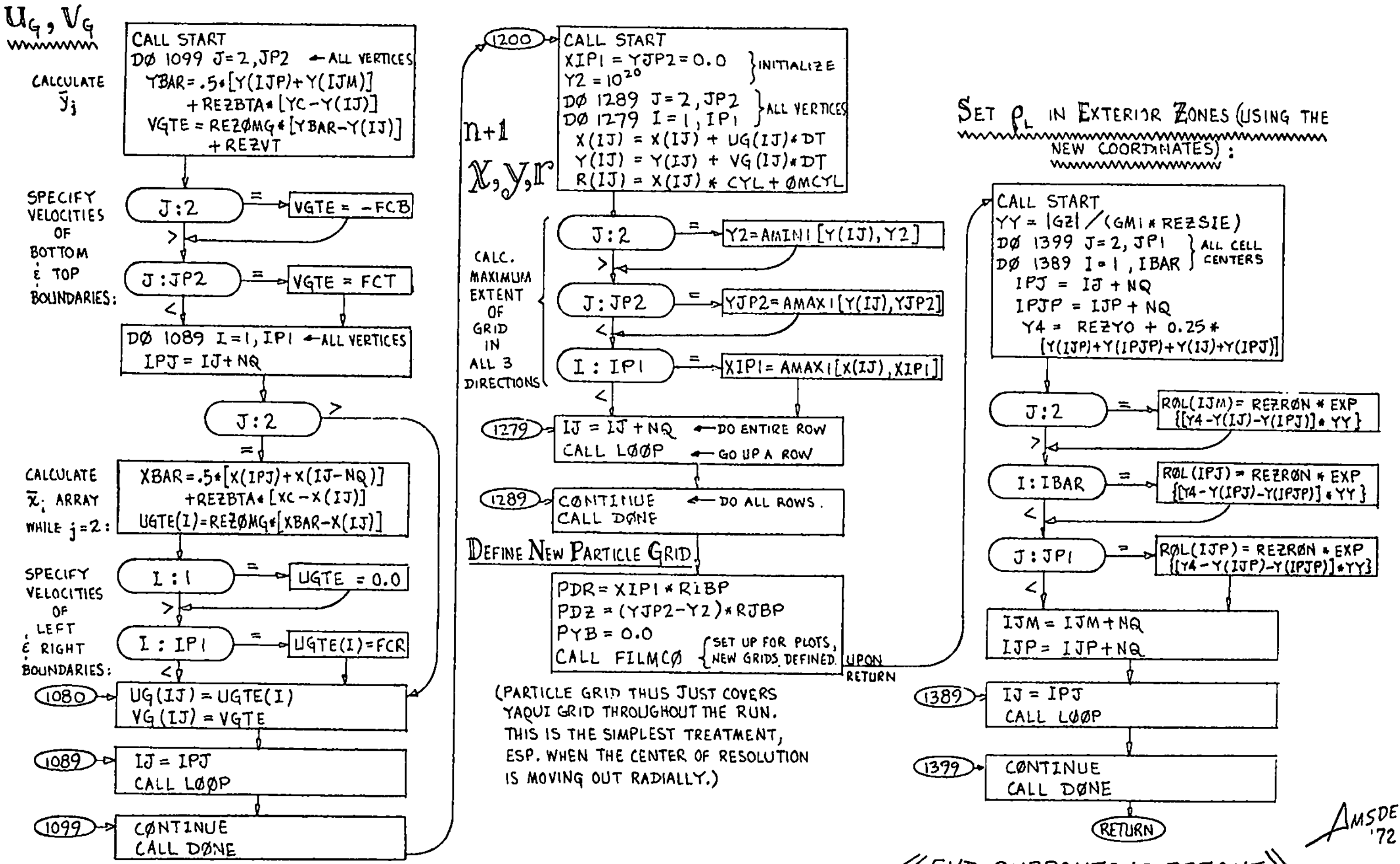
«SUBROUTINE REZONE» - PAGE 2



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«END SUBROUTINE REZONE»

APPENDIX B

FORTRAN IV INDEX LISTING OF THE YAQUI PROGRAM

```
INDEX  01/12/73            OVERLAY(YAQUFIL,0,0)                                 PAGE    1
          1         OVERLAY(YAQUFIL,0,0)                                         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,ASQ,A0,A0FAC,A0M,B0,COLAMU,CYL,         COMMON2 00003
                  1        DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTO(10),DTOC(10),        COMMON2 00004
                  2        DTO16,DTO2,DTO4,DTO8,DTPOS,DTV,DT8,DZ,EM10,EPS,FIBP,     COMMON2 00005
                  3        FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,        COMMON2 00006
                  4        FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IBAR,IBP,IBP1,ICOLOR,   COMMON2 00007
                  5        IDTO,IJ,IJM,IJP,IJPS,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,LPB,     COMMON2 00011
                  9        LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQI,NQIB,NQI2,NSC,   COMMON2 00012
                  1        NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV, COMMON2 00013
                  2        PXL,PXR,PXRP,PYB,PYRM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE, COMMON2 00014
                  3        REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJB,RIBP,RJBP,ROMFR,     COMMON2 00015
                  4        RON,RPDR,RPDRDZ,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,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),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,PM0),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL, EQVREAL 00006
                  5            VL,PMY,PV),(AASC(14),Q,ROL)          ,               EQVREAL 00007
          6         REAL LAM,LAMD,M,MB,MC,ML,MP,MPAR,MR,MT,MTE,MU,MU02,MU04         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 (IBAR) 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 (1H1)                                                    YAQUI   00018
         18    110  FORMAT (5I4,7F8.3,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      ()R   4CO   EPS      -R   4CO   IJM     -I   4CO   JP1     -I   4CO   NUMTD   -I   4CO   READ    -   9F    U      -R   5EQ
 AA1     ()R   2LC   EQUIVAL  -    5F    IJP     -I   4CO   JP2     -I   4CO   OM      -R   4CO   REAL    -   6F    UG     -R   5EQ
 AA2     ()R   2LC   ETIL     -R   5EQ   IJPS    -I   4CO   JP4     -I   4CO   OMANC   -R   4CO   REZRON  -R  4CO   UL     -R   5EQ
 ADV     -    10SU   FIBP     -R   4CO   IMOME3  -I   4CO   JP402   -I   4CO   OMCYL   -R   4CO   REZSIE  -R  4CO   UP     -R   5EQ
 ANC     -R    4CO   FIPXL    -R   4CO   IMOMX   -I   4CO   JUNF02  -I   4CO   OMEM10  -R   4CO   REZUE   -R  4CO   UTIL   -R   5EQ
 ASQ     -R    4CO   FIPXR    -R   4CO   IM1     -I   4CO   LAMD    -R   6RL   OPEM10  -R   4CO   REZVE   -R  4CO   V      -R   5EQ
 AOFAC   -R    4CO   FIPYB    -R   4CO   IM6     -I   4CO   LCM     -    2F    P       -R   5EQ   REZVT   -R  4CO   VG     -R   5EQ
 COLAMU  -R    4CO   FIPYT    -R   4CO   INP     -I   1AG   LINCNT  -   11SU   PDR     -R   4CO   REZYO   -R  4CO   VL     -R   5EQ
 CO      -R    5EQ   FIXL     -R   4CO   IPAR    -I   4CO   LJP2    -I   4CO   PDZ     -R   4CO   RIBAR   -R  4CO   VP     -R   5EQ
 DELSM   -R    5EQ   FIXR     -R   4CO   IPXL    -I   4CO   LPB     -I   4CO   PL      -R   5EQ   RIBJB   -R  4CO   VTIL   -R   5EQ
 DT      -R    4CO   FIYB     -R   4CO   IPXR    -I   4CO   LPR     -I   4CO   PMX     -R   5EQ   RIBP    -R  4CO   VV     -R   4CO
 DTC     -R    4CO   FIYT     -R   4CO   IPYB    -I   4CO   MB      -R   6RL   PMY     -R   5EQ   RJBP    -R  4CO   X      -R   5EQ
 DTFAC   -R    4CO   FJBP     -R   4CO   IPYT    -I   4CO   MC      -R   6RL   PMO     -R   5EQ   RM      -R  5EQ   XCONV  -R   4CO
 DTGR    -R    4CO   FREZ     -R   4CO   IP1     -I   4CO   ML      -R   6RL   PRINT   -    8F    RMP     -R  5EQ   XL     -R   4CO
 DTGZ    -R    4CO   FSET12   -R   1AG   IP2     -I   4CO   MR      -R   6RL   PU      -R   5EQ   RO      -R  5EQ   XPAR   -R   5EQ
 DTGZP   -R    4CO   FSET7    -R   1AG   ISCF1   -I   4CO   MT      -R   6RL   PV      -R   5EQ   ROL     -R  5EQ   XR     -R   4CO
 DTO     ()R   4CO   FSET8    -R   1AG   ISCF2   -I   4CO   MTE     -R   6RL   PXCONV  -R   4CO   ROMFR   -R  4CO   Y      -R   5EQ
 DTOC    ()R   4CO   FSET9    -R   1AG   ISC2    -I   4CO   MU02    -R   6RL   PXL     -R   4CO   RON     -R  4CO   YAQUI  -    1SU
 DTO16   -R    4CO   GGM1     -R   4CO   ISC3    -I   4CO   MU04    -R   6RL   PXR     -R   4CO   RPDR    -R  4CO   YB     -R   4CO
 DTO2    -R    4CO   GM1      -R   4CO   ITV     -I   4CO   NAME    ()I  4CO   PXRP    -R   4CO   RPDRDZ  -R  4CO   YCONV  -R   4CO
 DTO4    -R    4CO   GR       -R   4CO   IXL     -I   4CO   NCYC    -I   4CO   PYB     -R   4CO   RPDZ    -R  4CO   YLC1   -    2CN
 DTO8    -R    4CO   GZ       -R   4CO   IXR     -I   4CO   NLC     -I   4CO   PYBM    -R   4CO   RVOL    -R  5EQ   YLC2   -    2CN
 DTPOS   -R    4CO   GZP      -R   4CO   IYB     -I   4CO   NPS     -I   4CO   PYCONV  -R   4CO   SIE     -R  5EQ   YPAR   -R   5EQ
 DTV     -R    4CO   I        -I   4CO   IYT     -I   4CO   NPT     -I   4CO   PYT     -R   4CO   T       -R  4CO   YSC1   -    3CN
 DT8     -R    4CO   IBP      -I   4CO   J       -I   4CO   NQI     -I   4CO   PYTP    -R   4CO   THIRD   -R  4CO   YSC2   -    4CN
 E       -R    5EQ   IBP1     -I   4CO   JBP     -I   4CO   NQIB    -I   4CO   Q       -R   5EQ   TLIMD   -R  4CO   YT     -R   4CO
 EMPTY   -    16SU   ICOLOR   -I   4CO   JBP2    -I   4CO   NQI2    -I   4CO   R       -R   5EQ   TOUT    -R  4CO   ZZ     -R   4CO
 FM10    -R    4CO   IDTO     -I   4CO   JM10    -I   4CO   NSC     -I   4CO   RCSQ    -R   5EQ   TWFIN   -R  4CO
 FP      -R    5EQ   IJ       -I   4CO   JM14    -I   4CO   NUMIT   -I   4CO   RDT     -R   4CO   T20MD   -R  4CO
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
MULTIPLY-REFERENCED VARIABLES
    10 -      9*    15
    20 -     12     13*
    30 -     12     14*
    40 -     12     16*
   100 -      8PR   17*
   110 -      9RD   18*
AASC    ()R   3CO   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ   5EQ
AO      -R    4CO   9RD
AOM     -R    4CO   9RD
BO      -R    4CO   9RD
COMMON  -     3F    4F
CYL     -R    4CO   9RD
DR      -R    4CO   9RD
DZ      -R    4CO   9RD
FILM    -R    1AG   1AG
GRDVEL  -R    4CO   9RD
IBAR    -I    4CO   9RD   12
IUNF    -I    4CO   9RD
JBAR    -I    4CO   9RD
JCEN    -I    4CO   9RD
JUNF    -I    4CO   9RD
KXI     -I    4CO   9RD
LAM     -R    4CO   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)           PAGE   4
MU      -R    4CO   6RL
NO      -I    4CO   7=
OUT     -R    1AG   1AG
OVERLAY -    13SU  14SU
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      SUBROUTINE LOOP                                                   YAQUI   00021
      COMMON /YSC1/ AASC(4242)                                          COMMON2 00002
      COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,B0,COLAMU,CYL,           COMMON2 00003
     1       DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTO(10),DTOC(10),          COMMON2 00004
     2       DT016,DT02,DT04,DT08,DTPOS,DTV,DT8,DZ,EM10,EPS,FIBP,       COMMON2 00005
     3       FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,          COMMON2 00006
     4       FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IBAR,IBP,IBP1,ICOLOR,     COMMON2 00007
     5       IDTO,IJ,IJM,IJP,IJPS,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,NQI,NQIB,NQI2,NSC,     COMMON2 00012
     1       NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV,   COMMON2 00013
     2       PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE,   COMMON2 00014
     3       REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJB,RIBP,RJBP,ROMFR,       COMMON2 00015
     4       RON,RPDR,RPDRDZ,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,T20MD,       COMMON2 00016
     5       VV,XCONV,XL,XR,YB,YCONV,YT,ZZ                              COMMON2 00017
      CALL ECWR (AASC(IJMS),IECW,NQI,NE)                                YAQUI   00023
      IECW = IECW + NQI                                                 YAQUI   00024
      GO TO (10,20,30) IBUF                                             YAQUI   00025
   10 IJP = IJPS = 1                                                    YAQUI   00026
      IJ  = ISC3                                                        YAQUI   00027
      IJM = IJMS = ISC2                                                 YAQUI   00028
      IBUF = 2                                                          YAQUI   00029
      GO TO 40                                                          YAQUI   00030
   20 IJP = IJPS = ISC2                                                 YAQUI   00031
      IJ  = 1                                                           YAQUI   00032
      IJM = IJMS = ISC3                                                 YAQUI   00033
      IBUF = 3                                                          YAQUI   00034
      GO TO 40                                                          YAQUI   00035
      ENTRY START                                                       YAQUI   00036
      IJPS = 1                                                          YAQUI   00037
      IECR = IECW = 0                                                   YAQUI   00038
      CALL ECRD (AASC(IJPS),IECR,NQI,NE)                                YAQUI   00039
      IECR = IECR + NQI                                                 YAQUI   00040
      IJPS = ISC2                                                       YAQUI   00041
      CALL ECRD (AASC(IJPS),IECR,NQI,NE)                                YAQUI   00042
      IECR = IECR + NQI                                                 YAQUI   00043
   30 IJP  = IJPS = ISC3                                                YAQUI   00044
      IJ = ISC2                                                         YAQUI   00045
      IJM = IJMS = IBUF = 1                                             YAQUI   00046
   40 CALL ECRD (AASC(IJPS),IECR,NQI,NE)                                YAQUI   00047
      IECR = IECR + NQI                                                 YAQUI   00048
      RETURN                                                            YAQUI   00049
      ENTRY DONE                                                        YAQUI   00050
      CALL ECWR (AASC(IJMS),IECW,NQI,NE)                                YAQUI   00051
      IECW = IECW + NQI                                                 YAQUI   00052
      GO TO (50,60,70) IBUF                                             YAQUI   00053
   50 IJMS = ISC2                                                       YAQUI   00054
      GO TO 80                                                          YAQUI   00055
   60 IJMS = ISC3                                                       YAQUI   00056
      GO TO 80                                                          YAQUI   00057
   70 IJMS = 1                                                          YAQUI   00058
   80 CALL ECWR (AASC(IJMS),IECW,NQI,NE)                                YAQUI   00059
      RETURN                                                            YAQUI   00060
      ENTRY LOOPD                                                       YAQUI   00061
  100 CALL ECWR (AASC(IJS),IECW,NQI,NE)                                 YAQUI   00062
      IECW = IECW - NQI                                                 YAQUI   00063
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INDEX  01/12/73                SUBROUTINE LOOP                                  PAGE   6
                GO TO (110,120,140) IBUF                                        YAQUI  00064
         110    IBUF = 2                                                        YAQUI  00065
                IJ = ISCF1                                                      YAQUI  00066
                IJS = 1                                                         YAQUI  00067
                IJM = ISCF2                                                     YAQUI  00068
                IJMS = ISC2                                                     YAQUI  00069
                GO TO 130                                                       YAQUI  00070
                ENTRY STARTD                                                    YAQUI  00071
                IJMS = ISC2                                                     YAQUI  00072
                IECR = IECW = ITV                                               YAQUI  00073
                CALL ECRD (AASC(IJMS),IECR,NQI,NE)                              YAQUI  00074
                IECR = IECR - NQI                                               YAQUI  00075
         120    IJM = ISCF1                                                     YAQUI  00076
                IJMS = IBUF = 1                                                 YAQUI  00077
                IJ = ISCF2                                                      YAQUI  00078
                IJS = ISC2                                                      YAQUI  00079
         130    IF (IECR.LT.0) GO TO 150                                        YAQUI  00080
                CALL ECRD (AASC(IJMS),IECR,NQI,NE)                              YAQUI  00081
                IECR = IECR - NQI                                               YAQUI  00082
         140    RETURN                                                          YAQUI  00083
         150    IBUF = 3                                                        YAQUI  00084
                GO TO 100                                                       YAQUI  00085
                ENTRY RIROW                                                     YAQUI  00086
                IEC = (J-1) * NQI                                               YAQUI  00087
                CALL ECRD (AASC(1),IEC,NQI,NE)                                  YAQUI  00088
                RETURN                                                          YAQUI  00089
                ENTRY SETIJ                                                     YAQUI  00090
                IJ = (I-1) * NQ + 1                                             YAQUI  00091
                RETURN                                                          YAQUI  00092
                ENTRY WIROW                                                     YAQUI  00093
                IEC = (J-1)*NQI                                                 YAQUI  00094
                CALL ECWR (AASC(1),IEC,NQI,NE)                                  YAQUI  00095
                RETURN                                                          YAQUI  00096
                END                                                             YAQUI  00097
```

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   INDEX  01/12/73                                SUBROUTINE LOOP                                   PAGE   7
 SINGLY REFERENCED VARIABLES
  AA       ()R   3CO   DT08     -R   3CO   GZ       -R   3CO   IYT      -I   3CO   NCYC     -I   3CO   PYCONV   -R   3CO   STARTD   -   52SU
  ANC       -R   3CO   DTPOS    -R   3CO   GZP      -R   3CO   JBAR     -I   3CO   NLC      -I   3CO   PYT      -R   3CO   T        -R   3CO
  ASQ       -R   3CO   DTV      -R   3CO   IBAR     -I   3CO   JBP      -I   3CO   NPS      -I   3CO   PYTP     -R   3CO   THIRD    -R   3CO
  A0        -R   3CO   DT8      -R   3CO   IBP      -I   3CO   JBP2     -I   3CO   NPT      -I   3CO   RDT      -R   3CO   TLIMD    -R   3CO
  A0FAC     -R   3CO   DZ       -R   3CO   IBP1     -I   3CO   JCEN     -I   3CO   NQIB     -I   3CO   REZRON   -R   3CO   TOUT     -R   3CO
  A0M       -R   3CO   EM10     -R   3CO   ICOLOR   -I   3CO   JM10     -I   3CO   NQI2     -I   3CO   REZSIE   -R   3CO   TWFIN    -R   3CO
  B0        -R   3CO   EPS      -R   3CO   IDT0     -I   3CO   JM14     -I   3CO   NSC      -I   3CO   REZUE    -R   3CO   T20MD    -R   3CO
  COLAMU    -R   3CO   FIBP     -R   3CO   IMOME3   -I   3CO   JP1      -I   3CO   NUMIT    -I   3CO   REZVE    -R   3CO   VV       -R   3CO
  CYL       -R   3CO   FIPXL    -R   3CO   IMOMX    -I   3CO   JP2      -I   3CO   NUMTD    -I   3CO   REZVT    -R   3CO   W1ROW    -   74SU
  DONE      -   31SU   FIPXR    -R   3CO   IMI      -I   3CO   JP4      -I   3CO   OM       -R   3CO   REZY0    -R   3CO   XCONV    -R   3CO
  DR        -R   3CO   FIPYB    -R   3CO   IM6      -I   3CO   JP402    -I   3CO   OMANC    -R   3CO   RIBAR    -R   3CO   XL       -R   3CO
  DT        -R   3CO   FIPYT    -R   3CO   IPAR     -I   3CO   JUNF     -I   3CO   OMCYL    -R   3CO   RIBJB    -R   3CO   XR       -R   3CO
  DTC       -R   3CO   FIXL     -R   3CO   IPXL     -I   3CO   JUNF02   -I   3CO   OMEM10   -R   3CO   RIBP     -R   3CO   YB       -R   3CO
  DTFAC     -R   3CO   FIXR     -R   3CO   IPXR     -I   3CO   KXI      -I   3CO   OPEM10   -R   3CO   RJBP     -R   3CO   YCONV    -R   3CO
  DTGR      -R   3CO   FIYB     -R   3CO   IPYB     -I   3CO   LAM      -I   3CO   PDR      -R   3CO   ROMFR    -R   3CO   YSC1     -   2CN
  DTGZ      -R   3CO   FIYT     -R   3CO   IPYT     -I   3CO   LJP2     -I   3CO   PDZ      -R   3CO   RON      -R   3CO   YSC2     -   3CN
  DTGZP     -R   3CO   FJBP     -R   3CO   IPI      -I   3CO   LOOP     -    1SU   PXCONV   -R   3CO   RPDR     -R   3CO   YT       -R   3CO
  DT0      ()R   3CO   FREZ     -R   3CO   IP2      -I   3CO   LOOPD    -   42SU   PXL      -R   3CO   RPDRDZ   -R   3CO   ZZ       -R   3CO
  DT0C     ()R   3CO   GGM1     -R   3CO   IUNF     -I   3CO   LPB      -I   3CO   PXR      -R   3CO   RPDZ     -R   3CO
  DT016     -R   3CO   GM1      -R   3CO   IXL      -I   3CO   LPR      -I   3CO   PXRP     -R   3CO   R1ROW    -  67SU
  DT02      -R   3CO   GR       -R   3CO   IXR      -I   3CO   MU       -I   3CO   PYB      -R   3CO   SETIJ    -  71SU
  DT04      -R   3CO   GRDVEL   -R   3CO   IYB      -I   3CO   NAME     ()I  3CO   PYBM     -R   3CO   START    -  17SU
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
 MULTIPLY-REFERENCED VARIABLES
      10 -     6      7*
      20 -     6     12*
      30 -     6     25*
      40 -    11     16      28*
      50 -    34     35*
      60 -    34     37*
      70 -    34     39*
      80 -    36     38      40*
     100 -    43*    66
     110 -    45     46*
     120 -    45     57*
     130 -    51     61*
     140 -    45     64*
     150 -    61     65*
 AASC    ()R    2CO    4AG    20AG   23AG   28AG   32AG   40AG   43AG   55AG   62AG   69AG   76AG
 COMMON   -     2F     3F
 ECRD     -    20SU   23SU   28SU   55SU   62SU   69SU
 ECWR     -     4SU   32SU   40SU   43SU   76SU
 FNTRY    -    17F    31F    42F    52F    67F    71F    74F
 I        -I    3CO   72
 IBUF     -I    6     10=    15=    27=    34     45     46=    58=    65=
 IEC      -I   68=    69AG   75=    76AG
 IECR     -I   19=    20AG   21=    21     23AG   24=    24     28AG   29=    29     54=    55AG   56=    56     61     62AG   63=
               63
 IECW     -I    4AG   5=     5      19=    32AG   33=    33     40AG   43AG   44=    44     54=
 IJ       -I    3CO   8=     13=    26=    47=    59=    72=
 IJM      -I    3CO   9=     14=    27=    49=    57=
 IJMS     -I    4AG   9=     14=    27=    32AG   35=    37=    39=    40AG   50=    53=    55AG   58=    62AG
 IJP      -I    3CO   7=     12=    25=
 IJPS     -I    3CO   7=     12=    18=    20AG   22=    23AG   25=    28AG
 IJS      -I   43AG   48=    60=
 ISCF1    -I    3CO   47     57
 ISCF2    -I    3CO   49     59


     INDEX  01/12/73                              SUBROUTINE LOOP                                   PAGE   8
 ISC2     -I    3CO   9      12     22     26     35     50     53     60
 ISC3     -I    3CO   8      14     25     37
 ITV      -I    3CO   54
 J        -I    3CO   68     75
 NE       -I    4AG   20AG   23AG   28AG   32AG   40AG   43AG   55AG   62AG   69AG   76AG
 NQ       -I    3CO   72
 NQI      -I    3CO   4AG    5      20AG   21     23AG   24     28AG   29     32AG   33     40AG   43AG   44     55AG   56     62AG
               63    68     69AG   75     76AG
 RETURN   -    30F    41F    64F    70F    73F    77F
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INDEX  01/12/73                SUBROUTINE FILMCO                                PAGE    9
    1          SUBROUTINE FILMCO                                               YAQUI   00098
    2          COMMON /YSC1/ AASC(4242)                                        COMMON2 00002
    3          COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,BC,COLAMU,CYL,         COMMON2 00003
             1        DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTO(10),DTOC(10),        COMMON2 00004
             2        DTO16,DTO2,DTO4,DTO8,DTPOS,DTV,DT8,DZ,EM10,EPS,FIBP,     COMMON2 00005
             3        FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,        COMMCN2 00006
             4        FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IBAR,IBP,IBP1,ICOLOR,   COMMON2 00007
             5        IDTO,IJ,IJM,IJP,IJPS,IMOME3,IMOMX,IM1,IM6,               COMMCN2 00008
             6        IPAR,IPXL,IPXR,IPYB,IPYT,IP1,IP2,ISCF1,ISCF2,ISC2,ISC3,  COMMON2 00009
             7        ITV,IUNF,IXL,IXR,IYB,IYT,J,JBAP,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,NQI,NQIB,NQI2,NSC,   COMMON2 00012
             1        NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV, COMMON2 00013
             2        PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE, COMMON2 00014
             3        REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJB,RIBP,RJBP,ROMFR,     COMMON2 00015
             4        RON,RPDR,RPDRDZ,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,T20MD,     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),RO),    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,PM0),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL, EQVREAL 00006
             5            VL,PMY,PV),(AASC(14),Q,ROL)                          EQVREAL 00007
    5          REAL LAM,LAMD,M,MB,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),RO(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          PMY(1),PV(1),Q(1),ROL(1),PM0(1)                        DIMEN   00006
    7          XL = 0.0                                                        YAQUI   00102
    8          YB = 1.E+20                                                     YAQUI   00103
    9          XR = YT = -YB                                                   YAQUI   00104
   10          CALL START                                                      YAQUI   00105
   11          DO 129 J=2,JP2                                                  YAQUI   00106
   12          DO 119 I=1,IP1                                                  YAQUI   00107
   13          XR = AMAX1(XR,X(IJ))                                            YAQUI   00108
   14          YB = AMIN1(YB,Y(IJ))                                            YAQUI   00109
   15          YT = AMAX1(YT,Y(IJ))                                            YAQUI   00110
   16      119 IJ = IJ + NQ                                                    YAQUI   00111
   17          CALL LOOP                                                       YAQUI   00112
   18      129 CONTINUE                                                        YAQUI   00113
   19          VV = 0.9*XR*RIBAR                                               YAQUI   00114
   20          FIYB = 916.0                                                    YAQUI   00115
   21          XD  = XR/(YT-YB)                                                YAQUI   00116
   22          YY    = 0.0                                                     YAQUI   00117
   23          IF (XD.LE.1.13556) YY=1.                                        YAQUI   00118
   24          FIXL = AMAX1(0.,(511.-450.*XD)*YY)                              YAQUI   00119
   25          FIXR = (511.+450.*XD)*YY + 1022.*(1.-YY)                        YAQUI   00120
   26          FIYT = 16.*YY  + (916.-1022./XD)*(1.-YY)                        YAQUI   00121
   27          XCONV = (FIXR-FIXL)/(XR-XL)                                     YAQUI   00122
   28          YCONV = (FIYT-FIYB)/(YT-YB)                                     YAQUI   00123
   29          IXL = FIXL                                                      YAQUI   00124
   30          IXR = FIXR                                                      YAQUI   00125
   31          IYB = FIYB                                                      YAQUI   00126
   32          IYT = FIYT                                                      YAQUI   00127
   33          IF (NPT.EQ.0) RETURN                                            YAQUI   00128
   34          PXL = 0.0                                                       YAQUI   00129
   35          PYB = YB + PYB                                                  YAQUI   00130
```

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INDEX  01/12/73                   SUBROUTINE FILMCO                                  PAGE  10
        36          PXR = PDR*FIBP                                                   YAQUI   00131
        37          PYT = PYB + PDZ*FJBP                                             YAQUI   00132
        38          PXRP = PXR*OPEM10                                                YAQUI   00133
        39          PYBM = PYB*OMEM10                                                YAQUI   00134
        40          PYTP = PYT*OPEM10                                                YAQUI   00135
        41          RPDR = 1./PDR                                                    YAQUI   00136
        42          RPDZ = 1./PDZ                                                    YAQUI   00137
        43          RPDRDZ = RPDR*RPDZ                                               YAQUI   00138
        44          FJPYB = 916.0                                                    YAQUI   00139
        45          XD = PXR/(PYT-PYB)                                               YAQUI   00140
        46          YY = 0.0                                                         YAQUI   00141
        47          IF (XD.LE.1.13556) YY=1.                                         YAQUI   00142
        48          FIPXL = AMAX1(0.,(511.-450.*XD)*YY)                              YAQUI   00143
        49          FIPXR = (511.+450.*XD)*YY + 1022.*(1.-YY)                        YAQUI   00144
        50          FIPYT = 16.*YY + (916.-1022./XD) *(1.-YY)                        YAQUI   00145
        51          PXCONV = (FIPXR-FIPXL)/(PXR-PXL)                                 YAQUI   00146
        52          PYCONV = (FIPYT-FIPYB)/(PYT-PYB)                                 YAQUI   00147
        53          IPXL = FIPXL                                                     YAQUI   00148
        54          IPXR = FIPXR                                                     YAQUI   00149
        55          IPYB = FIPYB                                                     YAQUI   00150
        56          IPYT = FIPYT                                                     YAQUI   00151
        57          RETURN                                                           YAQUI   00152
        58          END                                                              YAQUI   00153
```

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 INDEX  01/12/73                             SUBROUTINE FILMCO                                           PAGE  11
SINGLY REFERENCED VARIABLES
 AA      ()R   3CO    DTO     ()R   3CO    GROVEL  -R   3CO    ISCF2   -I   3CO    LJP2    -I   3CO    NQI2    -I   3CO    ROMFR   -R   3CO
 AMIN1   -    14SU    DTOC    ()R   3CO    GZ      -R   3CO    ISC2    -I   3CO    LOOP    -   17SU    NSC     -I   3CO    RON     -R   3CO
 ANC     -R    3CO    DT016   -R    3CO    GZP     -R   3CO    ISC3    -I   3CO    LPB     -I   3CO    NUMIT   -I   3CO    START   -   10SU
 ASO     -R    3CO    DT02    -R    3CO    IBAR    -I   3CO    ITV     -I   3CO    LPR     -I   3CO    NUMTD   -I   3CO    T       -R   3CO
 A0      -R    3CO    DT04    -R    3CO    IBP     -I   3CO    IUNF    -I   3CO    MB      -R   5RL    OM      -R   3CO    THIRD   -R   3CO
 A0FAC   -R    3CO    DT08    -R    3CO    IBP1    -I   3CO    JBAR    -I   3CO    MC      -R   5RL    OMANC   -R   3CO    TLIMD   -R   3CO
 A0M     -R    3CO    DTPOS   -R    3CO    ICOLOR  -I   3CO    JBP     -I   3CO    ML      -R   5RL    OMCYL   -R   3CO    TOUT    -R   3CO
 B0      -R    3CO    DTV     -R    3CO    IDTO    -I   3CO    JBP2    -I   3CO    MR      -R   5RL    RDT     -R   3CO    TWFIN   -R   3CO
 COLAMU  -R    3CO    DT8     -R    3CO    IJM     -I   3CO    JCEN    -I   3CO    MT      -R   5RL    REAL    -    5F     T20MD   -R   3CO
 CYL     -R    3CO    DZ      -R    3CO    IJP     -I   3CO    JM10    -I   3CO    MTE     -R   5RL    REZRON  -R   3CO    YSC1    -    2CN
 DIMENSI -     6F     EM10    -R    3CO    IJPS    -I   3CO    JM14    -I   3CO    MU02    -R   5RL    REZSIE  -R   3CO    YSC2    -    3CN
 DR      -R    3CO    EPS     -R    3CO    IMOME3  -I   3CO    JP1     -I   3CO    MU04    -R   5RL    REZUE   -R   3CO    ZZ      -R   3CO
 DT      -R    3CO    EQUIVAL -     4F     IMOMX   -I   3CO    JP4     -I   3CO    NAME    ()I  3CO    REZVE   -R   3CO
 DTC     -R    3CO    FILMCO  -     1SU    IM1     -I   3CO    JP402   -I   3CO    NCYC    -I   3CO    REZVT   -R   3CO
 DTFAC   -R    3CO    FREZ    -R    3CO    IM6     -I   3CO    JUNF    -I   3CO    NLC     -I   3CO    REZY0   -R   3CO
 DTGR    -R    3CO    GGM1    -R    3CO    IPAR    -I   3CO    JUNF02  -I   3CO    NPS     -I   3CO    RIBJB   -R   3CO
 DTGZ    -R    3CO    GM1     -R    3CO    IP2     -I   3CO    KXI     -I   3CO    NQI     -I   3CO    RIBP    -R   3CO
 DTGZP   -R    3CO    GR      -R    3CO    ISCF1   -I   3CO    LAMD    -R   5RL    NQIB    -I   3CO    RJBP    -R   3CO
♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-♦-
 MULTIPLY-REFERENCED VARIABLES
    119 -     1200   16*
    129 -     1100   18*
AASC    ()R   2CO    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ
AMAX1   -    13SU   15SU   24SU   48SU
COMMON  -     2F     3F
CQ      ()R   4EQ    6DI
DELSM   ()R   4EQ    6DI
E       ()R   4EQ    6DI
EP      ()R   4EQ    6DI
FTIL    ()R   4EQ    6DI
FIBP    -R    3CO    36
FIPXL   -R    3CO    48=    51     53
FIPXR   -R    3CO    49=    51     54
FIPYB   -R    3CO    44=    52     55
FIPYT   -R    3CO    50=    52     56
FIXL    -R    3CO    24=    27     29
FIXR    -R    3CO    25=    27     30
FIYB    -R    3CO    20=    28     31
FIYT    -R    3CO    26=    28     32
FJBP    -R    3CO    37
I       -I    3CO    1200
IJ      -I    3CO    13     14     15     16*    16
IPXL    -I    3CO    53=
IPXR    -I    3CO    54=
IPYB    -I    3CO    55=
IPYT    -I    3CO    56=
IP1     -I    3CO    1200
IXL     -I    3CO    29=
IXR     -I    3CO    30=
IYB     -I    3CO    31=
IYT     -I    3CO    32=
J       -I    3CO    1100
JP2     -I    3CO    1100
LAM     -R    3CO     5RL
M       ()R   4EQ     5RL    6DI
MP      ()R   4EQ     5RL    6DI
MPAR    ()R   4EQ     5RL    6DI
```

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    INDEX  01/12/73                    SUBROUTINE FILMCO                            PAGE  12
MU       -R     3CO     5RL
NPT      -I     3CO    33
NQ       -I     3CO    16
OMEMI0   -R     3CO    39
OPEMI0   -R     3CO    38      40
P       ()R     4EQ     6DI
PDR      -R     3CO    36      41
PDZ      -R     3CO    37      42
PL      ()R     4EQ     6DI
PMX     ()R     4EQ     6DI
PMY     ()R     4EQ     6DI
PMO     ()R     4EQ     6DI
PU      ()R     4EQ     6DI
PV      ()R     4EQ     6DI
PXCONV   -R     3CO    51=
PXL      -R     3CO    34=     51
PXR      -R     3CO    36=     38      45      51
PXRP     -R     3CO    38=
PYB      -R     3CO    35=     35      37      39      45      52
PYRM     -R     3CO    39=
PYCONV   -R     3CO    52=
PYT      -R     3CO    37=     40      45      52
PYTP     -R     3CO    40=
Q       ()R     4EQ     6DI
R       ()R     4EQ     6DI
RCSQ    ()R     4EQ     6DI
RETURN   -     33F     57F
RIBAR    -R     3CO    19
RM      ()R     4EQ     6DI
RMP     ()R     4EQ     6DI
RO      ()R     4EQ     6DI
ROL     ()R     4EQ     6DI
RPDR     -R     3CO    41=     43
RPDRDZ   -R     3CO    43=
RPDZ     -R     3CO    42=     43
RVOL    ()R     4EQ     6DI
SIF     ()R     4EQ     6DI
U       ()R     4EQ     6DI
UG      ()R     4EQ     6DI
UL      ()R     4EQ     6DI
UP      ()R     4EQ     6DI
UTIL    ()R     4EQ     6DI
V       ()R     4EQ     6DI
VG      ()R     4EQ     6DI
VL      ()R     4EQ     6DI
VP      ()R     4EQ     6DI
VTIL    ()R     4EQ     6DI
VV       -R     3CO    19=
X       ()R     4EQ     6DI     13
XCONV    -R     3CO    27=
XD       -R    21=     23      24      25      26      45=     47      48      49      50
XL       -R     3CO     7=     27
XPAR    ()R     4EQ     6DI
XR       -R     3CO     9=     13=     13      19      21      27
Y       ()R     4EQ     6DI     14      15
YB       -R     3CO     8=      9      14=     14      21      28      35
YCONV    -R     3CO    28=
YPAR    ()R     4EQ     6DI
```

```
   INDEX  01/12/73                     SUBROUTINE FILMCO                                 PAGE  13
YT      -R    3CO     9=     15=     15      21     28
YY      -R   22=     23=     24      25      25     26      26      46=     47=     48      49      49      50      50
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
```

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

```
   INDEX  01/12/73                     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*
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
```

```
      SUBROUTINE YASET1                                                 YASET    00008
      LCM /YLC1/   AA1(131000)   /YLC2/ AA2(131000)                     YASET    00009
      COMMON /YSC1/ AASC(4242)                                          COMMON2  00002
      COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,B0,COLAMU,CYL,           COMMON2  00003
     1        DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTO(10),DTOC(10),         COMMON2  00004
     2        DTO16,DTO2,DTO4,DTO8,DTPOS,DTV,DT8,DZ,EM10,EPS,FIBP,      COMMON2  00005
     3        FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,         COMMON2  00006
     4        FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IBAR,IBP,IBP1,ICOLOR,    COMMON2  00007
     5        IDTO,IJ,IJM,IJP,IJPS,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,NQI,NQIB,NQI2,NSC,    COMMON2  00012
     1        NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV,  COMMON2  00013
     2        PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE,  COMMON2  00014
     3        REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJB,RIBP,RJBP,ROMFR,      COMMON2  00015
     4        RON,RPDR,RPDRDZ,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,T20MD,      COMMON2  00016
     5        VV,XCONV,XL,XR,YB,YCONV,YT,ZZ                             COMMON2  00017
      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),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,PM0),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL, EQVREAL  00006
     5             VL,PMY,PV),(AASC(14),Q,ROL)                          EQVREAL  00007
      REAL LAM,LAMD,M,MB,MC,ML,MP,MPAR,MR,MT,MTE,MU,MU02,MU04           EQVREAL  00008
      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),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           PMY(1),PV(1),Q(1),ROL(1),PM0(1)                        DIMEN    00006
      READ 500, NAME                                                    YASET    00013
      READ 510, MU,LAM,OM,EPS,GR,GZ,ASQ,RON,GM1                         YASET    00014
      READ 515, FREZ,YB,REZY0,REZUE,REZVE,REZVT,REZRON,REZSIE           YASET    00015
      READ 520, IBP,JBP,PDR,PDZ,PYB,GZP,IMOMX                           YASET    00016
      READ 530, T,DT,T20MD,TLIMD,TWFIN,LPR,ICOLOR                       YASET    00017
      READ 540, (DTO(N),N=1,10)                                         YASET    00018
      READ 540, (DTOC(N),N=1,10)                                        YASET    00019
      KT = 9                                                            YASET    00020
      ASSIGN 110 TO KRET                                                YASET    00021
  100 WRITE(KT,500) NAME                                                YASET    00022
      WRITE(KT,550) IBAR,JBAR,IUNF,JUNF,JCEN,DR,DZ,CYL,GRDVEL,          YASET    00023
     1              A0,A0M,B0,KXI                                       YASET    00024
      WRITE(KT,560) MU,LAM,OM,EPS,GR,GZ,ASQ,RON,GM1                     YASET    00025
      WRITE(KT,565) FREZ,YB,REZY0,REZUE,REZVE,REZVT,REZRON,REZSIE       YASET    00026
      WRITE(KT,570) IBP,JBP,PDR,PDZ,PYB,GZP,IMOMX                       YASET    00027
      WRITE(KT,580) T,DT,T20MD,TLIMD,TWFIN,LPR,ICOLOR                   YASET    00028
      WRITE(KT,590) (DTO(N),N=1,10)                                     YASET    00029
      WRITE(KT,600) (DTOC(N),N=1,10)                                    YASET    00030
      GO TO KRET                                                        YASET    00031
  110 IF (LPR.EQ.0) GOTO 120                                            YASET    00032
      KT = 12                                                           YASET    00033
      ASSIGN 120 TO KRET                                                YASET    00034
      GO TO 100                                                         YASET    00035
  120 IM1   = IBAR - 1                                                  YASET    00036
      IM6 = IBAR-6                                                      YASET    00037
      IP1   = IBAR + 1                                                  YASET    00038
      IP2   = IBAR + 2                                                  YASET    00039
      JM10 = JBAR-10                                                    YASET    00040
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      JM14  = JBAR - 14                                       YASET   00041
      JP1   = JBAR + 1                                        YASET   00042
      JP2   = JBAR + 2                                        YASET   00043
      JP4   = JBAR + 4                                        YASET   00044
      JP402 = JP4  /  2                                       YASET   00045
      RIBAR = 1./FLOAT(IBAR)                                  YASET   00046
      RIBJB = 1./FLOAT(IBAR*JBAR)                             YASET   00047
      NQIB = NQ * IBAR                                        YASET   00048
      OMCYL = 1.-CYL                                          YASET   00049
      NQI   = NQ * IP1                                        YASET   00050
      ISC2  = NQI + 1                                         YASET   00051
      ISC3  = ISC2 + NQI                                      YASET   00052
      ITV   = JP1 * NQI                                       YASET   00053
      ISCF1 = ISC2 - NQ                                       YASET   00054
      ISCF2 = ISCF1 + NQI                                     YASET   00055
      NSC   = LOCF(ZZ) - LOCF(AA) +1                          YASET   00056
      NLC   = LOCF(AA1(JP4*NQI)) - LOCF(AA1) +1               YASET   00057
      LJP2 = JP2 - JP2/3 * 3                                  YASET   00058
      IF (LJP2.EQ.0) LJP2 = 3                                 YASET   00059
      LJP2 = LJP2*NQI -NQ +1                                  YASET   00060
      IDTO = 1                                                YASET   00061
      TOUT = T + DTO(1)                                       YASET   00062
      DT = DTPOS = DT*0.1                                     YASET   00063
      NCYC = NUMTD = 0                                        YASET   00064
      EM10 = 1.E-10                                           YASET   00065
      OMEM10 = 1.-EM10                                        YASET   00066
      OPEM10 = 1.+EM10                                        YASET   00067
      ANC = 0.05                                              YASET   00068
      OMANC = 1.-ANC                                          YASET   00069
      COLAMU = (1.0+1.67)/(LAM+MU+MU+EM10)                    YASET   00070
      AOFAC = AOM/(2.0*(1.+AOM**2))                           YASET   00071
      GGM1 = (GM1+1.)*GM1                                     YASET   00072
      THIRD = 1./3.                                           YASET   00073
      IUNF    = MAX0(IUNF,1)                                  YASET   00074
      JUNF    = MAX0(JUNF,2)                                  YASET   00075
      JUNF02 = JUNF/2                                         YASET   00076
      IF (JCEN.EQ.0) JCEN = JBAR/2                            YASET   00077
      IF (FREZ.NE.1.) ROMFR = 1./(1.-FREZ)                    YASET   00078
      CALL PARTGEN                                            YASET   00079
      CALL MESHMKR                                            YASET   00080
      CALL FILMCO                                             YASET   00081
200   CALL START                                              YASET   00082
      DO 229 J=2,JP1                                          YASET   00083
      DO 219 I=1,IBAR                                         YASET   00084
      IPJ = IJ + NQ                                           YASET   00085
      IPJP = IJP + NQ                                         YASET   00086
      X1 = X(IPJ)                                             YASET   00087
      Y1 = Y(IPJ)                                             YASET   00088
      R1 = R(IPJ)                                             YASET   00089
      X2 = X(IPJP)                                            YASET   00090
      Y2 = Y(IPJP)                                            YASET   00091
      R2 = R(IPJP)                                            YASET   00092
      X3 = X(IJP)                                             YASET   00093
      Y3 = Y(IJP)                                             YASET   00094
      R3 = R(IJP)                                             YASET   00095
      X4 = X(IJ)                                              YASET   00096
      Y4 = Y(IJ)                                              YASET   00097
      R4 = R(IJ)                                              YASET   00098
```

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            ATR = .5*(X1*(Y2-Y3)+X2*(Y3-Y1)+X3*(Y1-Y2))                           YASET   00099
            ABL = .5*(X1*(Y3-Y4)+X3*(Y4-Y1)+X4*(Y1-Y3))                           YASET   00100
            M(IJ) = THIRD*(ATR*(R1+R2+R3)+ABL*(R1+R3+R4))*RO(IJ)                  YASET   00101
            RVOL(IJ) = RO(IJ)/M(IJ)                                               YASET   00102
            E(IJ) = SIE(IJ)+.125*(U(IPJ)**2+U(IPJP)**2+U(IJP)**2+U(IJ)**2         YASET   00103
           1                        +V(IPJ)**2+V(IPJP)**2+V(IJP)**2+V(IJ)**2)     YASET   00104
            IJ = IPJ                                                              YASET   00105
      219   IJP = IPJP                                                            YASET   00106
            CALL LOOP                                                             YASET   00107
      229   CONTINUE                                                              YASET   00108
            CALL DONE                                                             YASET   00109
      300   CALL STARTD                                                           YASET   00110
            DO 359 JJ=2,JP2                                                       YASET   00111
            J = JP4 - JJ                                                          YASET   00112
            DO 349 II=1,IP1                                                       YASET   00113
            I = IP2 - II                                                          YASET   00114
            IMJ = IJ - NQ                                                         YASET   00115
            IMJM = IJM -NQ                                                        YASET   00116
            XX = 0.0                                                              YASET   00117
            IF (I.NE.IP1 .AND. J.NE.2  ) XX = M(IJM)                              YASET   00118
            IF (I.NE.IP1 .AND. J.NE.JP2) XX = XX+M(IJ)                            YASET   00119
            IF (I.NE.1   .AND. J.NE.JP2) XX = XX+M(IMJ)                           YASET   00120
            IF (I.NE.1   .AND. J.NE.2  ) XX = XX+M(IMJM)                          YASET   00121
      340   RM(IJ) = 4./XX                                                        YASET   00122
            IJ = IMJ                                                              YASET   00123
      349   IJM = IMJM                                                            YASET   00124
            CALL LOOPD                                                            YASET   00125
      359   CONTINUE                                                              YASET   00126
            RETURN                                                                YASET   00127
      C                                                                           YASET   00128
      500   FORMAT(10A8)                                                          YASET   00129
      510   FORMAT(9F8.3)                                                         YASET   00130
      515   FORMAT(8F8.3)                                                         YASET   00131
      520   FORMAT(2I4,4F8.3,I4)                                                  YASET   00132
      530   FORMAT(5F8.3,2I4)                                                     YASET   00133
      540   FORMAT(10F8.3)                                                        YASET   00134
      550   FORMAT(3X*IBAR=*I4/3X*JBAR=*I4/3X*IUNF=*I4/3X*JUNF=*I4/3X*JCEN=*I4    YASET   00135
           1/5X*DR=*1PE12.5/5X*DZ=*E12.5/4X*CYL=*E12.5/* GRDVEL=*E12.5/5X*A0=*    YASET   00136
           2E12.5/4X*A0M=*E12.5/5X*B0=*E12.5/4X*KXI=*I2)                          YASET   00137
      560   FORMAT(5X*MU=*1PE12.5/4X*LAM=*E12.5/5X*OM=*E12.5/4X*EPS=*E12.5/5X*    YASET   00138
           1GP=*E12.5/5X*GZ=*E12.5/4X*ASQ=*E12.5/4X*RON=*E12.5/4X*GM1=*E12.5)     YASET   00139
      565   FORMAT(3X*FREZ=*1PE12.5/5X*YB=*E12.5/*  REZY0=*E12.5/*  REZUE=*        YASET   00140
           1 E12.5/*  REZVE=*E12.5/*  REZVT=*E12.5/* REZRON=*E12.5/* REZSIE=*     YASET   00141
           2 E12.5)                                                               YASET   00142
      570   FORMAT(4X*IBP=*I4/4X*JBP=*I4/4X*PDR=*1PE12.5/4X*PDZ=*E12.5/4X*PYB=    YASET   00143
           1*E12.5/4X*GZP=*E12.5/2X*IMOMX=*I2)                                    YASET   00144
      580   FORMAT(6X*T=*1PE12.5/5X*DT=*E12.5/*  T20MD=*E12.5/*  TLIMD=*E12.5/    YASET   00145
           1*  TWFIN=*E12.5/4X*LPR=*I2/* ICOLOR=*I2)                              YASET   00146
      590   FORMAT(*  DTO(1-10)=*5(1PE12.5,2X)/12X,5(E12.5,2X))                   YASET   00147
      600   FORMAT(* DTOC(1-10)=*5(1PE12.5,2X)/12X,5(E12.5,2X))                   YASET   00148
            END                                                                   YASET   00149
```

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   INDEX  01/12/73                                 SUBROUTINE YASET1                                      PAGE  20
 SINGLY REFERENCED VARIABLES
      200 -    76*    DTO4     -R    4CO    FIYB     -R    4CO    IYB      -I    4CO    MT       -R    6RL    PYBM     -R    4CO    STARTD   -  103SU
      300 -   103*    DTOR     -R    4CO    FIYT     -R    4CO    IYT      -I    4CO    MTE      -R    6RL    PYCONV   -R    4CO    VV       -R    4CO
      340 -   115*    DTV      -R    4CO    FJBP     -R    4CO    JBP2     -I    4CO    MUO2     -R    6RL    PYT      -R    4CO    XCONV    -R    4CO
  AA2     ()R    2LC    DT8      -R    4CO    IBPI     -I    4CO    LAMD     -R    6RL    MUO4     -R    6RL    PYTP     -R    4CO    XL       -R    4CO
  DIMENSI -      7F     EQUIVAL  -     5F     IJPS     -I    4CO    LCM      -     2F     NPS      -I    4CO    RDT      -R    4CO    XR       -R    4CO
  DONE    -   102SU    FIBP     -R    4CO    IMOME3   -I    4CO    LOOP     -  100SU    NPT      -I    4CO    REAL     -     6F     YASET1   -    1SU
  DTC     -R     4CO    FILMCO   -   75SU    IPAR     -I    4CO    LOOPD    -  118SU    NQI2     -I    4CO    RETURN   -   120F     YCONV    -R    4CO
  DTFAC   -R     4CO    FIPXL    -R    4CO    IPXL     -I    4CO    LPB      -I    4CO    NUMIT    -I    4CO    RIBP     -R    4CO    YLC1     -     2CN
  DTGR    -R     4CO    FIPXR    -R    4CO    IPXR     -I    4CO    MB       -R    6RL    PARTGEN  -   73SU    RJBP     -R    4CO    YLC2     -     2CN
  DTGZ    -R     4CO    FIPYB    -R    4CO    IPYB     -I    4CO    MC       -R    6RL    PXCONV   -R    4CO    RPDR     -R    4CO    YSC1     -     3CN
  DTGZP   -R     4CO    FIPYT    -R    4CO    IPYT     -I    4CO    MESHMKR  -   74SU    PXL      -R    4CO    RPDRDZ   -R    4CO    YSC2     -     4CN
  DTO16   -R     4CO    FIXL     -R    4CO    IXL      -I    4CO    ML       -R    6RL    PXR      -R    4CO    RPDZ     -R    4CO    YT       -R    4CO
  DTO2    -R     4CO    FIXR     -R    4CO    IXR      -I    4CO    MR       -R    6RL    PXRP     -R    4CO    START    -   76SU
◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-◆-
 MULTIPLY-REFERENCED VARIABLES
      100 -     17*    29
      110 -     16AS   26*
      120 -     26     28AS   30*
      219 -     78DO   99*
      229 -     77DO  101*
      349 -    106DO  117*
      359 -    104DO  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       ()R     4CO    50
 AASC     ()R     3CO     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ
 AA1      ()R     2LC    51      51
 ABL       -R    94=     95
 ANC       -R     4CO    62=     63
 ASQ       -R     4CO     9RD    19WR
 ASSIGN    -     16F     28F
 ATR       -R    93=     95
 AO        -R     4CO    18WR
 AOFAC     -R     4CO    65=
 AOM       -R     4CO    18WR    65      65
 BO        -R     4CO    18WR
 COLAMU    -R     4CO    64=
 COMMON    -      3F      4F
 CQ       ()R     5EQ     7DI
 CYL       -R     4CO    18WR    43
 DELSM    ()R     5EQ     7DI
 DR        -R     4CO    18WR
 DT        -R     4CO    12RD    22WR    57=     57
 DTO      ()R     4CO    13RD    23WR    56
 DTOC     ()R     4CO    14RD    24WR
 DTPOS     -R     4CO    57=
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DZ       -R     4CO   18WR
E        ()R    5EQ    7DI   97=
EM10     -R     4CO   59=    60     61     64
EP       ()R    5EQ    7DI
EPS      -R     4CO    9RD   19WR
ETIL     ()R    5EQ    7DI
FLOAT    -     40SU   41SU
FRFZ     -R     4CO   10RD   20WR   72     72
GGM1     -R     4CO   66=
GM1      -R     4CO    9RD   19WR   66     66
GR       -R     4CO    9RD   19WR
GRDVEL   -R     4CO   18WR
GZ       -R     4CO    9RD   19WR
GZP      -R     4CO   11RD   21WR
I        -I     4CO   78DO  107=   111    112    113    114
IBAR     -I     4CO   18WR   30     31     32     33     40     41     42     7800
IBP      -I     4CO   11RD   21WR
ICOLOR   -I     4CO   12RD   22WR
IDTO     -I     4CO   55=
II       -I   106DO  107
IJ       -I     4CO   79     90     91     92     95     95     96     96     96     97     97     97     97     98=   108    112
               115   116=
IJM      -I     4CO  109    111    117=
IJP      -I     4CO   80     87     88     89     97     97     99=
IMJ      -I   108=   113    116
IMJM     -I   109=   114    117
IMOMX    -I     4CO   11RD   21WR
IM1      -I     4CO   30=
IM6      -I     4CO   31=
IPJ      -I    79=    81     82     83     97     97     98
IPJP     -I    80=    84     85     86     97     97     99
IP1      -I     4CO   32=    44    106DO  111    112
IP2      -I     4CO   33=   107
ISCF1    -I     4CO   48=    49
ISCF2    -I     4CO   49=
ISC2     -I     4CO   45=    46     48
ISC3     -I     4CO   46=
ITV      -I     4CO   47=
IUNF     -I     4CO   18WR   68=    68
J        -I     4CO   77DO  105=   111    112    113    114
JBAR     -I     4CO   18WR   34     35     36     37     38     41     71
JBP      -I     4CO   11RD   21WR
JCEN     -I     4CO   18WR   71     71=
JJ       -I   104DO  105
JM10     -I     4CO   34=
JM14     -I     4CO   35=
JP1      -I     4CO   36=    47     77DO
JP2      -I     4CO   37=    52     52    104DO  112    113
JP4      -I     4CO   38=    39     51    105
JP402    -I     4CO   39=
JUNF     -I     4CO   18WR   69=    69     70
JUNF02   -I     4CO   70=
KRFT     -I    16AS   25     28AS
KT       -I    15=    17WR   18WR   19WR   20WR   21WR   22WR   23WR   24WR   27=
KXT      -I     4CO   18WR
LAM      -R     4CO    6RL    9RD   19WR   64
LJP2     -I     4CO   52=    53     53=    54=    54
LOCF     -     50SU   50SU   51SU   51SU
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     INDEX  01/12/73                                  SUBROUTINE YASET1                                  PAGE  22
LPR      -I     4CO     12RD     22WR     26
M       ()R     5EQ      6RL      7DI     95=      96      111      112      113      114
MAXO     -     68SU     69SU
MP      ()R     5EQ      6RL      7DI
MPAR    ()R     5EQ      6RL      7DI
MU       -R     4CO      6RL      9RD     19WR     64       64
N        -I    13RD     13RD     14RD     14RD     23WR     23WR     24WR     24WR
NAME    ()I     4CO      8RD     17WR
NCYC     -I     4CO     58=
NLC      -I     4CO     51=
NQ       -I     4CO     42       44       48       54       79       80       108      109
NQI      -I     4CO     44=      45       46       47       49       51        54
NQIB     -I     4CO     42=
NSC      -I     4CO     50=
NUMTD    -I     4CO     58=
OM       -R     4CO      9RD     19WR
OMANC    -R     4CO     63=
OMCYL    -R     4CO     43=
OMEM10   -R     4CO     60=
OPEM10   -R     4CO     61=
P       ()R     5EQ      7DI
PDR      -R     4CO     11RD     21WR
PD7      -R     4CO     11RD     21WR
PL      ()R     5EQ      7DI
PMX     ()R     5EQ      7DI
PMY     ()R     5EQ      7DI
PMO     ()R     5EQ      7DI
PU      ()R     5EQ      7DI
PV      ()R     5EQ      7DI
PYR      -R     4CO     11RD     21WR
Q       ()R     5EQ      7DI
R       ()R     5EQ      7DI     83       86       89       92
RCSQ    ()R     5EQ      7DI
READ     -      8F       9F      10F      11F      12F      13F      14F
REZRON   -R     4CO     10RD     20WR
REZSIE   -R     4CO     10RD     20WR
REZUF    -R     4CO     10RD     20WR
REZVE    -R     4CO     10RD     20WR
REZVT    -R     4CO     10RD     20WR
REZYO    -R     4CO     10RD     20WR
RIBAR    -R     4CO     40=
RIBJB    -R     4CO     41=
RM      ()R     5EQ      7DI    115=
RMP     ()R     5EQ      7DI
RO      ()R     5EQ      7DI     95       96
ROL     ()R     5EQ      7DI
ROMFR    -R     4CO     72=
RON      -R     4CO      9RD     19WR
RVOL    ()R     5EQ      7DI     96=
R1       -R    83=      95       95
R2       -R    86=      95
R3       -R    89=      95       95
R4       -R    92=      95
SIE     ()R     5EQ      7DI     97
T        -R     4CO     12RD     22WR     56
THIRD    -R     4CO     67=      95
TLIMD    -R     4CO     12RD     22WR
TOUT     -R     4CO     56=
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    INDEX  01/12/73                              SUBROUTINE YASET1                                  PAGE  23
TWFIN    -R     4CO    12RD    22WR
T20MD    -R     4CO    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     4CO    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     4CO    50
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
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INDEX  01/12/73              SUBROUTINE PARTGEN                                    PAGE  24
     1          SUBROUTINE PARTGEN                                                 YASET    00150
     2          LCM /YLC1/   AA1(131000)  /YLC2/ AA2(131000)                       YASET    00151
     3          COMMON /YSC1/ AASC(4242)                                           COMMON2 00002
     4          COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,B0,COLAMU,CYL,            COMMON2 00003
              1        DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTO(10),DTOC(10),           COMMON2 00004
              2        DTO16,DTO2,DTO4,DTO8,DTPOS,DTV,DTR,DZ,EM10,EPS,FIBP,        COMMON2 00005
              3        FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,           COMMON2 00006
              4        FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IBAR,IBP,IBP1,ICOLOR,      COMMON2 00007
              5        IDTO,IJ,IJM,IJP,IJPS,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,LPB,        COMMON2 00011
              9        LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQI,NQIB,NQI2,NSC,      COMMON2 00012
              1        NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV,    COMMON2 00013
              2        PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE,    COMMON2 00014
              3        REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJB,RIBP,RJBP,ROMFR,        COMMON2 00015
              4        RON,RPDR,RPDRDZ,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,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),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,PM0),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL,    EQVREAL 00006
              5            VL,PMY,PV),(AASC(14),Q,ROL)                             EQVREAL 00007
     6          REAL LAM,LAMD,M,MR,MC,ML,MP,MPAR,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),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          PMY(1),PV(1),Q(1),ROL(1),PM0(1)                           DIMEN    00006
     8          NPT = 0                                                            YASET    00155
     9          IF (IBP.EQ.0) RETURN                                               YASET    00156
    10          IF (IBP.GT.IBAR .OR. JBP.GT.JBAR) GO TO 300                        YASET    00157
    11          FIBP = IBP                                                         YASET    00158
    12          FJBP = JBP                                                         YASET    00159
    13          RIBP = 1./FIBP                                                     YASET    00160
    14          RJBP = 1./FJBP                                                     YASET    00161
    15          IBP1 = IBP+1                                                       YASET    00162
    16          JBP2 = JBP+2                                                       YASET    00163
    17          NQI2 = NQI*2                                                       YASET    00164
    18          IFCP = IPAR = LOCF(AA2)                                            YASET    00165
    19          LPB = NQI/3 *3                                                     YASET    00166
    20          IMOME3 = IMOMX*1000                                                YASET    00167
    21          KP = 1                                                             YASET    00168
    22          MT = 0.                                                            YASET    00169
    23          IF (FREZ.EQ.1.0) GO TO 100                                         YASET    00170
    24          XMAX =          (FLOAT(IUNF)    + FREZ*(1.-FREZ**(IBAR      -IUNF  )) YASET    00171
              1                  *ROMFR)*DR                                        YASET    00172
    25          YMAX = REZY0 + (FLOAT(JUNF02) + FREZ*(1.-FREZ**(JBAR-JCEN-JUNF02)) YASET    00173
              1                  *ROMFR)*DZ                                        YASET    00174
    26          YMIN = REZY0 - (FLOAT(JUNF02) + FREZ*(1.-FREZ**(JCEN      -JUNF02)) YASET    00175
              1                  *ROMFR)*DZ                                        YASET    00176
    27          PDR  = XMAX*RIBP                                                   YASET    00177
    28          PDZ  = (YMAX-YMIN)*RJBP                                            YASET    00178
    29      100 READ 900, DRPAR,DZPAR,XC,YC,XD,YD,UPAR,VPAR,MTE,DRAG               YASET    00179
    30          IF (DRPAR.LE.0.) GOTO 290                                          YASET    00180
    31          PRINT 910, DRPAR,DZPAR,XC,YC,XD,YD,UPAR,VPAR,MTE,DRAG              YASET    00181
    32          IF (LPR.GT.0) WRITE(12,910) DRPAR,DZPAR,XC,YC,XD,YD,UPAR,VPAR,     YASET    00182
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         1                           MTE,DRAG                               YASET   00183
           USH  =  SHIFT(UPAR,30).AND.7777777777B                           YASET   00184
           VSH  =  SHIFT(VPAR,30).AND.7777777777B                           YASET   00185
           DRAG = DRAG.AND..NOT.7777777777B                                 YASET   00186
           YTOP = YC+XD                                                     YASET   00187
           YBOT = YC-XD                                                     YASET   00188
           IF (YD.LT.EM10) GO TO 200                                        YASET   00189
           YTOP = YD                                                        YASET   00190
           YBOT = YC                                                        YASET   00191
           IF (FREZ.EQ.1.0) GO TO 200                                       YASET   00192
           YTOP = YMAX                                                      YASET   00193
           YBOT = YMIN                                                      YASET   00194
           XD   = XMAX                                                      YASET   00195
     200   YTE = YBOT+.5*DZPAR                                              YASET   00196
     210   XTE = XC+.5*DRPAR                                                YASET   00197
     220   IF (YD.LE.0. .AND. (YTE-YC)**2+XTE**2.GT.XD**2) GO TO 240        YASET   00198
           XPAR(KP) = (XTE.AND. .NOT. 7777777777B) .OR. USH                 YASET   00199
           YPAR(KP) = (YTE.AND. .NOT. 7777777777B) .OR. VSH                 YASET   00200
           MC = MTE*(XTE*CYL+OMCYL)                                         YASET   00201
           MT = MT + MC                                                     YASET   00202
           MPAR(KP) = DRAG .OR. (SHIFT(MC,30).AND.7777777777B)              YASET   00203
           KP = KP+3                                                        YASET   00204
           NPT = NPT+1                                                      YASET   00205
           IF (KP.GT.LPB) GO TO 250                                         YASET   00206
     230   XTE = XTE+DRPAR                                                  YASET   00207
           IF (XTE.LE.XD) GO TO 220                                         YASET   00208
     240   YTE = YTE+DZPAR                                                  YASET   00209
           IF (YTE.LE.YTOP) GO TO 210                                       YASET   00210
           GO TO 100                                                        YASET   00211
     250   CALL ECWR(AASC,IECP,LPB,NE)                                      YASET   00212
           IECP = IECP+LPB                                                  YASET   00213
           KP = 1                                                           YASET   00214
           GO TO 230                                                        YASET   00215
     290   CALL ECWR (AASC,IECP,LPB,NE)                                     YASET   00216
           NPS = LOCF(AA2(NPT*3)) - IPAR + 1                                YASET   00217
           PRINT 920, NPT,MT                                                YASET   00218
           IF (LPR.GT.0) WRITE(12,920) NPT,MT                               YASET   00219
           RETURN                                                           YASET   00220
     300   PRINT 990                                                        YASET   00221
           RETURN                                                           YASET   00222
     C                                                                      YASET   00223
     900   FORMAT(10F8.3)                                                   YASET   00224
     910   FORMAT(*  DRPAR=*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
     920   FORMAT(4XI6* PARTICLES GENERATED, WITH TOTAL MASS=*1PE12.5)      YASET   00228
     990   FORMAT(* PARTICLE GRID TOO LARGE FOR SCM LAYOUT.*)               YASET   00229
           END                                                              YASET   00230
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   INDEX  01/12/73                      SUBROUTINE PARTGEN                                   PAGE  26
 SINGLY REFERENCED VARIABLES
  AA       ()R   4CO   DT04     -R   4CO   GZP     -R   4CO   ITV     -I   4CO   MU02     -R   6RL   PYBM    -R   4CO   TLIMD   -R   4CO
  AA1      ()R   2LC   DT08     -R   4CO   I       -I   4CO   IXL     -I   4CO   MU04     -R   6RL   PYCONV  -R   4CO   TOUT    -R   4CO
  ANC       -R   4CO   DTPOS    -R   4CO   ICOLOR  -I   4CO   IXR     -I   4CO   NAME     ()I   4CO   PYT     -R   4CO   TWFIN   -R   4CO
  ASQ       -R   4CO   DTV      -R   4CO   IDTO    -I   4CO   IYB     -I   4CO   NCYC     -I   4CO   PYTP    -R   4CO   T20MD   -R   4CO
  A0        -R   4CO   DT8      -R   4CO   IJ      -I   4CO   IYT     -I   4CO   NLC      -I   4CO   RDT     -R   4CO   VV      -R   4CO
  A0FAC     -R   4CO   EPS      -R   4CO   IJM     -I   4CO   J       -I   4CO   NQ       -I   4CO   READ    -   29F   XCONV   -R   4CO
  A0M       -R   4CO   EQUIVAL  -    5F    IJP     -I   4CO.  JM10    -I   4CO   NQIB     -I   4CO   REAL    -    6F   XL      -R   4CO
  B0        -R   4CO   FIPXL    -R   4CO   IJPS    -I   4CO   JM14    -I   4CO   NSC      -I   4CO   REZRON  -R   4CO   XR      -R   4CO
  COLAMU    -R   4CO   FIPXR    -R   4CO   IM1     -I   4CO   JP1     -I   4CO   NUMIT    -I   4CO   REZSIE  -R   4CO   Y8      -R   4CO
  DIMENSI   -    7F    FIPYB    -R   4CO   IM6     -I   4CO   JP2     -I   4CO   NUMTD    -I   4CO   REZUE   -R   4CO   YCONV   -R   4CO
  DT        -R   4CO   FIPYT    -R   4CO   IPXL    -I   4CO   JP4     -I   4CO   OM       -R   4CO   REZVE   -R   4CO   YLC1    -   2CN
  DTC       -R   4CO   FIXL     -R   4CO   IPXR    -I   4CO   JP402   -I   4CO   OMANC    -R   4CO   REZVT   -R   4CO   YLC2    -   2CN
  DTFAC     -R   4CO   FIXR     -R   4CO   IPYB    -I   4CO   JUNF    -I   4CO   OMEM10   -R   4CO   RIBAR   -R   4CO   YSC1    -   3CN
  DTGR      -R   4CO   FIYB     -R   4CO   IPYT    -I   4CO   KXI     -I   4CO   OPEM10   -R   4CO   RIBJB   -R   4CO   YSC2    -   4CN
  DTGZ      -R   4CO   FIYT     -R   4CO   IP1     -I   4CO   LAMD    -R   6RL   PARTGEN  -   1SU   RON     -R   4CO   YT      -R   4CO
  DTGZP     -R   4CO   GGM1     -R   4CO   IP2     -I   4CO   LCM     -    2F    PXCONV   -R   4CO   RPDR    -R   4CO   ZZ      -R   4CO
  DT0      ()R   4CO   GM1      -R   4CO   ISCF1   -I   4CO   LJP2    -I   4CO   PXL      -R   4CO   RPDRDZ  -R   4CO
  DT0C     ()R   4CO   GR       -R   4CO   ISCF2   -I   4CO   MB      -R   6RL   PXR      -R   4CO   RPDZ    -R   4CO
  DT016     -R   4CO   GROVEL   -R   4CO   ISC2    -I   4CO   ML      -R   6RL   PXRP     -R   4CO   T       -R   4CO
  DT02      -R   4CO   GZ       -R   4CO   ISC3    -I   4CO   MR      -R   6RL   PYR      -R   4CO   THIRD   -R   4CO
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 MULTIPLY-REFERENCED VARIABLES
    100 -     23      29*     60
    200 -     38      41      45*
    210 -     46*     59
    220 -     47*     57
    230 -     56*     64
    240 -     47      58*
    250 -     55      61*
    290 -     30      65*
    300 -     10      70*
    900 -     29RD    72*
    910 -     31PR    32WR    73*
    920 -     67PR    68WR    74*
    990 -     70PR    75*
AASC    ()R    3CO     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ     5EQ    61AG    65AG
AA2     ()R    2LC     18      66
COMMON   -     3F      4F
CQ      ()R    5EQ     7DI
CYL      -R    4CO     50
DELSM   ()R    5EQ     7DI
DR       -R    4CO     24
DRAG     -R    29RD    31PR    32WR    35=     35      52
DRPAR    -R    29RD    30      31PR    32WR    46      56
DZ       -R    4CO     25      26
DZPAR    -R    29RD    31PR    32WR    45      58
E       ()R    5EQ     7DI
FCWR     -     61SU    65SU
FM10     -R    4CO     38
EP      ()R    5EQ     7DI
ETIL    ()R    5EQ     7DI
FIBP     -R    4CO     11=     13
FJBP     -R    4CO     12=     14
FLOAT    -     24SU    25SU    26SU
FRFZ     -R    4CO     23      24      24      25      25      26      26      41
IBAR     -I    4CO     10      24
IBP      -I    4CO      9      10      11      15
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     INDEX  01/12/73                            SUBROUTINE PARTGEN                          PAGE  27
IBP1     -I      4CO     15=
IECP     -I     18=      61AG     62=      62       65AG
IMOME3   -I      4CO     20=
IMOMX    -I      4CO     20
IPAR     -I      4CO     18=      66
IUNF     -I      4CO     24       24
JBAR     -I      4CO     10       25
JBP      -I      4CO     10       12       16
JBP2     -I      4CO     16=
JCEN     -I      4CO     25       26
JUNF02   -I      4CO     25       25       26       26
KP       -I     21=      48       49       52       53=      53       55       63=
LAM      -R      4CO      6RL
LOCF     -      18SU     66SU
LPB      -I      4CO     19=      55       61AG     62       65AG
LPR      -I      4CO     32       68
M       ()R      5EQ      6RL      70I
MC       -R      6RL     50=      51       52
MP      ()R      5EQ      6RL      70I
MPAR    ()R      5EQ      6RL      70I      52=
MT       -R      6RL     22=      51=      51       67PR     68WR
MTE      -R      6RL     29RD     31PR     32WR     50
MU       -R      4CO      6RL
NE       -I     61AG     65AG
NPS      -I      4CO     66=
NPT      -I      4CO      8=      54=      54       66       67PR     68WR
NQT      -I      4CO     17       19
NQT2     -I      4CO     17=
OMCYL    -R      4CO     50
P       ()R      5EQ      70I
PDR      -R      4CO     27=
PDZ      -R      4CO     28=
PL      ()R      5EQ      70I
PMX     ()R      5EQ      70I
PMY     ()R      5EQ      70I
PM0     ()R      5EQ      70I
PRINT    -      31F      67F      70F
PU      ()R      5EQ      70I
PV      ()R      5EQ      70I
Q       ()R      5EQ      70I
R       ()R      5EQ      70I
RCSQ    ()R      5EQ      70I
RETURN   -       9F      69F      71F
REZY0    -R      4CO     25       26
RIBP     -R      4CO     13=      27
RJBP     -R      4CO     14=      28
RM      ()R      5EQ      70I
RMP     ()R      5EQ      70I
RO      ()R      5EQ      70I
ROL     ()R      5EQ      70I
ROMFR    -R      4CO     24       25       26
RVOL    ()R      5EQ      70I
SHIFT    -      33SU     34SU     52SU
SIE     ()R      5EQ      70I
U       ()R      5EQ      70I
UG      ()R      5EQ      70I
UL      ()R      5EQ      70I
UP      ()R      5EQ      70I
```

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    INDEX  01/12/73                      SUBROUTINE PARTGEN                                    PAGE  28
UPAR     -R    29RD   31PR   32WR   33
USH      -R    33=    48
UTIL    ()R     5EQ    7DI
V       ()R     5EQ    7DI
VG      ()R     5EQ    7DI
VL      ()R     5EQ    7DI
VP      ()R     5EQ    7DI
VPAR     -R    29RD   31PR   32WR   34
VSH      -R    34=    49
VTIL    ()R     5EQ    7DI
WRITE    -     32F    68F
X       ()R     5EQ    7DI
XC       -R    29RD   31PR   32WR   46
XD       -R    29RD   31PR   32WR   36     37     44=    47     57
XMAX     -R    24=    27     44
XPAR    ()R     5EQ    7DI   48=
XTE      -R    46=    47     48     50     56=    56     57
Y       ()R     5EQ    7DI
YBOT     -R    37=    40=    43=    45
YC       -R    29RD   31PR   32WR   36     37     40     47
YD       -R    29RD   31PR   32WR   38     39     47
YMAX     -R    25=    28     42
YMIN     -R    26=    28     43
YPAR    ()R     5EQ    7DI   49=
YTF      -R    45=    47     49     58=    58     59
YTOP     -R    36=    39=    42=    59
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INDEX  01/12/73               SUBROUTINE MESHMKR                                      PAGE  29
          1           SUBROUTINE MESHMKR                                              YASET    00231
          2           COMMON /YSC1/ AASC(4242)                                        COMMON2 00002
          3           COMMON /YSC2/ AA(1),ANC,ASO,A0,A0FAC,A0M,B0,COLAMU,CYL,         COMMON2 00003
                     1      DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTO(10),DTOC(10),         COMMON2 00004
                     2      DTO16,DTO2,DTO4,DTO8,DTPOS,DTV,DT8,DZ,EM10,EPS,FIBP,      COMMON2 00005
                     3      FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,         COMMON2 00006
                     4      FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IBAR,IBP,IBP1,ICOLOR,    COMMON2 00007
                     5      IDTO,IJ,IJM,IJP,IJPS,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,LPB,      COMMON2 00011
                     9      LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQI,NQIB,NQI2,NSC,    COMMON2 00012
                     1      NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV,  COMMON2 00013
                     2      PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE,  COMMON2 00014
                     3      REZUE,REZVE,REZVT,REZYO,RIBAR,RIBJB,RIBP,RJBP,ROMFR,      COMMON2 00015
                     4      RON,RPDR,RPDRDZ,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,T20MD,      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),RO),  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,PMO),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL, EQVREAL 00006
                     5             VL,PMY,PV),(AASC(14),Q,ROL)                        EQVREAL 00007
          5           REAL LAM,LAMD,M,MB,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),RO(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            PMY(1),PV(1),Q(1),ROL(1),PMO(1)                     DIMEN   00006
          7           NQIM = NQI-1                                                    YASET   00235
          8           CALL START                                                      YASET   00236
          9           DO 119 J=1,JP4                                                  YASET   00237
         10           K = IJM + NQIM                                                  YASET   00238
         11           DO 109 I=IJM,K                                                  YASET   00239
         12      109  AASC(I) = 0.                                                    YASET   00240
         13           CALL LOOP                                                       YASET   00241
         14      119  CONTINUE                                                        YASET   00242
         15           CALL DONE                                                       YASET   00243
         16      200  XX = 0.0                                                        YASET   00244
         17           YY = YB                                                         YASET   00245
         18           CALL START                                                      YASET   00246
         19           DO 229 J=2,JP2                                                  YASET   00247
         20           DO 219 I=1,IP1                                                  YASET   00248
         21           X(IJ) = XX                                                      YASET   00249
         22           Y(IJ) = YY                                                      YASET   00250
         23           R(IJ) = XX*CYL+OMCYL                                            YASET   00251
         24           XX = XX + DR                                                    YASET   00252
         25      219  IJ = IJ + NQ                                                    YASET   00253
         26           XX = 0.                                                         YASET   00254
         27           YY = YY + DZ                                                    YASET   00255
         28           CALL LOOP                                                       YASET   00256
         29      229  CONTINUE                                                        YASET   00257
         30           CALL DONE                                                       YASET   00258
         31           IF (FREZ.EQ.1.0) GO TO 300                                      YASET   00259
         32           JCEN = JCEN + 2                                                 YASET   00260
         33           JTOP = JCEN + JUNF02                                            YASET   00261
         34           JBOT = JCEN - JUNF02                                            YASET   00262
         35           TJ   = FLOAT(JUNF02) * DZ                                       YASET   00263
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```
      CALL START                                                       YASET  00264
      DO 249 J=2,JP2                                                   YASET  00265
      DO 239 I=1,IP1                                                   YASET  00266
      IMJ = IJ - NQ                                                    YASET  00267
      IF (I.GT.IUNF+1) X(IJ) = X(IMJ) + FREZ*(X(IMJ)-X(IMJ-NQ))        YASET  00268
      R(IJ) = X(IJ)*CYL + OMCYL                                        YASET  00269
      JDT = IABS(J-JTOP)                                               YASET  00270
      JDB = IABS(J-JBOT)                                               YASET  00271
      IF (J.LT.JBOT) Y(IJ) = REZYO - TJ - DZ*FREZ*(1.-FREZ**JDB)*ROMFR  YASET  00272
      IF (J.GT.JTOP) Y(IJ) = REZYO + TJ + DZ*FREZ*(1.-FREZ**JDT)*ROMFR  YASET  00273
      IF (J.EQ.2) YB = Y(IJ)                                           YASET  00274
  239 IJ = IJ + NQ                                                     YASET  00275
      CALL LOOP                                                        YASET  00276
  249 CONTINUE                                                         YASET  00277
      CALL DONE                                                        YASET  00278
  300 READ 1000, NB,NR,NT,NL,UI,VI,ROI,SIEI                            YASET  00279
      IF (NR.EQ.0) RETURN                                              YASET  00280
      IF (NR.EQ.1000) GO TO 400                                        YASET  00281
      PRINT 1010, NB,NR,NT,NL,UI,VI,ROI,SIEI                           YASET  00282
      IF (LPR.GT.0) WRITE(12,1010) NB,NR,NT,NL,UI,VI,ROI,SIEI          YASET  00283
      NB2 = NB + 2                                                     YASET  00284
      NR1 = NR + 1                                                     YASET  00285
      NT2 = NT + 2                                                     YASET  00286
      NL1 = NL + 1                                                     YASET  00287
      DO 329 J=NB2,NT2                                                 YASET  00288
      CALL R1ROW                                                       YASET  00289
      DO 319 I=NL1,NR1                                                 YASET  00290
      CALL SETIJ                                                       YASET  00291
      IF (I.GT.1 .AND. I.LT.IP1) U(IJ)=UI                              YASFT  00292
      IF (J.GT.2 .AND. J.LT.JP2) V(IJ)=VI                              YASET  00293
      IF (J.EQ.NT2 .OR. I.EQ.NR1) GO TO 319                            YASET  00294
      RO(IJ) = ROI                                                     YASET  00295
      SIE(IJ) = SIEI                                                   YASET  00296
  319 CONTINUE                                                         YASET  00297
      CALL W1ROW                                                       YASET  00298
  329 CONTINUE                                                         YASET  00299
      GO TO 300                                                        YASET  00300
  400 XX = GM1*REZSIE                                                  YASET  00301
      YY = .5*ABS(GZ)                                                  YASET  00302
      CALL START                                                       YASET  00303
      YJC2 = .5*(Y(IJP)+Y(IJ))                                         YASET  00304
      ROSAV = REZRON*EXP(-GZ*(REZYO-YJC2)/XX)                          YASET  00305
      FNUM  = (Y(IJP)-Y(IJ))*YY                                        YASET  00306
      FDEN  = FNUM*FREZ                                                YASET  00307
      ROJ1  = ROSAV*(XX+FNUM)/(XX-FDEN)                                YASET  00308
      DO 459 I=1,IP1                                                   YASET  00309
      RO(IJ) = ROSAV                                                   YASET  00310
      RO(IJM) = ROJ1                                                   YASET  00311
      E(IJ) = E(IJM) = REZSIE                                          YASET  00312
      IJ = IJ + NQ                                                     YASET  00313
  459 IJM = IJM + NQ                                                   YASET  00314
      CALL LOOP                                                        YASET  00315
      DO 479 J=3,JP1                                                   YASET  00316
      FDEN = (Y(IJP)-Y(IJ))*YY                                         YASET  00317
      FNUM = (Y(IJ)-Y(IJM))*YY                                         YASET  00318
      ROSAV = ROSAV*(XX-FNUM)/(XX+FDEN)                                YASET  00319
      DO 469 I=1,IP1                                                   YASET  00320
      RO(IJ) = ROSAV                                                   YASET  00321
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      E(IJ) = REZSIE                                                    YASET   00322
  469 IJ = IJ + NQ                                                      YASET   00323
      CALL LOOP                                                         YASET   00324
  479 CONTINUE                                                          YASET   00325
      FNUM = FNUM*FREZ                                                  YASET   00326
      FDEN = FDEN*FREZ                                                  YASET   00327
      ROJP2 = ROSAV*(XX-FNUM)/(XX+FDEN)                                 YASET   00328
      DO 489 I=1,IP1                                                    YASET   00329
      RO(IJ) = ROJP2                                                    YASET   00330
      E(IJ) = REZSIE                                                    YASET   00331
  489 IJ = IJ + NQ                                                      YASET   00332
      CALL DONE                                                         YASET   00333
  500 READ 1020, I,JJ,ROI,SIEI,VI,UI                                    YASET   00334
      IF (I.EQ.0) GO TO 520                                             YASET   00335
      J = JJ + NT-1                                                     YASET   00336
      CALL R1ROW                                                        YASET   00337
      CALL SETIJ                                                        YASET   00338
      RO(IJ) = ROI                                                      YASET   00339
      SIE(IJ) = SIEI                                                    YASET   00340
      UL(IJ) = UI                                                       YASET   00341
      VL(IJ) = VI                                                       YASET   00342
      CALL W1ROW                                                        YASET   00343
      J = J-2*JJ+1                                                      YASET   00344
      CALL R1ROW                                                        YASET   00345
      CALL SETIJ                                                        YASET   00346
      RO(IJ) = ROI                                                      YASET   00347
      SIE(IJ) = SIEI                                                    YASET   00348
      UL(IJ) = UI                                                       YASET   00349
      CALL W1ROW                                                        YASET   00350
      J = J-1                                                           YASET   00351
      CALL R1ROW                                                        YASET   00352
      CALL SETIJ                                                        YASET   00353
      VL(IJ) = -VI                                                      YASET   00354
      CALL W1ROW                                                        YASET   00355
      GO TO 500                                                         YASET   00356
  520 CALL START                                                        YASET   00357
      DO 549 J=2,JBAR                                                   YASET   00358
      DO 539 I=1,IM1                                                    YASET   00359
      IPJ = IJ+NQ                                                       YASET   00360
      IPJP = IJP+NQ                                                     YASET   00361
      IF(I.EQ.1) V(IJP) = VL(IJ)                                        YASET   00362
      U(IPJP) = .5*(UL(IJ)+UL(IJP))                                     YASET   00363
      V(IPJP) = .5*(VL(IJ)+VL(IPJ))                                     YASET   00364
      IJ = IPJ                                                          YASET   00365
  539 IJP = IPJP                                                        YASET   00366
      CALL LOOP                                                         YASET   00367
  549 CONTINUE                                                          YASET   00368
      CALL DONE                                                         YASET   00369
      RETURN                                                            YASET   00370
C                                                                       YASET   00371
 1000 FORMAT(4I4,4F8.3)                                                 YASET   00372
 1010 FORMAT(* NB=*I3* NH=*I3* NT=*I3* NL=*I3* UI=*1PE12.5* VI=*        YASET   00373
     1 E12.5* ROI=*E12.5* SIEI=*E12.5)                                  YASET   00374
 1020 FORMAT(2I5,4(4X,E11.5))                                           YASET   00375
      END                                                               YASET   00376
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   INDEX  01/12/73                                   SUBROUTINE MESHMKR                                      PAGE  32
 SINGLY REFERENCED VARIABLES
     200 -    16*     DT04     -R     3CO    GR       -R     3CO    ISC3     -I     3CO    MT       -R     5RL    PXCONV   -R     3CO    RPDZ     -R     3CO
  AA      ()R    3CO  DT08     -R     3CO    GRDVEL   -R     3CO    ITV      -I     3CO    MTE      -R     5RL    PXL      -R     3CO    T        -R     3CO
  ABS      -    74SU  DTPOS    -R     3CO    GZP      -R     3CO    IXL      -I     3CO    MU02     -R     5RL    PXR      -R     3CO    THIRD    -R     3CO
  ANC     -R     3CO  DTV      -R     3CO    IBAR     -I     3CO    IXR      -I     3CO    MU04     -R     5RL    PXRP     -R     3CO    TLIMD    -R     3CO
  ASQ     -R     3CO  DT8      -R     3CO    IBP      -I     3CO    IYB      -I     3CO    NAME     ()I    3CO    PYB      -R     3CO    TOUT     -R     3CO
  A0      -R     3CO  EM10     -R     3CO    IBP1     -I     3CO    IYT      -I     3CO    NCYC     -I     3CO    PYBM     -R     3CO    TWFIN    -R     3CO
  A0FAC   -R     3CO  EPS      -R     3CO    ICOLOR   -I     3CO    JBP      -I     3CO    NLC      -I     3CO    PYCONV   -R     3CO    T20MD    -R     3CO
  A0M     -R     3CO  EQUIVAL  -      4F     IDTO     -I     3CO    JBP2     -I     3CO    NPS      -I     3CO    PYT      -R     3CO    VV       -R     3CO
  B0      -R     3CO  EXP      -     77SU    IJPS     -I     3CO    JM10     -I     3CO    NPT      -I     3CO    PYTP     -R     3CO    WRITE    -     55F
  COLAMU  -R     3CO  FIBP     -R     3CO    IMOME3   -I     3CO    JM14     -I     3CO    NQIB     -I     3CO    RDT      -R     3CO    XCONV    -R     3CO
  DIMENSI -      6F   FIPXL    -R     3CO    IMOMX    -I     3CO    JP402    -I     3CO    NQI2     -I     3CO    REAL     -      5F     XL       -R     3CO
  DT      -R     3CO  FIPXR    -R     3CO    IM6      -I     3CO    JUNF     -I     3CO    NSC      -I     3CO    REZUE    -R     3CO    XR       -R     3CO
  DTC     -R     3CO  FIPYB    -R     3CO    IPAR     -I     3CO    KXI      -I     3CO    NUMIT    -I     3CO    REZVE    -R     3CO    YCONV    -R     3CO
  DTFAC   -R     3CO  FIPYT    -R     3CO    IPXL     -I     3CO    LAMD     -R     5RL    NUMTD    -I     3CO    REZVT    -R     3CO    YSC1     -      2CN
  DTGR    -R     3CO  FIXL     -R     3CO    IPXR     -I     3CO    LJP2     -I     3CO    OM       -R     3CO    RIBAR    -R     3CO    YSC2     -      3CN
  DTGZ    -R     3CO  FIXR     -R     3CO    IPYB     -I     3CO    LPB      -I     3CO    OMANC    -R     3CO    RIBJB    -R     3CO    YT       -R     3CO
  DTGZP   -R     3CO  FIYB     -R     3CO    IPYT     -I     3CO    MB       -R     5RL    OMEM10   -R     3CO    RIBP     -R     3CO    ZZ       -R     3CO
  DT0     ()R    3CO  FIYT     -R     3CO    IP2      -I     3CO    MC       -R     5RL    OPEM10   -R     3CO    RJBP     -R     3CO
  DT0C    ()R    3CO  FJBP     -R     3CO    ISCF1    -I     3CO    MESHMKR  -      1SU    POR      -R     3CO    RON      -R     3CO
  DT016   -R     3CO  FLOAT    -     35SU    ISCF2    -I     3CO    ML       -R     5RL    PDZ      -R     3CO    RPDR     -R     3CO
  DT02    -R     3CO  GGM1     -R     3CO    ISC2     -I     3CO    MR       -R     5RL    PRINT    -    54F     RPDRDZ   -R     3CO
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 MULTIPLY-REFERENCED VARIABLES
     109 -     1100   12*
     119 -      900   14*
     219 -     2000   25*
     229 -     1900   29*
     239 -     3800   47*
     249 -     3700   49*
     300 -     31     51*    72
     319 -     6200   66     69*
     329 -     6000   71*
     400 -     53     73*
     459 -     8100   86*
     469 -     9200   95*
     479 -     8800   97*
     489 -     10100  104*
     500 -     106*   128
     520 -     107    129*
     539 -     13100  138*
     549 -     13000  140*
    1000 -     51RD   143*
    1010 -     54PR   55WR   144*
    1020 -     106RD  145*
AASC     ()R   2CO    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    12=
COMMON   -     2F     3F
CQ       ()R   4EQ    6DI
CYL      -R    3CO    23     41
DELSH    ()R   4EQ    6DI
DONE     -     15SU   30SU   50SU   105SU  141SU
DR       -R    3CO    24
DZ       -R    3CO    27     35     44     45
E        ()R   4EQ    6DI    84=    84=    94=    103=
EP       ()R   4EQ    6DI
FTIL     ()R   4EQ    6DI
FDEN     -R    79=    80     89=    91     99=    99     100
FNUM     -R    78=    79     80     90=    91     98=    98     100
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    INDEX  01/12/73                            SUBROUTINE MESHMKR                                        PAGE  33
FREZ     -R     3C0    31     40     44     44     45     45     79     98     99
GM1      -R     3C0    73
GZ       -R     3C0    74     77
I        -I     3C0    1100   12     2000   3800   40     6200   64     64     66     8100   9200   10100  106RD  107    13100  134
IABS     -      42SU   43SU
IJ       -I     3C0    21     22     23     25=    25     39     40     41     41     44     45     46     47=    47     64     65
                67     68     76     78     82     84     85=    85     89     90     93     94     95=    95     102    103    104=
                104    111    112    113    114    119    120    121    126    132    134    135    136    137=
IJM      -I     3C0    10     1100   83     84     86=    86     90
IJP      -I     3C0    76     78     89     133    134    135    138=
IMJ      -I     39=    40     40     40
IM1      -I     3C0    13100
IPJ      -I     132=   136    137
IPJP     -I     133=   135    136    138
IP1      -I     3C0    2000   3800   64     8100   9200   10100
IUNF     -I     3C0    40
J        -I     3C0    900    1900   3700   42     43     44     45     46     6000   65     65     66     8800   108=   116=   116
                123=   123    13000
JBAR     -I     3C0    13000
JBOT     -I     34=    43     44
JCEN     -I     3C0    32=    32     33     34
JDB      -I     43=    44
JDT      -I     42=    45
JJ       -I     106RD  108    116
JP1      -I     3C0    8800
JP2      -I     3C0    1900   3700   65
JP4      -I     3C0    900
JTOP     -I     33=    42     45
JUNF02   -I     3C0    33     34     35
K        -I     10=    1100
LAM      -R     3C0    5RL
LOOP     -      13SU   28SU   48SU   87SU   96SU   139SU
LPR      -I     3C0    55
M        ()R    4EQ    5RL    6DI
MP       ()R    4EQ    5RL    6DI
MPAR     ()R    4EQ    5RL    6DI
MU       -R     3C0    5RL
NB       -I     51RD   54PR   55WR   56
NB2      -I     56=    6000
NL       -I     51RD   54PR   55WR   59
NL1      -I     59=    6200
NQ       -I     3C0    25     39     40     47     85     86     95     104    132    133
NQI      -I     3C0    7
NQIM     -I     7=     10
NR       -I     51RD   52     53     54PR   55WR   57
NR1      -I     57=    6200   66
NT       -I     51RD   54PR   55WR   58     108
NT2      -I     58=    6000   66
OMCYL    -R     3C0    23     41
P        ()R    4EQ    6DI
PL       ()R    4EQ    6DI
PMX      ()R    4EQ    6DI
PMY      ()R    4EQ    6DI
PM0      ()R    4EQ    6DI
PU       ()R    4EQ    6DI
PV       ()R    4EQ    6DI
Q        ()R    4EQ    6DI
R        ()R    4EQ    6DI    23=    41=
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    INDEX  01/12/73                      SUBROUTINE MESHMKR                                  PAGE  34
RCSQ    ()R   4EQ    6DI
READ     -    51F    106F
RETURN   -    52F    142F
REZRON  -R    3CO    77
REZSIE  -R    3CO    73     84     94     103
REZYO   -R    3CO    44     45     77
RM      ()R   4EQ    6DI
RMP     ()R   4EQ    6DI
RO      ()R   4EQ    6DI    67=    82=    83=    93=    102=   111=   119=
ROI     -R    51RD   54PR   55WR   67     106RD  111    119
ROJP2   -R    100=   102
ROJ1    -R    80=    83
ROL     ()R   4EQ    6DI
ROMFR   -R    3CO    44     45
ROSAV   -R    77=    80     82     91=    91     93     100
RVOL    ()R   4EQ    6DI
R1ROW    -    61SU   109SU  117SU  124SU
SETIJ    -    63SU   110SU  118SU  125SU
SIE     ()R   4EQ    6DI    68=    112=   120=
SIEI    -R    51RD   54PR   55WR   68     106RD  112    120
START    -    8SU    18SU   36SU   75SU   129SU
TJ      -R    35=    44     45
U       ()R   4EQ    6DI    64=    135=
UG      ()R   4EQ    6DI
UI      -R    51RD   54PR   55WR   64     106RD  113    121
UL      ()R   4EQ    6DI    113=   121=   135    135
UP      ()R   4EQ    6DI
UTIL    ()R   4EQ    6DI
V       ()R   4EQ    6DI    65=    134=   136=
VG      ()R   4EQ    6DI
VI      -R    51RD   54PR   55WR   65     106RD  114    126
VL      ()R   4EQ    6DI    114=   126=   134    136    136
VP      ()R   4EQ    6DI
VTIL    ()R   4EQ    6DI
W1ROW    -    70SU   115SU  122SU  127SU
X       ()R   4EQ    6DI    21=    40=    40     40     40     41
XPAR    ()R   4EQ    6DI
XX      -R    16=    21     23     24=    24     26=    73=    77     80     80     91     91     100    100
Y       ()R   4EQ    6DI    22=    44=    45=    46     76     76     78     78     89     89     90     90
YB      -R    3CO    17     46=
YJC2    -R    76=    77
YPAR    ()R   4EQ    6DI
YY      -R    17=    22     27=    27     74=    78     89     90
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                                                                              PAGE  35
INDEX  01/12/73                    OVERLAY(YAQUFIL,2,0)                       YAQUI1   00002
         1          OVERLAY(YAQUFIL,2,0)
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                                                                              PAGE  36
INDEX  01/12/73                    PROGRAM YAQUI1                             YAQUI1   00003
         1          PROGRAM YAQUI1                                            YAQUI1   00004
         2          PRINT 10                                                  YAQUI1   00005
         3          CALL YAQUI2                                               YAQUI1   00006
         4     10   FORMAT(*  YAQUI2 CALLED*)                                 YAQUI1   00007
         5          END
```

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                                                                              PAGE  37
  INDEX  01/12/73                    PROGRAM YAQUI1
SINGLY REFERENCED VARIABLES
 PRINT   -    2F    YAQUI1  -    1SU   YAQUI2  -    3SU
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
MULTIPLY-REFERENCED VARIABLES
    10 -     2PR    4*
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
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INDEX  01/12/73                SUBROUTINE YAQUI2                                    PAGE  38
          1        SUBROUTINE YAQUI2                                              YAQUI1  00008
          2        LCM /YLC1/   AA1(131000)  /YLC2/ AA2(131000)                   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      DR,DT,DTC,DTFAC,DTGR,DTG7,DTGZP,DT0(10),DTOC(10),        COMMON2 00004
                  2      DT016,DT02,DT04,DT08,DTPOS,DTV,DT8,DZ,EM10,EPS,FIBP,     COMMON2 00005
                  3      FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,        COMMON2 00006
                  4      FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IBAR,IBP,IBP1,ICOLOR,   COMMON2 00007
                  5      IDT0,IJ,IJM,IJP,IJPS,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,NQI,NQIB,NQI2,NSC,   COMMON2 00012
                  1      NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV, COMMON2 00013
                  2      PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE, COMMON2 00014
                  3      REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJR,RIBP,RJBP,ROMFR,     COMMON2 00015
                  4      RON,RPDR,RPDRDZ,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,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),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,PM0),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL, EQVREAL 00006
                  5            VL,PMY,PV),(AASC(14),Q,ROL)                        EQVREAL 00007
          6        REAL LAM,LAMD,M,MR,MC,ML,MP,MPAR,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),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          PMY(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 SECOND (TBASE)                                            YAQUI1  00018
         12        T1 = TBASE                                                     YAQUI1  00019
         13        CALL GETQ (4LKJBN,JNM)                                         YAQUI1  00020
         14        CALL H4020                                                     YAQUI1  00021
         15        CALL GETQ (4LKTLM,II)                                          YAQUI1  00022
         16        TLIM = II                                                      YAQUI1  00023
         17        DTVSAV = DTCSAV = 0.0                                          YAQUI1  00024
         18        IF (IBAR.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 199 J=2,JP1                                                 YAQUI1  00029
         23        DO 189 I=1,IBAR                                                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        SIET = 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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         IF (NCYC.EQ.0) P(IJ) = -RON*GZ*(YT-YB-(FLOAT(J)-1.5)*DZ)          YAQUI1  00041
   180   IJP = IPJP                                                        YAQUI1  00042
   189   IJ = IPJ                                                          YAQUI1  00043
         CALL LOOP                                                         YAQUI1  00044
   199   CONTINUE                                                          YAQUI1  00045
         CALL DONE                                                         YAQUI1  00046
   200   TOLD = T2                                                         YAQUI1  00047
         CALL SECOND (T2)                                                  YAQUI1  00048
         XX = (T2-TOLD)*RIBJB                                              YAQUI1  00049
         IF (LPR.GT.0) WRITE(12,4000) T,NCYC,DT,XX,CIRC,DTV,IDTV,JDTV,     YAQUI1  00050
        1                                    NUMIT,T2,DTC,IDTC,JDTC        YAQUI1  00051
         CALL EMPTY                                                        YAQUI1  00052
         PRINT 4000,                         T,NCYC,DT,XX,CIRC,DTV,IDTV,JDTV,  YAQUI1  00053
        1                                    NUMIT,T2,DTC,IDTC,JDTC        YAQUI1  00054
         IF (T+ EM10 .GE.TOUT) GO TO 290                                   YAQUI1  00055
         IF (NCYC.LE.1 .OR. NUMIT.GT.499) GO TO 300                        YAQUI1  00056
   210   IF (T2-T1.GE.1200. .AND. T2OMD.GT.EM10) GO TO 320                 YAQUI1  00057
         IF (T2-TBASE.GE.TLIM) GO TO 330                                   YAQUI1  00058
   220   IF (T.GE.TWFIN) GO TO 340                                         YAQUI1  00059
         NCYC = NCYC + 1                                                   YAQUI1  00060
         IF (NCYC.EQ.2) DT = DTPOS = DT*10.                                YAQUI1  00061
         IF (NCYC.GE.3) DT = DTPOS = AMIN1(DTV,DTC)                        YAQUI1  00062
         DTFAC = 1.25                                                      YAQUI1  00063
         DTV = DTC = DT*DTFAC                                              YAQUI1  00064
         IF (T+DT.GT.TOUT) DT = TOUT-T                                     YAQUI1  00065
         T = T + DT                                                        YAQUI1  00066
         RDT   = 1./DT                                                     YAQUI1  00067
         DTO2  = .5*DT                                                     YAQUI1  00068
         DTO4  = .25*DT                                                    YAQUI1  00069
         DTO8  = .125*DT                                                   YAQUI1  00070
         DTO16 = .0625*DT                                                  YAQUI1  00071
         DT8 = DT*8.                                                       YAQUI1  00072
         DTGR = DT*GR                                                      YAQUI1  00073
         DTGZ = DT*GZ                                                      YAQUI1  00074
         DTGZP = DT*GZP                                                    YAQUI1  00075
         GO TO 1000                                                        YAQUI1  00076
   290   TOUT  = TOUT + DTO(IDTO)                                          YAQUI1  00077
         IF (T+ EM10 .LT.DTOC(IDTO)) GO TO 300                             YAQUI1  00078
         TOUT  = DTOC(IDTO) + DTO(IDTO+1)                                  YAQUI1  00079
         IDTO  = IDTO + 1                                                  YAQUI1  00080
   300   ASSIGN 310 TO KRET                                                YAQUI1  00081
         GO TO 500                                                         YAQUI1  00082
   310   ASSIGN 210 TO KRET                                                YAQUI1  00083
         GO TO 400                                                         YAQUI1  00084
   320   T1 = T2                                                           YAQUI1  00085
         ASSIGN 220 TO KRET                                                YAQUI1  00086
         GO TO 350                                                         YAQUI1  00087
   330   ASSIGN 340 TO KRET                                                YAQUI1  00088
         GO TO 350                                                         YAQUI1  00089
   340   RETURN                                                            YAQUI1  00090
   350   PRINT 4010, NUMTD,T,NCYC                                          YAQUI1  00091
         IF (LPR.GT.0) WRITE(12,4010) NUMTD,T,NCYC                         YAQUI1  00092
         WRITE(8) (AA(N),N=1,NSC)                                          YAQUI1  00093
         WRITE(8) (AA1(N),N=1,NLC)                                         YAQUI1  00094
         IF (NPT.GT.0) WRITE(8) (AA2(N),N=1,NPS)                           YAQUI1  00095
         CALL DATAREL (5LFSET8)                                            YAQUI1  00096
         CALL AFSREL (3LOUT)                                               YAQUI1  00097
         CALL AFSREL (4LFILM)                                              YAQUI1  00098
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            NUMTD = NUMTD + 1                                     YAQUI1  00099
            GO TO KRET                                            YAQUI1  00100
      370   REWIND 7                                              YAQUI1  00101
            JTD = JBAR                                            YAQUI1  00102
            JNSC = LOCF(ZZ) - LOCF(AA) +1                         YAQUI1  00103
            READ(7) (AA(N),N=1,JNSC)                              YAQUI1  00104
            IF (JTD.NE.NUMTD) GO TO 380                           YAQUI1  00105
            READ(7) (AA1(N),N=1,NLC)                              YAQUI1  00106
            IF (NPT.GT.0)  READ(7) (AA2(N),N=1,NPS)               YAQUI1  00107
            CALL AFSRFL (5LFSET7)                                 YAQUI1  00108
            NUMTD = NUMTD + 1                                     YAQUI1  00109
            TLIM = TLIM*27.5E-9 - 40. + (1.-TLIMD)*1.E+10         YAQUI1  00110
            PRINT 4020, JTD                                       YAQUI1  00111
            PRINT 4030, NAME,T,NCYC                               YAQUI1  00112
            IF (LPR.EQ.0) GO TO 220                               YAQUI1  00113
            WRITE(12,4020) JTD                                    YAQUI1  00114
            WRITE(12,4030) NAME,T,NCYC                            YAQUI1  00115
            GO TO 220                                             YAQUI1  00116
      380   PRINT 4040                                            YAQUI1  00117
            WRITE(12,4040)                                        YAQUI1  00118
            CALL AFSREL (5LFSET7)                                 YAQUI1  00119
            RETURN                                                YAQUI1  00120
      400   IF (LPR.EQ.0) GO TO KRET                              YAQUI1  00121
            ASSIGN 440 TO KRF                                     YAQUI1  00122
            ASSIGN 440 TO KRP                                     YAQUI1  00123
            ASSIGN 460 TO KRFP                                    YAQUI1  00124
            GO TO (420,410,458) LPR                               YAQUI1  00125
      410   ASSIGN 458 TO KRF                                     YAQUI1  00126
            ASSIGN 456 TO KRFP                                    YAQUI1  00127
      420   CALL LINCNT (64)                                      YAQUI1  00128
            CALL ADV (1)                                          YAQUI1  00129
            GO TO 454                                             YAQUI1  00130
      440   KRF = KRFP                                            YAQUI1  00131
            ASSIGN 460 TO KRP                                     YAQUI1  00132
            CALL START                                            YAQUI1  00133
            DO 489 J=1,JP2                                        YAQUI1  00134
            DO 479 I=1,IP1                                        YAQUI1  00135
            IPJM = IJM + NQ                                       YAQUI1  00136
            IPJ  = IJ + NQ                                        YAQUI1  00137
            D = PRM = PRV = PRSIE = 0.                            YAQUI1  00138
            IF (J.EQ.1) GO TO 450                                 YAQUI1  00139
            IF (RM(IJM).NE.0.) PRM=1./RM(IJM)                     YAQUI1  00140
            IF (I.EQ.IP1 .OR. J.EQ.JP2) GO TO 450                 YAQUI1  00141
            PRSIE = SIE(IJM)                                      YAQUI1  00142
            IF (RVOL(IJM).NE.0.) PRV=1./RVOL(IJM)                 YAQUI1  00143
            X1 = X(IPJM)                                          YAQUI1  00144
            Y1 = Y(IPJM)                                          YAQUI1  00145
            R1 = R(IPJM)                                          YAQUI1  00146
            U1 = U(IPJM)                                          YAQUI1  00147
            V1 = V(IPJM)                                          YAQUI1  00148
            X2 = X(IPJ)                                           YAQUI1  00149
            Y2 = Y(IPJ)                                           YAQUI1  00150
            R2 = R(IPJ)                                           YAQUI1  00151
            U2 = U(IPJ)                                           YAQUI1  00152
            V2 = V(IPJ)                                           YAQUI1  00153
            X3 = X(IJ)                                            YAQUI1  00154
            Y3 = Y(IJ)                                            YAQUI1  00155
            R3 = R(IJ)                                            YAQUI1  00156
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```
      U3 = U(IJ)
      V3 = V(IJ)
      X4 = X(IJM)
      Y4 = Y(IJM)
      R4 = R(IJM)
      U4 = U(IJM)
      V4 = V(IJM)
      D = .25*RVOL(IJM)*((R1+R2)*((U1+U2)*(Y2-Y1)+(V1+V2)*(X1-X2))
     1                   +(R2+R3)*((U2+U3)*(Y3-Y2)+(V2+V3)*(X2-X3))
     2                   +(R3+R4)*((U3+U4)*(Y4-Y3)+(V3+V4)*(X3-X4))
     3                   +(R4+R1)*((U4+U1)*(Y1-Y4)+(V4+V1)*(X4-X1)))
  450 GO TO (452,452,456) LPR
  452 WRITE(12,4070) I,J,X(IJM),Y(IJM),U(IJM),V(IJM),PRSIE,RO(IJM),PRV,
     1               D,PRM,P(IJM)
      LINESF = LINESF + 1
      IF (LINESF.LT.62) GO TO KRF
  454 LINESF = 0
      WRITE(12,4080) JNM,NAME,T,NCYC
      WRITE(12,4060)
      GO TO KRF
  456 PRINT 4070,    I,J,X(IJM),Y(IJM),U(IJM),V(IJM),PRSIE,RO(IJM),PRV,
     1               D,PRM,P(IJM)
      LINESP = LINESP + 1
      IF (LINESP.LT.57) GO TO KRP
  458 LINESP = 0
      PRINT 4050
      PRINT 4080, JNM,NAME,T,NCYC
      PRINT 4060
      GO TO KRP
  460 IJ = IPJ
  479 IJM = IPJM
      CALL LOOP
  489 CONTINUE
      IF (LPR.GT.2) GO TO KRET
  490 CALL EMPTY
      GO TO KRET
  500 IF (NPT.GT.0) CALL PARPLOT
      IF (LPR.EQ.0) GO TO 490
      IF (GRDVEL.GT.EM10 .OR. NCYC.EQ.0) CALL ADV(1)
      DRMIN = DZMIN = 1.E+20
      DRMAX = DZMAX = VMAX = 0.
      CALL START
      DO 549 J=2,JP1
      DO 539 I=1,IBAR
      IPJ = IJ + NQ
      IPJP = IJP + NQ
      VMAX = AMAX1 (VMAX,ABS(U(IJ)),ABS(V(IJ)))
      IF (NCYC.GT.0 .AND. GRDVEL.LT.EM10) GO TO 530
      X1 = X(IPJ)
      X2 = X(IPJP)
      X3 = X(IJP)
      X4 = X(IJ)
      Y1 = Y(IPJ)
      Y2 = Y(IPJP)
      Y3 = Y(IJP)
      Y4 = Y(IJ)
      XY14  = SQRT((X1-X4)**2 + (Y1-Y4)**2)
      XY23  = SQRT((X2-X3)**2 + (Y2-Y3)**2)
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      DRMIN = AMIN1(DRMIN,XY14,XY23)                                    YAQUI1  00215
      DRMAX = AMAX1(DRMAX,XY14,XY23)                                    YAQUI1  00216
      XY21  = SQRT((X2-X1)**2 + (Y2-Y1)**2)                             YAQUI1  00217
      XY34  = SQRT((X3-X4)**2 + (Y3-Y4)**2)                             YAQUI1  00218
      DZMIN = AMIN1(DZMIN,XY21,XY34)                                    YAQUI1  00219
      DZMAX = AMAX1(DZMAX,XY21,XY34)                                    YAQUI1  00220
      IX1 = FIXL + (X1-XL)*XCONV                                        YAQUI1  00221
      IY1 = FIYB + (Y1-YB)*YCONV                                        YAQUI1  00222
      IX2 = FIXL + (X2-XL)*XCONV                                        YAQUI1  00223
      IY2 = FIYB + (Y2-YB)*YCONV                                        YAQUI1  00224
      IX3 = FIXL + (X3-XL)*XCONV                                        YAQUI1  00225
      IY3 = FIYB + (Y3-YB)*YCONV                                        YAQUI1  00226
      IX4 = FIXL + (X4-XL)*XCONV                                        YAQUI1  00227
      IY4 = FIYB + (Y4-YB)*YCONV                                        YAQUI1  00228
      IF (I.EQ.1) CALL DRV (IX3,IY3,IX4,IY4)                            YAQUI1  00229
      IF (J.EQ.2) CALL DRV (IX4,IY4,IX1,IY1)                            YAQUI1  00230
      CALL DRV (IX1,IY1,IX2,IY2)                                        YAQUI1  00231
      CALL DRV (IX2,IY2,IX3,IY3)                                        YAQUI1  00232
  530 IJ = IPJ                                                          YAQUI1  00233
  539 IJP = IPJP                                                        YAQUI1  00234
      CALL LOOP                                                         YAQUI1  00235
  549 CONTINUE                                                          YAQUI1  00236
      IF (NCYC.GT.0 .AND. GRDVEL.LT.EM10) GO TO 550                     YAQUI1  00237
      CALL LINCNT(59)                                                   YAQUI1  00238
      WRITE(12,4140) DRMIN,DRMAX,DZMIN,DZMAX,XR,YB,YT                   YAQUI1  00239
      WRITE(12,4080) JNM,NAME,T,NCYC                                    YAQUI1  00240
  550 IF (VMAX.LT.EM10) GO TO 600                                       YAQUI1  00241
      DROU = VV/VMAX                                                    YAQUI1  00242
      CALL ADV(1)                                                       YAQUI1  00243
      CALL START                                                        YAQUI1  00244
      DO 599 J=2,JP2                                                    YAQUI1  00245
      DO 589 I=1,IP1                                                    YAQUI1  00246
      IX1 = FIXL + (X(IJ)-XL)*XCONV                                     YAQUI1  00247
      IY1 = FIYB + (Y(IJ)-YB)*YCONV                                     YAQUI1  00248
      IX2 = FIXL + (X(IJ)+U(IJ)*DROU-XL)*XCONV                          YAQUI1  00249
      IY2 = FIYB + (Y(IJ)+V(IJ)*DROU-YB)*YCONV                          YAQUI1  00250
      IF (IY2.GE.1) GO TO 580                                           YAQUI1  00251
      IX2 = IX1 + (IX2-IX1)*(IY1-1)/(IY1-IY2)                           YAQUI1  00252
      IY2 = 1                                                           YAQUI1  00253
  580 CALL DRV (IX1,IY1,IX2,IY2)                                        YAQUI1  00254
      CALL PLT (IX1,IY1,16)                                             YAQUI1  00255
  589 IJ = IJ + NQ                                                      YAQUI1  00256
      CALL LOOP                                                         YAQUI1  00257
  599 CONTINUE                                                          YAQUI1  00258
      CALL LINCNT(59)                                                   YAQUI1  00259
      WRITE(12,4150) VMAX                                               YAQUI1  00260
      WRITE(12,4080) JNM,NAME,T,NCYC                                    YAQUI1  00261
  600 IF (IBAR.EQ.1 .OR. JBAR.EQ.1) GO TO 490                           YAQUI1  00262
      L = 0                                                             YAQUI1  00263
  610 L = L+1                                                           YAQUI1  00264
      GO TO (620,620,640,490)L                                          YAQUI1  00265
  620 CALL START                                                        YAQUI1  00266
      DO 639 J=2,JP1                                                    YAQUI1  00267
      DO 629 I=1,IBAR                                                   YAQUI1  00268
      CQ(IJ) = RO(IJ+L-1)                                               YAQUI1  00269
  629 IJ = IJ + NQ                                                      YAQUI1  00270
      CALL LOOP                                                         YAQUI1  00271
  639 CONTINUE                                                          YAQUI1  00272
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      CALL DONE
      GO TO 700
  640 CALL START
      DO 659 J=2,JP1
      DO 649 I=1,IBAR
      IPJ = IJ + NQ
      IPJP = IJP + NQ
      X1 = X(IPJ)
      Y1 = Y(IPJ)
      U1 = U(IPJ)
      V1 = V(IPJ)
      X2 = X(IPJP)
      Y2 = Y(IPJP)
      U2 = U(IPJP)
      V2 = V(IPJP)
      X3 = X(IJP)
      Y3 = Y(IJP)
      U3 = U(IJP)
      V3 = V(IJP)
      X4 = X(IJ)
      Y4 = Y(IJ)
      U4 = U(IJ)
      V4 = V(IJ)
      R1 = .125*RVOL(IJ)*(R(IPJ)+R(IPJP)+R(IJP)+R(IJ))
      CQ(IJ) = R1*((U1+U4)*(X1-X4)+(V1+V4)*(Y1-Y4)
     2            +(U2+U1)*(X2-X1)+(V2+V1)*(Y2-Y1)
     3            +(U3+U2)*(X3-X2)+(V3+V2)*(Y3-Y2)
     4            +(U4+U3)*(X4-X3)+(V4+V3)*(Y4-Y3))
      IJ = IPJ
  649 IJP = IPJP
      CALL LOOP
  659 CONTINUE
      CALL DONE
  700 QMN = 1.E+6
      QMX = -QMN
      CALL START
      DO 719 J=2,JP1
      DO 709 I=1,IBAR
      QMN = AMIN1 (CQ(IJ),QMN)
      QMX = AMAX1 (CQ(IJ),QMX)
  709 IJ = IJ + NQ
      CALL LOOP
  719 CONTINUE
      XX = QMX/(QMN+EM10)
      IF (XX.LE.2.0) GO TO 735
      K = 10./ALOG10(XX)
      XX = K+1
      DQ = 10.**(1./XX)
      K = ALOG10(QMN)
      XX = 10.**(K-1)
      K = 1
  720 XX = XX*DQ
      IF (XX.LT.QMN) GO TO 720
  730 CON(K) = XX
      IF (XX.GT.QMX) GO TO 740
      K = K+1
      XX = XX*DQ
      GO TO 730
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 735  XX = QMX-QMN                                                    YAQUI1  00331
      IF (ABS(XX).LT.1.E-3*AMAX1(ABS(QMX),ABS(QMN))) GO TO 610        YAQUI1  00332
      DQ = .1*(XX+.001)                                               YAQUI1  00333
      DO 739 K=1,11                                                   YAQUI1  00334
 739  CON(K) = QMN+(FLOAT(K-1))*DQ                                    YAQUI1  00335
      K = 11                                                          YAQUI1  00336
 740  CALL ADV(1)                                                     YAQUI1  00337
      CALL LINCNT (59)                                                YAQUI1  00338
      GO TO (750,760,770)L                                            YAQUI1  00339
 750  WRITE(12,4090)                                                  YAQUI1  00340
      GO TO 780                                                       YAQUI1  00341
 760  WRITE(12,4100)                                                  YAQUI1  00342
      GO TO 780                                                       YAQUI1  00343
 770  WRITE(12,4110)                                                  YAQUI1  00344
 780  WRITE(12,4120) QMN,QMX,CON(1),CON(K-1),DQ                       YAQUI1  00345
      WRITE(12,4080) JNM,NAME,T,NCYC                                  YAQUI1  00346
      CALL START                                                      YAQUI1  00347
      DO 899 J=2,JBAR                                                 YAQUI1  00348
      CALL LOOP                                                       YAQUI1  00349
      DO 889 I=1,IM1                                                  YAQUI1  00350
      IPJ = IJ + NQ                                                   YAQUI1  00351
      IPJM = IJM + NQ                                                 YAQUI1  00352
      N = 0                                                           YAQUI1  00353
      DO 879 KK=1,K                                                   YAQUI1  00354
      K1 = K2 = K3 = K4 = 0                                           YAQUI1  00355
      IF (CO(IJM) .LE.CON(KK)) K1=1                                   YAQUI1  00356
      IF (CO(IPJM).LE.CON(KK)) K2=1                                   YAQUI1  00357
      IF (CO(IJ)  .LE.CON(KK)) K3=1                                   YAQUI1  00358
      IF (CO(IPJ) .LE.CON(KK)) K4=1                                   YAQUI1  00359
      IF (K1*K2*K3*K4 .NE. 0 .OR. K1+K2+K3+K4 .EQ. 0) GO TO 879       YAQUI1  00360
      IF (N.GT.0) GO TO 800                                           YAQUI1  00361
      IJB = IJM                                                       YAQUI1  00362
      IJA = IJ                                                        YAQUI1  00363
      DO 799 JJ=1,2                                                   YAQUI1  00364
      DO 789 II=1,2                                                   YAQUI1  00365
      IPJB = IJB+NQ                                                   YAQUI1  00366
      IPJA = IJA+NQ                                                   YAQUI1  00367
      N = N+1                                                         YAQUI1  00368
      XCO(N) = .25*(X(IPJB)+X(IPJA)+X(IJA)+X(IJB))                    YAQUI1  00369
      YCO(N) = .25*(Y(IPJB)+Y(IPJA)+Y(IJA)+Y(IJB))                    YAQUI1  00370
      IJA = IPJA                                                      YAQUI1  00371
 789  IJB = IPJB                                                      YAQUI1  00372
      IJB = IJ                                                        YAQUI1  00373
 799  IJA = IJP                                                       YAQUI1  00374
 800  LL = 0                                                          YAQUI1  00375
      IF (K1+K3.NE.1) GO TO 810                                       YAQUI1  00376
      IC1 = 1                                                         YAQUI1  00377
      IC2 = 3                                                         YAQUI1  00378
      IJ1 = IJM                                                       YAQUI1  00379
      IJ2 = IJ                                                        YAQUI1  00380
      ASSIGN 810 TO KR1                                               YAQUI1  00381
      GO TO 840                                                       YAQUI1  00382
 810  IF (K1+K2.NE.1) GO TO 820                                       YAQUI1  00383
      IC1 = 1                                                         YAQUI1  00384
      IC2 = 2                                                         YAQUI1  00385
      IJ1 = IJM                                                       YAQUI1  00386
      IJ2 = IPJM                                                      YAQUI1  00387
      ASSIGN 820 TO KR1                                               YAQUI1  00388
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        GO TO 840                                                 YAQUI1  00389
  820   IF (K2+K4.NE.1) GO TO 830                                 YAQUI1  00390
        IC1 = 2                                                   YAQUI1  00391
        IC2 = 4                                                   YAQUI1  00392
        IJ1 = IPJM                                                YAQUI1  00393
        IJ2 = IPJ                                                 YAQUI1  00394
        ASSIGN 830 TO KR1                                         YAQUI1  00395
        GO TO 840                                                 YAQUI1  00396
  830   IF (K3+K4.NE.1) GO TO 879                                 YAQUI1  00397
        IC1 = 3                                                   YAQUI1  00398
        IC2 = 4                                                   YAQUI1  00399
        IJ1 = IJ                                                  YAQUI1  00400
        IJ2 = IPJ                                                 YAQUI1  00401
        ASSIGN 879 TO KR1                                         YAQUI1  00402
  840   LL = LL+1                                                 YAQUI1  00403
        XX = (CON(KK)-CQ(IJ1))/(CQ(IJ2)-CQ(IJ1))                  YAQUI1  00404
        IX1(LL) = FIXL + (XCO(IC1)+XX*(XCO(IC2)-XCO(IC1))-XL)*XCONV YAQUI1  00405
        IY1(LL) = FIYB + (YCO(IC1)+XX*(YCO(IC2)-YCO(IC1))-YB)*YCONV YAQUI1  00406
        IF (LL.LT.2) GO TO KR1                                    YAQUI1  00407
        CALL DRV (IX1,IY1,IX2,IY2)                                YAQUI1  00408
        IF (KK.EQ.1)   CALL PLT (IX1,IY1,35)                      YAQUI1  00409
        IF (KK.EQ.K-1) CALL PLT (IX1,IY1,24)                      YAQUI1  00410
        LL = 0                                                    YAQUI1  00411
        IF (IJ2.EQ.IPJM) GO TO 820                                YAQUI1  00412
  879   CONTINUE                                                  YAQUI1  00413
        IJM = IPJM                                                YAQUI1  00414
        IJ = IPJ                                                  YAQUI1  00415
  889   IJP = IJP+NQ                                              YAQUI1  00416
  899   CONTINUE                                                  YAQUI1  00417
        CALL START                                                YAQUI1  00418
        DO 949 J=2,JP1                                            YAQUI1  00419
        DO 939 I=1,IBAR                                           YAQUI1  00420
        IPJ = IJ + NQ                                             YAQUI1  00421
        IPJP = IJP + NQ                                           YAQUI1  00422
        IX1 = FIXL + (X(IPJ) -XL)*XCONV                           YAQUI1  00423
        IY1 = FIYB + (Y(IPJ) -YB)*YCONV                           YAQUI1  00424
        IX2 = FIXL + (X(IPJP)-XL)*XCONV                           YAQUI1  00425
        IY2 = FIYB + (Y(IPJP)-YB)*YCONV                           YAQUI1  00426
        IX3 = FIXL + (X(IJP) -XL)*XCONV                           YAQUI1  00427
        IY3 = FIYB + (Y(IJP) -YB)*YCONV                           YAQUI1  00428
        IX4 = FIXL + (X(IJ)  -XL)*XCONV                           YAQUI1  00429
        IY4 = FIYB + (Y(IJ)  -YB)*YCONV                           YAQUI1  00430
        IF (I.EQ.1)    CALL DRV (IX3,IY3,IX4,IY4)                 YAQUI1  00431
        IF (J.EQ.2)    CALL DRV (IX4,IY4,IX1,IY1)                 YAQUI1  00432
        IF (I.EQ.IBAR) CALL DRV (IX1,IY1,IX2,IY2)                 YAQUI1  00433
        IF (J.EQ.JP1)  CALL DRV (IX2,IY2,IX3,IY3)                 YAQUI1  00434
        IJ = IPJ                                                  YAQUI1  00435
  939   IJP = IPJP                                                YAQUI1  00436
        CALL LOOP                                                 YAQUI1  00437
  949   CONTINUE                                                  YAQUI1  00438
        GO TO 610                                                 YAQUI1  00439
 1000   CALL START                                                YAQUI1  00440
        Y1 = ANC*ROT                                              YAQUI1  00441
        DO 1099 J=2,JP2                                           YAQUI1  00442
        DO 1089 I=1,IP1                                           YAQUI1  00443
        IMJ = IJ-NQ                                               YAQUI1  00444
        IPJ = IJ+NQ                                               YAQUI1  00445
        IPJP = IJP+NQ                                             YAQUI1  00446
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      XX = YY = 1.                                       YAQUI1  00447
      X1 = U1 = V1 = 0.                                  YAQUI1  00448
      IF (I.EQ.1  ) GO TO 1015                           YAQUI1  00449
      U1 = U(IMJ)                                        YAQUI1  00450
      V1 = V(IMJ)                                        YAQUI1  00451
      GO TO 1020                                         YAQUI1  00452
1015  X1 = 1.0                                           YAQUI1  00453
      XX = 0.0                                           YAQUI1  00454
1020  IF (J.EQ.2  ) GO TO 1025                           YAQUI1  00455
      U1 = U1+U(IJM)                                     YAQUI1  00456
      V1 = V1+V(IJM)                                     YAQUI1  00457
      GO TO 1030                                         YAQUI1  00458
1025  X1 = X1+1.0                                        YAQUI1  00459
      YY = 0.0                                           YAQUI1  00460
1030  IF (I.EQ.IP1) GO TO 1035                           YAQUI1  00461
      U1 = U1+U(IPJ)                                     YAQUI1  00462
      V1 = V1+V(IPJ)                                     YAQUI1  00463
      GO TO 1040                                         YAQUI1  00464
1035  X1 = X1 + 1.0                                      YAQUI1  00465
      XX = 0.0                                           YAQUI1  00466
1040  IF (J.EQ.JP2) GO TO 1045                           YAQUI1  00467
      U1 = U1+U(IJP)                                     YAQUI1  00468
      V1 = V1+V(IJP)                                     YAQUI1  00469
      GO TO 1050                                         YAQUI1  00470
1045  X1 = X1+1.0                                        YAQUI1  00471
      YY = 0.0                                           YAQUI1  00472
1050  X1 = 1./(4.-X1)                                    YAQUI1  00473
      AX = GR +Y1*(U1*X1-U(IJ))                          YAQUI1  00474
      AY = GZ +Y1*(V1*X1-V(IJ))                          YAQUI1  00475
      UTIL(IJ) = (U(IJ)+DT*AX)*XX                        YAQUI1  00476
      VTIL(IJ) = (V(IJ)+DT*AY)*YY                        YAQUI1  00477
      Q(IJ) = DT*(AX*U(IJ)+AY*V(IJ))                     YAQUI1  00478
      IJ = IPJ                                           YAQUI1  00479
      IJP = IPJP                                         YAQUI1  00480
1089  IJM = IJM+NQ                                       YAQUI1  00481
      CALL LOOP                                          YAQUI1  00482
1099  CONTINUE                                           YAQUI1  00483
      CALL DONE                                          YAQUI1  00484
1100  CALL START                                         YAQUI1  00485
      DO 1299 J=2,JP1                                    YAQUI1  00486
      DO 1199 I=1,IBAR                                   YAQUI1  00487
      IPJ = IJ + NQ                                      YAQUI1  00488
      IPJP = IJP + NQ                                    YAQUI1  00489
      X1 = X(IPJ)                                        YAQUI1  00490
      Y1 = Y(IPJ)                                        YAQUI1  00491
      R1 = R(IPJ)                                        YAQUI1  00492
      U1 = U(IPJ)                                        YAQUI1  00493
      V1 = V(IPJ)                                        YAQUI1  00494
      X2 = X(IPJP)                                       YAQUI1  00495
      Y2 = Y(IPJP)                                       YAQUI1  00496
      R2 = R(IPJP)                                       YAQUI1  00497
      U2 = U(IPJP)                                       YAQUI1  00498
      V2 = V(IPJP)                                       YAQUI1  00499
      X3 = X(IJP)                                        YAQUI1  00500
      Y3 = Y(IJP)                                        YAQUI1  00501
      R3 = R(IJP)                                        YAQUI1  00502
      U3 = U(IJP)                                        YAQUI1  00503
      V3 = V(IJP)                                        YAQUI1  00504
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            X4 = X(IJ)                                                    YAQUI1  00505
            Y4 = Y(IJ)                                                    YAQUI1  00506
            R4 = R(IJ)                                                    YAQUI1  00507
            U4 = U(IJ)                                                    YAQUI1  00508
            V4 = V(IJ)                                                    YAQUI1  00509
            X12 = X1-X2                                                   YAQUI1  00510
            X23 = X2-X3                                                   YAQUI1  00511
            X34 = X3-X4                                                   YAQUI1  00512
            X41 = X4-X1                                                   YAQUI1  00513
            X24 = X2-X4                                                   YAQUI1  00514
            X31 = X3-X1                                                   YAQUI1  00515
            Y21 = Y2-Y1                                                   YAQUI1  00516
            Y32 = Y3-Y2                                                   YAQUI1  00517
            Y43 = Y4-Y3                                                   YAQUI1  00518
            Y14 = Y1-Y4                                                   YAQUI1  00519
            Y24 = Y2-Y4                                                   YAQUI1  00520
            Y31 = Y3-Y1                                                   YAQUI1  00521
            R12 = R1+R2                                                   YAQUI1  00522
            R23 = R2+R3                                                   YAQUI1  00523
            R34 = R3+R4                                                   YAQUI1  00524
            R41 = R4+R1                                                   YAQUI1  00525
            HR13 = .5*(R1+R3)                                             YAQUI1  00526
            HR24 = .5*(R2+R4)                                             YAQUI1  00527
            U12 = U1+U2                                                   YAQUI1  00528
            U23 = U2+U3                                                   YAQUI1  00529
            U34 = U3+U4                                                   YAQUI1  00530
            U41 = U4+U1                                                   YAQUI1  00531
            U24 = U2+U4                                                   YAQUI1  00532
            U13 = U1+U3                                                   YAQUI1  00533
            V12 = V1+V2                                                   YAQUI1  00534
            V23 = V2+V3                                                   YAQUI1  00535
            V34 = V3+V4                                                   YAQUI1  00536
            V41 = V4+V1                                                   YAQUI1  00537
            V24 = V2+V4                                                   YAQUI1  00538
            V13 = V1+V3                                                   YAQUI1  00539
            DTO2M1 = DTO2*RM(IPJ)                                         YAQUI1  00540
            DTO2M2 = DTO2*RM(IPJP)                                        YAQUI1  00541
            DTO2M3 = DTO2*RM(IJP)                                         YAQUI1  00542
            DTO2M4 = DTO2*RM(IJ)                                          YAQUI1  00543
            XY = X24*Y31-X31*Y24                                          YAQUI1  00544
            D = .25*RVOL(IJ)*(R12*(U12*Y21+V12*X12)+R23*(U23*Y32+V23*X23) YAQUI1  00545
           1                 +R34*(U34*Y43+V34*X34)+R41*(U41*Y14+V41*X41))YAQUI1  00546
            XX = .5*(X2-X4+X1-X3)                                         YAQUI1  00547
            YY = .5*(Y2-Y4+Y3-Y1)                                         YAQUI1  00548
            IF (KXI.LT.0) GO TO 1130                                      YAQUI1  00549
            AK = RO(IJ)**KXI                                              YAQUI1  00550
            GO TO 1140                                                    YAQUI1  00551
      1130  VELIJ = U4**2 + V4**2                                         YAQUI1  00552
            VELMX = 0.7 * AMAX1(ABS(U4*XX),ABS(V4*YY))                    YAQUI1  00553
            AK = RO(IJ)*COLAMU*(DTO2*VELIJ + VELMX)                       YAQUI1  00554
      1140  LAMD = AMIN1(D,0.) *AK*LAM                                    YAQUI1  00555
            MU02 = .5*AK*MU                                               YAQUI1  00556
            MU04 = .5*MU02                                                YAQUI1  00557
            XX = XX*XX                                                    YAQUI1  00558
            YY = YY*YY                                                    YAQUI1  00559
            IF (KXI.LT.0 .AND. DT.LT.DTPOS)                               YAQUI1  00560
           1               AK = RO(IJ)*COLAMU*(.5*DTPOS*VELIJ + VELMX)    YAQUI1  00561
            DQ = RO(IJ)*OMANC*XX*YY/(2.* AK*(LAM+2.*MU) *(XX+YY)+EM10)    YAQUI1  00562
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      DTV = AMIN1(DTV,.5*DQ)                                            YAQUI1  00563
      IF (DTVSAV.NE.DTV) IDTV = I                                       YAQUI1  00564
      IF (DTVSAV.NE.DTV) JDTV = J                                       YAQUI1  00565
      DTVSAV = DTV                                                      YAQUI1  00566
      PIXX = MU02*RVOL(IJ)*(R12*U12*Y21+R23*U23*Y32                     YAQUI1  00567
     1       +R34*U34*Y43+R41*U41*Y14 -.5*CYL*(U12+U34)*XY) + LAMD      YAQUI1  00568
      PIYY = MU02*RVOL(IJ)*(R12*V12*X12+R23*V23*X23                     YAQUI1  00569
     1       +R34*V34*X34+R41*V41*X41) + LAMD                           YAQUI1  00570
      PIXY = MU04*RVOL(IJ)*(R12*(U12*X12+V12*Y21)+R23*(U23*X23+V23*Y32) YAQUI1  00571
     1                       +R34*(U34*X34+V34*Y43)+R41*(U41*X41+V41*Y14) YAQUI1  00572
     2                       -.5*CYL*(V12+V34)*XY)                      YAQUI1  00573
      PITH = .25*XY*CYL*(MU04*RVOL(IJ)*((U12+U34)*XY) + LAMD)           YAQUI1  00574
      XX = HR24*(PIXY*X24-PIXX*Y24)                                     YAQUI1  00575
      YY = Y24*P(IJ)                                                    YAQUI1  00576
      UTIL(IPJ)  = UTIL(IPJ) +DT02M1*(XX+R1*YY-PITH)                    YAQUI1  00577
      UTIL(IJP)  = UTIL(IJP) -DT02M3*(XX+R3*YY+PITH)                    YAQUI1  00578
      XX = HR13*(PIXY*X31-PIXX*Y31)                                     YAQUI1  00579
      YY = Y31*P(IJ)                                                    YAQUI1  00580
      UTIL(IPJP) = UTIL(IPJP)+DT02M2*(XX+R2*YY-PITH)                    YAQUI1  00581
      UTIL(IJ)   = UTIL(IJ)  -DT02M4*(XX+R4*YY+PITH)                    YAQUI1  00582
      PYYMP = PIYY-P(IJ)                                                YAQUI1  00583
      XX = HR24*(PYYMP*X24-PIXY*Y24)                                    YAQUI1  00584
      VTIL(IPJ)  = VTIL(IPJ) +DT02M1*XX                                 YAQUI1  00585
      VTIL(IJP)  = VTIL(IJP) -DT02M3*XX                                 YAQUI1  00586
      XX = HR13*(PYYMP*X31-PIXY*Y31)                                    YAQUI1  00587
      VTIL(IPJP) = VTIL(IPJP)+DT02M2*XX                                 YAQUI1  00588
      VTIL(IJ)   = VTIL(IJ)  -DT02M4*XX                                 YAQUI1  00589
      XX = .5*HR24*(U24*(X24*PIXY-Y24*PIXX)-V24*(Y24*PIXY-X24*PIYY))    YAQUI1  00590
      Q(IPJ)  = Q(IPJ) +DT02M1*XX                                       YAQUI1  00591
      Q(IJP)  = Q(IJP) -DT02M3*XX                                       YAQUI1  00592
      XX = .5*HR13*(U13*(X31*PIXY-Y31*PIXX)-V13*(Y31*PIXY-X31*PIYY))    YAQUI1  00593
      Q(IPJP) = Q(IPJP)+DT02M2*XX                                       YAQUI1  00594
      Q(IJ)   = Q(IJ)  -DT02M4*XX                                       YAQUI1  00595
      IJ = IPJ                                                          YAQUI1  00596
 1199 IJP = IPJP                                                        YAQUI1  00597
      UTIL(IJ) = UTIL(IJP) = UTIL(IJP-NQIB) = UTIL(IJ-NQIB) = 0.        YAQUI1  00598
      IF (J.NE.2)   GO TO 1220                                          YAQUI1  00599
      DO 1210 IJ=ISC2,ISCF2,NQ                                          YAQUI1  00600
 1210 VTIL(IJ) = 0.                                                     YAQUI1  00601
 1220 IF (J.NE.JP1) GO TO 1240                                          YAQUI1  00602
      DO 1230 IJP=IJPS,LJP2,NQ                                          YAQUI1  00603
 1230 VTIL(IJP) = 0.                                                    YAQUI1  00604
 1240 CALL LOOP                                                         YAQUI1  00605
 1299 CONTINUE                                                          YAQUI1  00606
      CALL DONE                                                         YAQUI1  00607
 1300 CALL START                                                        YAQUI1  00608
      DO 1399 J=2,JP1                                                   YAQUI1  00609
      DO 1389 I=1,IBAR                                                  YAQUI1  00610
      IPJ = IJ + NQ                                                     YAQUI1  00611
      IPJP = IJP + NQ                                                   YAQUI1  00612
      ETIL(IJ) = E(IJ)+.25*(Q(IPJ)+Q(IPJP)+Q(IJP)+Q(IJ))                YAQUI1  00613
      ROL(IJ) = RO(IJ)                                                  YAQUI1  00614
      RCSQ(IJ) = 1./(ASQ+GGM1*AMAX1(SIE(IJ),0.))                        YAQUI1  00615
      XX = (X(IPJP)-X(IJ)+X(IPJ)-X(IJP))**2                             YAQUI1  00616
      YY = (Y(IPJP)-Y(IJ)+Y(IJP)-Y(IPJ))**2                             YAQUI1  00617
      DELSM(IJ) = DT8*(XX+YY)/(XX*YY)                                   YAQUI1  00618
      IJ = IPJ                                                          YAQUI1  00619
 1389 IJP = IPJP                                                        YAQUI1  00620
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          CALL LOOP                                                 YAQUI1  00621
    1399  CONTINUE                                                  YAQUI1  00622
          CALL DONE                                                 YAQUI1  00623
    1500  CALL START                                                YAQUI1  00624
          DO 1599 J=2,JP1                                           YAQUI1  00625
          DO 1589 I=1,IBAR                                          YAQUI1  00626
          IMJ = IJ-NQ                                               YAQUI1  00627
          IPJ = IJ+NQ                                               YAQUI1  00628
          IPJP = IJP+NQ                                             YAQUI1  00629
          X1 = X(IPJ)                                               YAQUI1  00630
          Y1 = Y(IPJ)                                               YAQUI1  00631
          R1 = R(IPJ)                                               YAQUI1  00632
          X2 = X(IPJP)                                              YAQUI1  00633
          Y2 = Y(IPJP)                                              YAQUI1  00634
          R2 = R(IPJP)                                              YAQUI1  00635
          X3 = X(IJP)                                               YAQUI1  00636
          Y3 = Y(IJP)                                               YAQUI1  00637
          R3 = R(IJP)                                               YAQUI1  00638
          X4 = X(IJ)                                                YAQUI1  00639
          Y4 = Y(IJ)                                                YAQUI1  00640
          R4 = R(IJ)                                                YAQUI1  00641
          X12 = X1-X2                                               YAQUI1  00642
          X23 = X2-X3                                               YAQUI1  00643
          X34 = X3-X4                                               YAQUI1  00644
          X41 = X4-X1                                               YAQUI1  00645
          Y21 = Y2-Y1                                               YAQUI1  00646
          Y32 = Y3-Y2                                               YAQUI1  00647
          Y43 = Y4-Y3                                               YAQUI1  00648
          Y14 = Y1-Y4                                               YAQUI1  00649
          R12 = R1+R2                                               YAQUI1  00650
          R23 = R2+R3                                               YAQUI1  00651
          R34 = R3+R4                                               YAQUI1  00652
          R41 = R4+R1                                               YAQUI1  00653
          U1 = UTIL(IPJ)                                            YAQUI1  00654
          U2 = UTIL(IPJP)                                           YAQUI1  00655
          U3 = UTIL(IJP)                                            YAQUI1  00656
          U4 = UTIL(IJ)                                             YAQUI1  00657
          V1 = VTIL(IPJ)                                            YAQUI1  00658
          V2 = VTIL(IPJP)                                           YAQUI1  00659
          V3 = VTIL(IJP)                                            YAQUI1  00660
          V4 = VTIL(IJ)                                             YAQUI1  00661
          U12 = U1+U2                                               YAQUI1  00662
          U23 = U2+U3                                               YAQUI1  00663
          U34 = U3+U4                                               YAQUI1  00664
          U41 = U4+U1                                               YAQUI1  00665
          V12 = V1+V2                                               YAQUI1  00666
          V23 = V2+V3                                               YAQUI1  00667
          V34 = V3+V4                                               YAQUI1  00668
          V41 = V4+V1                                               YAQUI1  00669
          MR = ML  = MT = MB = MC = RO(IJ)/RVOL(IJ)                 YAQUI1  00670
          PR = PLE = PT = PB = PC = P(IJ)                           YAQUI1  00671
          IF (I.EQ.IBAR) GO TO 1510                                 YAQUI1  00672
          MR = RO(IPJ)/RVOL(IPJ)                                    YAQUI1  00673
          PR = P(IPJ)                                               YAQUI1  00674
    1510  IF (I.EQ.1   ) GO TO 1520                                 YAQUI1  00675
          ML = RO(IMJ)/RVOL(IMJ)                                    YAQUI1  00676
          PLE = P(IMJ)                                              YAQUI1  00677
    1520  IF (J.EQ.JP1 ) GO TO 1530                                 YAQUI1  00678
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                    MT = RO(IJP)/RVOL(IJP)                                                        YAQUI1  00679
                    PT = P(IJP)                                                                   YAQUI1  00680
             1530   IF (J.EQ.2   ) GO TO 1540                                                     YAQUI1  00681
                    MB = RO(IJM)/RVOL(IJM)                                                        YAQUI1  00682
                    PB = P(IJM)                                                                   YAQUI1  00683
             1540   P12 = (MR*PC+MC*PR)/(MR+MC)                                                   YAQUI1  00684
                    P23 = (MT*PC+MC*PT)/(MT+MC)                                                   YAQUI1  00685
                    P34 = (ML*PC+MC*PLE)/(ML+MC)                                                  YAQUI1  00686
                    P41 = (MB*PC+MC*PB)/(MB+MC)                                                   YAQUI1  00687
                    ETIL(IJ) = ETIL(IJ)-DTO4/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
                    IJ = IPJ                                                                      YAQUI1  00692
                    IJP = IPJP                                                                    YAQUI1  00693
             1589   IJM = IJM+NQ                                                                  YAQUI1  00694
                    CALL LOOP                                                                     YAQUI1  00695
             1599   CONTINUE                                                                      YAQUI1  00696
                    CALL DONE                                                                     YAQUI1  00697
             2000   NUMIT = 0                                                                     YAQUI1  00698
                    MUSTIT = 1                                                                    YAQUI1  00699
                    PLMAX = EM10                                                                  YAQUI1  00700
             2010   CALL START                                                                    YAQUI1  00701
                    DO 2099 J=2,JP1                                                               YAQUI1  00702
                    DO 2089 I=1,IBAR                                                              YAQUI1  00703
                    IPJ = IJ + NQ                                                                 YAQUI1  00704
                    IPJP = IJP + NQ                                                               YAQUI1  00705
                    X1 = X(IPJ)                                                                   YAQUI1  00706
                    Y1 = Y(IPJ)                                                                   YAQUI1  00707
                    R1 = R(IPJ)                                                                   YAQUI1  00708
                    U1 = UL(IPJ)                                                                  YAQUI1  00709
                    V1 = VL(IPJ)                                                                  YAQUI1  00710
                    X2 = X(IPJP)                                                                  YAQUI1  00711
                    Y2 = Y(IPJP)                                                                  YAQUI1  00712
                    R2 = R(IPJP)                                                                  YAQUI1  00713
                    U2 = UL(IPJP)                                                                 YAQUI1  00714
                    V2 = VL(IPJP)                                                                 YAQUI1  00715
                    X3 = X(IJP)                                                                   YAQUI1  00716
                    Y3 = Y(IJP)                                                                   YAQUI1  00717
                    R3 = R(IJP)                                                                   YAQUI1  00718
                    U3 = UL(IJP)                                                                  YAQUI1  00719
                    V3 = VL(IJP)                                                                  YAQUI1  00720
                    X4 = X(IJ)                                                                    YAQUI1  00721
                    Y4 = Y(IJ)                                                                    YAQUI1  00722
                    R4 = R(IJ)                                                                    YAQUI1  00723
                    U4 = UL(IJ)                                                                   YAQUI1  00724
                    V4 = VL(IJ)                                                                   YAQUI1  00725
                    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
                    S = RDT*(ROL(IJ)-RO(IJ))+ROL(IJ)*D                                            YAQUI1  00730
                    RA = RCSQ(IJ)*(RDT+D)+DELSM(IJ)                                               YAQUI1  00731
                    DP = -OM*S/RA                                                                 YAQUI1  00732
                    ROL(IJ) = ROL(IJ) + RCSQ(IJ)*DP                                               YAQUI1  00733
                    PLMAX = AMAX1(PLMAX,ABS(PL(IJ)))                                              YAQUI1  00734
                    IF (ABS(DP).LE.EPS*PLMAX) GO TO 2080                                          YAQUI1  00735
                    MUSTIT = 1                                                                    YAQUI1  00736
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      PL(IJ) = PL(IJ)+DP                                          YAQUI1  00737
      Y24 = Y2-Y4                                                 YAQUI1  00738
      Y31 = Y3-Y1                                                 YAQUI1  00739
      XR13= .5*(R1+R3)*(X1-X3)                                    YAQUI1  00740
      XR24= .5*(R2+R4)*(X2-X4)                                    YAQUI1  00741
      XX = DT02*DP                                                YAQUI1  00742
      DT02M1 = XX*RM(IPJ)                                         YAQUI1  00743
      DT02M2 = XX*RM(IPJP)                                        YAQUI1  00744
      DT02M3 = XX*RM(IJP)                                         YAQUI1  00745
      DT02M4 = XX*RM(IJ)                                          YAQUI1  00746
      UL(IPJ)  = U1+DT02M1*R1*Y24                                 YAQUI1  00747
      UL(IPJP) = U2+DT02M2*R2*Y31                                 YAQUI1  00748
      UL(IJP)  = U3-DT02M3*R3*Y24                                 YAQUI1  00749
      UL(IJ)   = U4-DT02M4*R4*Y31                                 YAQUI1  00750
      IF (J.EQ.2)   GO TO 2060                                    YAQUI1  00751
      VL(IPJ)  = V1-DT02M1*XR24                                   YAQUI1  00752
      VL(IJ)   = V4-DT02M4*XR13                                   YAQUI1  00753
 2060 IF (J.EQ.JP1) GO TO 2080                                    YAQUI1  00754
      VL(IPJP) = V2+DT02M2*XR13                                   YAQUI1  00755
      VL(IJP)  = V3+DT02M3*XR24                                   YAQUI1  00756
 2080 IJ = IPJ                                                    YAQUI1  00757
 2089 IJP = IPJP                                                  YAQUI1  00758
      UL(IJ) = UL(IJP) = UL(IJP-NQIB) = UL(IJ-NQIB) = 0.          YAQUI1  00759
      CALL LOOP                                                   YAQUI1  00760
 2099 CONTINUE                                                    YAQUI1  00761
      CALL DONE                                                   YAQUI1  00762
      NUMIT = NUMIT+1                                             YAQUI1  00763
      IF (MUSTIT.EQ.0) GO TO 3000                                 YAQUI1  00764
      MUSTIT = 0                                                  YAQUI1  00765
      IF (NUMIT.LT.500) GO TO 2010                                YAQUI1  00766
      LPR = 2                                                     YAQUI1  00767
      PRINT 4130                                                  YAQUI1  00768
 3000 IF (GRDVEL.GT.1.99) GO TO 3150                              YAQUI1  00769
      CALL START                                                  YAQUI1  00770
      DO 3019 J=2,JP2                                             YAQUI1  00771
      DO 3009 I=1,IP1                                             YAQUI1  00772
      UG(IJ) = UL(IJ)*GRDVEL                                      YAQUI1  00773
      VG(IJ) = VL(IJ)*GRDVEL                                      YAQUI1  00774
 3009 IJ = IJ + NQ                                                YAQUI1  00775
      CALL LOOP                                                   YAQUI1  00776
 3019 CONTINUE                                                    YAQUI1  00777
      CALL DONE                                                   YAQUI1  00778
 3100 CALL START                                                  YAQUI1  00779
      DO 3119 J=2,JP2                                             YAQUI1  00780
      DO 3109 I=1,IP1                                             YAQUI1  00781
      X(IJ) = X(IJ)+UG(IJ)*DT                                     YAQUI1  00782
      Y(IJ) = Y(IJ)+VG(IJ)*DT                                     YAQUI1  00783
      R(IJ) = X(IJ)*CYL+OMCYL                                     YAQUI1  00784
 3109 IJ = IJ + NQ                                                YAQUI1  00785
      CALL LOOP                                                   YAQUI1  00786
 3119 CONTINUE                                                    YAQUI1  00787
      CALL DONE                                                   YAQUI1  00788
      GO TO 3200                                                  YAQUI1  00789
 3150 CALL REZONE                                                 YAQUI1  00790
 3200 CALL START                                                  YAQUI1  00791
      DO 3269 J=2,JP1                                             YAQUI1  00792
      DO 3259 I=1,IBAR                                            YAQUI1  00793
         IMJ = IJ-NQ                                              YAQUI1  00794
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         IPJ = IJ+NQ                                                    YAQUI1  00795
         IPJP = IJP+NQ                                                  YAQUI1  00796
      X1 = X(IPJ)                                                       YAQUI1  00797
      Y1 = Y(IPJ)                                                       YAQUI1  00798
      R1 = R(IPJ)                                                       YAQUI1  00799
      X2 = X(IPJP)                                                      YAQUI1  00800
      Y2 = Y(IPJP)                                                      YAQUI1  00801
      R2 = R(IPJP)                                                      YAQUI1  00802
      X3 = X(IJP)                                                       YAQUI1  00803
      Y3 = Y(IJP)                                                       YAQUI1  00804
      R3 = R(IJP)                                                       YAQUI1  00805
      X4 = X(IJ)                                                        YAQUI1  00806
      Y4 = Y(IJ)                                                        YAQUI1  00807
      R4 = R(IJ)                                                        YAQUI1  00808
      UL1 = UL(IPJ)                                                     YAQUI1  00809
      VL1 = VL(IPJ)                                                     YAQUI1  00810
      UL2 = UL(IPJP)                                                    YAQUI1  00811
      VL2 = VL(IPJP)                                                    YAQUI1  00812
      UL3 = UL(IJP)                                                     YAQUI1  00813
      VL3 = VL(IJP)                                                     YAQUI1  00814
      UL4 = UL(IJ)                                                      YAQUI1  00815
      VL4 = VL(IJ)                                                      YAQUI1  00816
      UD1 = UG(IPJ)  - UL1                                              YAQUI1  00817
      VD1 = VG(IPJ)  - VL1                                              YAQUI1  00818
      UD2 = UG(IPJP) - UL2                                              YAQUI1  00819
      VD2 = VG(IPJP) - VL2                                              YAQUI1  00820
      UD3 = UG(IJP)  - UL3                                              YAQUI1  00821
      VD3 = VG(IJP)  - VL3                                              YAQUI1  00822
      UD4 = UG(IJ)   - UL4                                              YAQUI1  00823
      VD4 = VG(IJ)   - VL4                                              YAQUI1  00824
      X12 = X1-X2                                                       YAQUI1  00825
      X23 = X2-X3                                                       YAQUI1  00826
      X34 = X3-X4                                                       YAQUI1  00827
      X41 = X4-X1                                                       YAQUI1  00828
      Y21 = Y2-Y1                                                       YAQUI1  00829
      Y32 = Y3-Y2                                                       YAQUI1  00830
      Y43 = Y4-Y3                                                       YAQUI1  00831
      Y14 = Y1-Y4                                                       YAQUI1  00832
      Y31 = Y3-Y1                                                       YAQUI1  00833
      R12 = R1+R2                                                       YAQUI1  00834
      R23 = R2+R3                                                       YAQUI1  00835
      R34 = R3+R4                                                       YAQUI1  00836
      R41 = R4+R1                                                       YAQUI1  00837
      U12 = UL1+UL2                                                     YAQUI1  00838
      U23 = UL2+UL3                                                     YAQUI1  00839
      U34 = UL3+UL4                                                     YAQUI1  00840
      U41 = UL4+UL1                                                     YAQUI1  00841
      V12 = VL1+VL2                                                     YAQUI1  00842
      V23 = VL2+VL3                                                     YAQUI1  00843
      V34 = VL3+VL4                                                     YAQUI1  00844
      V41 = VL4+VL1                                                     YAQUI1  00845
      D = .25*RVOL(IJ)*(R12*(U12*Y21+V12*X12)+R23*(U23*Y32+V23*X23)     YAQUI1  00846
     1                    +R34*(U34*Y43+V34*X34)+R41*(U41*Y14+V41*X41)) YAQUI1  00847
      VOLR = VOLT = VOLC = 1./RVOL(IJ)                                  YAQUI1  00848
      IF (I.NE.IBAR) VOLR = 1./RVOL(IPJ)                                YAQUI1  00849
      IF (J.NE.JP1 ) VOLT = 1./RVOL(IJP)                                YAQUI1  00850
      IF (I.EQ.1) GO TO 3280                                            YAQUI1  00851
      FL = -FR                                                          YAQUI1  00852
```

```
 823             AL = -AR                                                    YAQUI1  00853
 824       3230  IF (J.EQ.2) GO TO 3290                                      YAQUI1  00854
 825             FB = -FT(I)                                                 YAQUI1  00855
 826             AB = -AT(I)                                                 YAQUI1  00856
 827       3240  FR    = DT08*R12*((UD1+UD2)*Y21+(VD1+VD2)*X12)              YAQUI1  00857
 828             AR    = A0M*SIGN(1.,FR   )+B0*4.*FR   /(VOLR+VOLC)          YAQUI1  00858
 829             FT(I) = DT08*R23*((UD2+UD3)*Y32+(VD2+VD3)*X23)              YAQUI1  00859
 830             AT(I) = A0M*SIGN(1.,FT(I))+B0*4.*FT(I)/(VOLT+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)+DTPOS*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)    *ROL(IJ)+(1.+AR)    *ROL(IPJ))     YAQUI1  00867
              2        +FT(I)*((1.-AT(I))*ROL(IJ)+(1.+AT(I))*ROL(IJP))       YAQUI1  00868
              3        +FL   *((1.-AL)    *ROL(IJ)+(1.+AL)    *ROL(IMJ))     YAQUI1  00869
              4        +FB   *((1.-AB)    *ROL(IJ)+(1.+AB)    *ROL(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(IPJ)*ETIL(IPJ))   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(IMJ)*ETIL(IMJ))   YAQUI1  00875
              4        +FB   *((1.-AB)    *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 = IPJ                                                    YAQUI1  00880
 843             IJP = IPJP                                                  YAQUI1  00881
 844       3259  IJM = IJM + NQ                                              YAQUI1  00882
 845             CALL LOOP                                                   YAQUI1  00883
 846       3269  CONTINUE                                                    YAQUI1  00884
 847             CALL DONE                                                   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  FB    = DT08*R41*((UD4+UD1)*Y14+(VD4+VD1)*X41)              YAQUI1  00890
 853             AB    = A0M*SIGN(1.,FB)+B0*2.*FB*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             E(IJ) = EP(IJ)                                              YAQUI1  00897
 860             IF (J.EQ.2   ) RO(IJM) = ROL(IJM)                           YAQUI1  00898
 861             IF (J.EQ.JP1 ) RO(IJP) = ROL(IJP)                           YAQUI1  00899
 862             IF (I.EQ.IBAR) RO(IJ+NQ) = ROL(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 DONE                                                   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
```

```
      I = IP2-II                                                YAQUI1  00911
      IMJ = IJ-NQ                                               YAQUI1  00912
      IMJM = IJM-NQ                                             YAQUI1  00913
      XX = 0.                                                   YAQUI1  00914
      IF (I.NE.IP1 .AND. J.NE.2  ) XX = MP(IJM)                 YAQUI1  00915
      IF (I.NE.IP1 .AND. J.NE.JP2) XX = XX+MP(IJ)               YAQUI1  00916
      IF (I.NE.1   .AND. J.NE.JP2) XX = XX+MP(IMJ)              YAQUI1  00917
      IF (I.NE.1   .AND. J.NE.2  ) XX = XX+MP(IMJM)             YAQUI1  00918
      RMP(IJ) = 4./XX                                           YAQUI1  00919
      IJ = IMJ                                                  YAQUI1  00920
 3389 IJM = IMJM                                                YAQUI1  00921
      CALL LOOPD                                                YAQUI1  00922
 3399 CONTINUE                                                  YAQUI1  00923
 3400 CALL START                                                YAQUI1  00924
      DO 3499 J=2,JP2                                           YAQUI1  00925
      DO 3489 I=1,IP1                                           YAQUI1  00926
      XX = RMP(IJ)/RM(IJ)                                       YAQUI1  00927
      UP(IJ) = XX*UL(IJ)                                        YAQUI1  00928
      VP(IJ) = XX*VL(IJ)                                        YAQUI1  00929
 3489 IJ = IJ + NQ                                              YAQUI1  00930
      CALL LOOP                                                 YAQUI1  00931
 3499 CONTINUE                                                  YAQUI1  00932
      CALL DONE                                                 YAQUI1  00933
      CALL START                                                YAQUI1  00934
      DO 3699 J=2,JP1                                           YAQUI1  00935
      DO 3599 I=1,IBAR                                          YAQUI1  00936
      IPJ = IJ+NQ                                               YAQUI1  00937
      IPJP = IJP+NQ                                             YAQUI1  00938
      X1   = X(IPJ)                                             YAQUI1  00939
      Y1   = Y(IPJ)                                             YAQUI1  00940
      R1   = R(IPJ)                                             YAQUI1  00941
      UL1 = UL(IPJ)                                             YAQUI1  00942
      UG1 = UG(IPJ)                                             YAQUI1  00943
      VL1 = VL(IPJ)                                             YAQUI1  00944
      VG1 = VG(IPJ)                                             YAQUI1  00945
      X2   = X(IPJP)                                            YAQUI1  00946
      Y2   = Y(IPJP)                                            YAQUI1  00947
      R2   = R(IPJP)                                            YAQUI1  00948
      UL2 = UL(IPJP)                                            YAQUI1  00949
      UG2 = UG(IPJP)                                            YAQUI1  00950
      VL2 = VL(IPJP)                                            YAQUI1  00951
      VG2 = VG(IPJP)                                            YAQUI1  00952
      X3   = X(IJP)                                             YAQUI1  00953
      Y3   = Y(IJP)                                             YAQUI1  00954
      R3   = R(IJP)                                             YAQUI1  00955
      UL3 = UL(IJP)                                             YAQUI1  00956
      UG3 = UG(IJP)                                             YAQUI1  00957
      VL3 = VL(IJP)                                             YAQUI1  00958
      VG3 = VG(IJP)                                             YAQUI1  00959
      X4   = X(IJ)                                              YAQUI1  00960
      Y4   = Y(IJ)                                              YAQUI1  00961
      R4   = R(IJ)                                              YAQUI1  00962
      UL4 = UL(IJ)                                              YAQUI1  00963
      UG4 = UG(IJ)                                              YAQUI1  00964
      VL4 = VL(IJ)                                              YAQUI1  00965
      VG4 = VG(IJ)                                              YAQUI1  00966
      XX = DTO16*ROL(IJ)                                        YAQUI1  00967
      UL13 = UL1+UL3                                            YAQUI1  00968
```

```
      VL13 = VL1+VL3                                                    YAQUI1 00969
      UL24 = UL2+UL4                                                    YAQUI1 00970
      VL24 = VL2+VL4                                                    YAQUI1 00971
      F13 = XX*(R1+R3)*((UG1+UG3-UL13)*(Y3-Y1)+(VG1+VG3-VL13)*(X1-X3))  YAQUI1 00972
      F24 = XX*(R2+R4)*((UG2+UG4-UL24)*(Y2-Y4)+(VG2+VG4-VL24)*(X4-X2))  YAQUI1 00973
      FM1 = F24*RMP(IPJ)                                                YAQUI1 00974
      FM2 = F13*RMP(IPJP)                                               YAQUI1 00975
      FM3 = F24*RMP(IJP)                                                YAQUI1 00976
      FM4 = F13*RMP(IJ)                                                 YAQUI1 00977
      XX = B0*4.*RVOL(IJ)/ROL(IJ)                                       YAQUI1 00978
      AL13 = A0*SIGN(1.,F13)+XX*F13                                     YAQUI1 00979
      AL24 = A0*SIGN(1.,F24)+XX*F24                                     YAQUI1 00980
      OPAL13 = 1.+AL13                                                  YAQUI1 00981
      OPAL24 = 1.+AL24                                                  YAQUI1 00982
      OMAL13 = 1.-AL13                                                  YAQUI1 00983
      OMAL24 = 1.-AL24                                                  YAQUI1 00984
      XX = UL3*OMAL24+UL1*OPAL24                                        YAQUI1 00985
      UP(IPJ)  = UP(IPJ) - FM1*XX                                       YAQUI1 00986
      UP(IJP)  = UP(IJP) + FM3*XX                                       YAQUI1 00987
      XX = UL4*OMAL13+UL2*OPAL13                                        YAQUI1 00988
      UP(IPJP) = UP(IPJP)- FM2*XX                                       YAQUI1 00989
      UP(IJ)   = UP(IJ)  + FM4*XX                                       YAQUI1 00990
      XX = VL3*OMAL24+VL1*OPAL24                                        YAQUI1 00991
      VP(IPJ)  = VP(IPJ) - FM1*XX                                       YAQUI1 00992
      VP(IJP)  = VP(IJP) + FM3*XX                                       YAQUI1 00993
      XX = VL4*OMAL13+VL2*OPAL13                                        YAQUI1 00994
      VP(IPJP) = VP(IPJP)- FM2*XX                                       YAQUI1 00995
      VP(IJ)   = VP(IJ)  + FM4*XX                                       YAQUI1 00996
      IJ = IPJ                                                          YAQUI1 00997
 3599 IJP = IPJP                                                        YAQUI1 00998
      UP(IJ) = UP(IJP) = UP(IJP-NQIB) = UP(IJ-NQIB) = 0.                YAQUI1 00999
      IF (J.NE.2)   GO TO 3620                                          YAQUI1 01000
      DO 3610 IJ=ISC2,ISCF2,NQ                                          YAQUI1 01001
 3610 VP(IJ) = 0.                                                       YAQUI1 01002
 3620 IF (J.NE.JP1) GO TO 3640                                          YAQUI1 01003
      DO 3630 IJP=IJPS,LJP2,NQ                                          YAQUI1 01004
 3630 VP(IJP) = 0.                                                      YAQUI1 01005
 3640 CALL LOOP                                                         YAQUI1 01006
 3699 CONTINUE                                                          YAQUI1 01007
      CALL DONE                                                         YAQUI1 01008
 3700 CALL START                                                        YAQUI1 01009
      DO 3719 J=2,JP2                                                   YAQUI1 01010
      DO 3709 I=1,IP1                                                   YAQUI1 01011
      U(IJ) = UP(IJ)                                                    YAQUI1 01012
      V(IJ) = VP(IJ)                                                    YAQUI1 01013
      RM(IJ) = RMP(IJ)                                                  YAQUI1 01014
 3709 IJ = IJ + NQ                                                      YAQUI1 01015
      CALL LOOP                                                         YAQUI1 01016
 3719 CONTINUE                                                          YAQUI1 01017
      CALL DONE                                                         YAQUI1 01018
 3800 CALL START                                                        YAQUI1 01019
      DO 3899 J=2,JP1                                                   YAQUI1 01020
      DO 3889 I=1,IBAR                                                  YAQUI1 01021
      IPJ = IJ+NQ                                                       YAQUI1 01022
      IPJP = IJP+NQ                                                     YAQUI1 01023
      SIE(IJ) = E(IJ)-.125*(U(IPJ)**2+U(IPJP)**2+U(IJP)**2+U(IJ)**2     YAQUI1 01024
     1                      +V(IPJ)**2+V(IPJP)**2+V(IJP)**2+V(IJ)**2)   YAQUI1 01025
      IJP = IPJP                                                        YAQUI1 01026
```

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 3889  IJ = IPJ                                                            YAQUI1  01027
       CALL LOOP                                                           YAQUI1  01028
 3899  CONTINUE                                                            YAQUI1  01029
       CALL DONE                                                           YAQUI1  01030
       IF (NPT.GT.0) CALL PARTMOV                                          YAQUI1  01031
       GO TO 100                                                           YAQUI1  01032
C                                                                          YAQUI1  01033
 4000  FORMAT(* T=*1PE12.5*  CYC=*I5*  DT=*E12.5*  GRINDS=*E12.5*  CIRC=*  YAQUI1  01034
      1 E12.5*  DTV=*E12.5*  IDTV,JDTV=*I3*,*I3/54X*ITERS=*I4*     CP=*    YAQUI1  01035
      1 E12.5*  DTC=*E12.5*  IDTC,JDTC=*I3*,*I3)                           YAQUI1  01036
 4010  FORMAT(*0  TAPE DUMP*I3* AT T=*1PE12.5* CYCLE*I5)                   YAQUI1  01037
 4020  FORMAT(*0  RESTARTING FROM TD*I3)                                   YAQUI1  01038
 4030  FORMAT(3X,10A8*    T=*1PE12.5* CYCLE=*I5)                           YAQUI1  01039
 4040  FORMAT(*0 WRONG TAPE - WRONG DUMP,*)                                YAQUI1  01040
 4050  FORMAT(1H1)                                                         YAQUI1  01041
 4060  FORMAT(*  I    J*7X*X*11X*Y*11X*U*11X*V*10X*SIE*9X*RHO*9X*VOL*10X   YAQUI1  01042
      1 *D*11X*M*11X*P*)                                                   YAQUI1  01043
 4070  FORMAT(1X,I3*,*I3,10(1X,1PE11.4))                                   YAQUI1  01044
  4080 FORMAT(5X,A10,10A8*    T=*1PE12.5* CYCLE=*I5)                       YAQUI1  01045
 4090  FORMAT(* ISOPYCNICS*)                                               YAQUI1  01046
 4100  FORMAT(* ISOTHERMS*)                                                YAQUI1  01047
 4110  FORMAT(* VORTICITY*)                                                YAQUI1  01048
 4120  FORMAT(12X* MIN=*1PE12.5* MAX=*E12.5* L=*E12.5* H=*E12.5* DQ=*      YAQUI1  01049
      1 F12.5)                                                             YAQUI1  01050
 4130  FORMAT(*0 ITERATION LIMIT EXCEEDED - RUN MAY ABORT.*)               YAQUI1  01051
 4140  FORMAT(* ZONES*/* DRMIN=*1PE12.5* DRMAX=*E12.5* DZMIN=*E12.5        YAQUI1  01052
      1 * DZMAX=*E12.5* XR=*E12.5* YR=*E12.5* YT=*E12.5)                   YAQUI1  01053
 4150  FORMAT(* VELOCITY VECTORS*/18X*VMAX=*1PE12.5)                       YAQUI1  01054
       END                                                                 YAQUI1  01055
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   INDEX  01/12/73                            SUBROUTINE YAQUI2                                   PAGE  57
 SINGLY REFERENCED VARIABLES
     200 -    40*     FIPYB    -R    4CO    IPXL     -I    4CO    JCEN     -I    4CO    PARPLOT -  179SU    REWIND   -    92F    RPDZ     -R    4CO
    1100 -   468*     FIPYT    -R    4CO    IPXR     -I    4CO    JM10     -I    4CO    PARTMOV -  992SU    REZONE   -  761SU    STARTD   -  869SU
    1300 -   585*     FIXR     -R    4CO    IPYB     -I    4CO    JM14     -I    4CO    PDR      -R   4CO    REZRON   -R   4CO    THIRD    -R    4CO
    1500 -   601*     FIYT     -R    4CO    IPYT     -I    4CO    JP402    -I    4CO    PDZ      -R   4CO    REZSIE   -R.  4CO    YAQUI2   -     1SU
    2000 -   672*     FJBP     -R    4CO    ISCFI    -I    4CO    JUNF     -I    4CO    PXCONV   -R   4CO    REZUE    -R   4CO    YLC1     -     2CN
    3100 -   750*     FREZ     -R    4CO    ISC3     -I    4CO    JUNF02   -I    4CO    PXL      -R   4CO    REZVE    -R   4CO    YLC2     -     2CN
    3400 -   886*     H4020    -    14SU    ITV      -I    4CO    LCM      -     2F     PXR      -R   4CO    REZVT    -R   4CO    YSC1     -     3CN
    3700 -   971*     IBP      -I    4CO    IUNF     -I    4CO    LOOPD    -   884SU    PXRP     -R   4CO    REZY0    -R   4CO    YSC2     -     4CN
    3800 -   981*     IBP1     -I    4CO    IXL      -I    4CO    LPR      -I    4CO    PYR      -R   4CO    RIBAR    -R   4CO    YSC3     -    10CN
 DATAREL -    87SU    ICOLOR   -I    4CO    IXR      -I    4CO    MTE      -R    6RL    PYRM     -R   4CO    RIBP     -R   4CO
 DR       -R   4CO    IMOME3   -I    4CO    IYB      -I    4CO    NQI      -I    4CO    PYCONV   -R   4CO    RJBP     -R   4CO
 FIBP     -R   4CO    IMOMX    -I    4CO    IYT      -I    4CO    NQI2     -I    4CO    PYT      -R   4CO    ROMFR    -R   4CO
 FIPXL    -R   4CO    IM6      -I    4CO    JBP      -I    4CO    OMEM10   -R    4CO    PYTP     -R   4CO    RPDR     -R   4CO
 FIPXR    -R   4CO    IPAR     -I    4CO    JBP2     -I    4CO    OPEM10   -R    4CO    REAL     -    6F     RPDRDZ   -R   4CO
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
 MULTIPLY-REFERENCED VARIABLES
    100 -     20*    993
    180 -     32      35*
    189 -     2300    36*
    199 -     2200    38*
    210 -     48*     74AS
    220 -     50*     77AS  104     107
    290 -     46      68*
    300 -     47      69      72*
    310 -     72AS    74*
    320 -     48      76*
    330 -     49      79*
    340 -     50      79AS    81*
    350 -     78      80      82*
    370 -     18      92*
    380 -     96     108*
    400 -     75     112SU
    410 -    116     117*
    420 -    116     119*
    440 -    113AS   114AS   122*
    450 -    130     132     156*
    452 -    156     156     157*
    454 -    121     160*
    456 -    118AS   156     164*
    458 -    116     117AS   167*
    460 -    115AS   123AS   172*
    479 -    12600   173*
    489 -    12500   175*
    490 -    177*    180     248     251
    500 -     73     179*
    530 -    190     219*
    539 -    18600   220*
    549 -    18500   222*
    550 -    223     227*
    580 -    237     240*
    589 -    23200   242*
    599 -    23100   244*
    600 -    227     248*
    610 -    250*    315     422
    620 -    251     251     252*
    629 -    25400   256*
    639 -    25300   258*
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 640 -   251    261*
 649 -   263DO  285*
 659 -   262DO  287*
 700 -   260    289*
 709 -   293DO  296*
 719 -   292DO  298*
 720 -   307*   308
 730 -   309*   313
 735 -   300    314*
 739 -   317DO  318*
 740 -   310    320*
 750 -   322    323*
 760 -   322    325*
 770 -   322    327*
 780 -   324    326    328*
 789 -   348DO  355*
 799 -   347DO  357*
 800 -   344    358*
 810 -   359    364AS  366*
 820 -   366    371AS  373*   395
 830 -   373    378AS  380*
 840 -   365    372    379    386*
 879 -   337DO  343    380    385AS  396*
 889 -   333DO  399*
 899 -   331DO  400*
 939 -   403DO  419*
 949 -   402DO  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 -   426DO  464*
1099 -   425DO  466*
1130 -   531    534*
1140 -   533    537*
1199 -   470DO  574*
1210 -   577DO  578*
1220 -   576    579*
1230 -   580DO  581*
1240 -   579    582*
1299 -   469DO  583*
1389 -   587DO  597*
1399 -   586DO  599*
1510 -   649    652*
1520 -   652    655*
1530 -   655    658*
1540 -   658    661*
1589 -   603DO  668*
1599 -   602DO  670*
2010 -   675*   737
2060 -   722    725*
2080 -   706    725    728*
2089 -   677DO  729*
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  2099 -   67600  732*
  3000 -   735    740*
  3009 -   74300  746*
  3019 -   74200  748*
  3109 -   75200  756*
  3119 -   75100  758*
  3150 -   740    761*
  3200 -   760    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  960*
  3610 -   96300  964*
  3620 -   962    965*
  3630 -   96600  967*
  3640 -   965    968*
  3699 -   89700  969*
  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  247WR  329WR 1002*
  4090 -   323WR 1003*
  4100 -   325WR 1004*
  4110 -   327WR 1005*
  4120 -   328WR 1006*
  4130 -   739PR 1007*
  4140 -   225WR 1008*
  4150 -   246WR 1009*
AA      ()R    4CO   84WR   94     95RD
AASC    ()R    3CO    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ    5EQ
AA1     ()R    2LC   85WR   97RD
AA2     ()R    2LC   86WR   98RD
AB      -R   826=   836    836    838    838    853=
ABL     -R   840=   841
ABS     -    189SU  189SU  315SU  315SU  315SU  535SU  535SU  705SU  706SU  831SU  831SU  831SU  831SU  832SU
ADV     -    120SU  181SU  229SU  320SU
AFSREL  -     88SU   89SU   99SU  110SU
AK      -R   532=   536=   537    538    542=   543
AL      -R   823=   836    836    838    838    850=
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      INDEX  01/12/73                        SUBROUTINE YAQUI2                                  PAGE  60
ALOG10   -    301SU  304SU
AL13    -R    941=   943    945
AL24    -R    942=   944    946
AMAX1   -      30SU  189SU  202SU  206SU  295SU  315SU  535SU  592SU  705SU  831SU
AMIN1   -      53SU  201SU  205SU  294SU  537SU  544SU  832SU
ANC     -R      4CO  424
AR      -R    823    828=   836    836    838    838
ASQ     -R      4CO   31     32     33    592
ASSIGN  -       72F   74F    77F    79F   113F   114F   115F   117F   118F   123F   364F   371F   378F   385F
AT      ()R     8DI    9EQ    9EQ    9EQ    9EQ    9EQ    9EQ  826    830=   836    836    838    838
ATR     -R    839=   841
AX      -R    457=   459    461
AY      -R    458=   460    461
A0      -R      4CO  941    942
A0FAC   -R      4CO  832
A0M     -R      4CO  828    830    850    853
B0      -R      4CO  828    830    850    853    940
CIRC    -R     21=    26=    26     27=    27     28=    28     29=    29     43WR   45PR
COLAMU  -R      4CO  536    542
COMMON  -       3F     4F    10F
CON     ()R     8DI    9EQ  309=   318=   328WR  328WR  339    340    341    342    387
CQ      ()R     5EQ    7DI  255=   283=   294    295    339    340    341    342    387    387    387
CYL     -R      4CO  548    550    551    755
D       -R    129=   155=   157WR  164PR  528=   537    700=   701    702    817=   832
DELSM   ()R     5EQ    7DI  595=   702
DIMENSI -       7F     8F
DONE    -      39SU  259SU  288SU  467SU  584SU  600SU  671SU  733SU  749SU  759SU  847SU  868SU  895SU  970SU  980SU  991SU
DP      -R    703=   704    706    708    713
DQ      -R    303=   307    312    316=   318    328WR  543=   544
DRMAX   -R    183=   202=   202    225WR
DRMIN   -R    182=   201=   201    225WR
DROU    -R    228=   235    236
DRV     -     215SU  216SU  217SU  218SU  240SU  391SU  414SU  415SU  416SU  417SU
DT      -R      4CO   43WR   45PR   52=    52     53=    55     56     56=    57     58     59     60     61     62     63     64
               65     66    459    460    461    542    753    754
DTC     -R      4CO   43WR   45PR   53     55=   832=   832    833    634    835
DTCSAV  -R     17=   833    834    835=
DTFAC   -R      4CO   54=    55
DTGR    -R      4CO   64=
DTGZ    -R      4CO   65=
DTGZP   -R      4CO   66=
DTO     ()R     4CO   68     70
DTOC    ()R     4CO   69     70
DTO16   -R      4CO   62=   929
DTO2    -R      4CO   59=   523    524    525    526    536    713
DTO2M1  -R    523=   554    562    568    714=   718    723
DTO2M2  -R    524=   558    565    571    715=   719    726
DTO2M3  -R    525=   555    563    569    716=   720    727
DTO2M4  -R    526=   559    566    572    717=   721    724
DTO4    -R      4CO   60=   665
DTO8    -R      4CO   61=   827    829    849    852
DTPOS   -R      4CO   52=    53=   542    542    832    832
DTV     -R      4CO   43WR   45PR   53     55=   544=   544    545    546    547
DTVSAV  -R     17=   545    546    547=
DT8     -R      4CO   63=   595
DZ      -R      4CO   34
DZMAX   -R    183=   206=   206    225WR
DZMIN   -R    182=   205=   205    225WR
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    INDEX  01/12/73                    SUBROUTINE YAQUI2                                       PAGE  61
E        ()R   5EQ     7DI    590     859=    986
EMPTY    -     44SU   177SU
EM10     -R    4CO    46      48      69      181     190     223     227     299     543     674     832
EP       ()R   5EQ     7DI    838=    859
EPS      -R    4CO    706
EQUIVAL  -     5F      9F
ETIL     ()R   5EQ     7DI    590=    665=    665     837     838     838     838     838
FB       -R   825=    831     836     838     852=    853     853
FIXL     -R    4CO    207     209     211     213     233     235     388     406     408     410     412
FIYB     -R    4CO    208     210     212     214     234     236     389     407     409     411     413
FL       -R   822=    831     836     838     849=    850     850
FLOAT    -     34SU   318SU
FM1      -R   936=    948     954
FM2      -R   937=    951     957
FM3      -R   938=    949     955
FM4      -R   939=    952     958
FR       -R   822     827=    828     828     831     836     838
FT       ()R   8DI     9EQ    825     829=    830     830     831     836     838
F13      -R   934=    937     939     941     941
F24      -R   935=    936     938     942     942
GETO     -     13SU    15SU
GGM1     -R    4CO    592
GM1      -R    4CO    31      33
GR       -R    4CO    64      457
GRDVEL   -R    4CO    181     190     223     740     744     745
GZ       -R    4CO    34      65      458
GZP      -R    4CO    66
HR13     -R   509=    556     564     570
HR24     -R   510=    552     561     567
I        -I    4CO    23DO    26      27      126DO   132     157WR   164PR   186DO   215     232DO   254DO   263DO   293DO   333DO   403DO   414
              416     426DO   432     444     470DO   545     587DO   603DO   649     652     677DO   743DO   752DO   764DO   819     821     825
              826     829     830     830     830     831     833     836     836     836     838     838     838     857DO   862     873=    877
              878     879     880     888DO   898DO   973DO   983DO
IBAR     -I    4CO    18      23DO    186DO   248     254DO   263DO   293DO   403DO   416     470DO   587DO   603DO   649     677DO   764DO   819
              857DO   862     898DO   983DO
IC1      -I   360=    367=    374=    381=    388     388     389     389
IC2      -I   361=    368=    375=    382=    388     389
IDTC     -I    43WR    45PR   833=
IDTO     -I    4CO    68      69      70      70      71=     71
IDTV     -I    43WR    45PR   545=
II       -I    15AG   16      348DO   872DO   873
IJ       -I    4CO    24      26      26      27      27      28      28      29      29      30      31      31      31      33      33      33
               34     36=     128     145     146     147     148     149     172=    187     189     189     194     198     219=    233     234
              235     235     236     236     242=    242     255     255     256=    256     264     278     279     280     281     282     282
              283     284=    294     295     296=    296     334     341     346     356     363     383     398=    404     412     413     418=
              427     428     457     458     459     459     460     460     461     461     461     462=    471     488     489     490     491
              492     526     528     532     536     542     543     548     549     550     551     553     557     559     559     560     566
              566     572     572     573=    575     575     577DO   578     588     590     590     590     591     591     592     592     593
              594     595     596=    604     605     616     617     618     634     638     647     647     648     665     665     666=    678
              695     696     697     698     699     700     701     701     701     702     702     704     704     704     705     708     708
              717     721     724     728=    730     730     744     744     745     745     746=    746     753     753     753     754     754
              754     755     755     756=    756     765     766     777     778     779     786     787     794     795     817     818     832
              836     836     836     836     836     836     837     837     838     838     841     842=    850     853     858     858     858
              859     859     862     862     865=    865     874     878     881     882=    889     889     890     890     891     891     892=
              892     899     922     923     924     925     926     927     928     929     939     940     940     952     952     958     958
              959=    961     961     963DO   964     974     974     975     975     976     976     977=    977     984     986     986     986
              986     988=
IJA      -I   346=    350     352     353     354=    357=
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    INDEX  01/12/73                         SUBROUTINE YAQUI2                                 PAGE  62
IJR     -I  345=    349     352     353     355=    356=
IJM     -I    4CO   127     131     131     133     134     134     150     151     152     153     154     155     157WR   157WR   157WR   157WR
            157WR   157WR   164PR   164PR   164PR   164PR   164PR   164PR   173=    335     339     345     362     369     397=    439     440
            464=    464     659     659     660     668=    668     836     838     838     844=    844     860     860     863=    863     875
            877     883=
IJP     -I    4CO    25      26      26      27      27      35=    188     193     197     220=    265     274     275     276     277     282
            285=    357     399=    399     405     410     411     419=    429     451     452     463=    472     483     484     485     486
            487     525     555     555     563     563     569     569     574=    575     575     580DO   581     589     590     593     594
            597=    606     613     614     615     633     637     656     656     657     667=    679     690     691     692     693     694
            716     720     727     729=    730     730     767     774     775     776     784     785     792     793     820     836     838
            838     843=    861     861     864=    864     900     915     916     917     918     919     920     921     938     949     949
            955     955     960=    961     961     966DO   967     985     986     986     987=
IJPS    -I    4CO   580DO   966DO
IJ1     -I  362=    369=    376=    383=    387     387
IJ2     -I  363=    370=    377=    384=    387     395
IMJ     -I  427=    433     434     604=    653     653     654     765=    836     838     838     874=    879     882
IMJM    -I  875=    880     883
IM1     -I    4CO    27     333DO
IPJ     -I   24=     28      28      29      29      36     128=    140     141     142     143     144     172     187=    191     195     219
            264=    266     267     268     269     282     284     334=    342     377     384     398     404=    406     407     418     428=
            445     446     462     471=    473     474     475     476     477     523     554     554     562     562     568     568     573
            588=    590     593     594     596     605=    607     608     609     631     635     650     650     651     666     678=    680
            681     682     683     684     714     718     723     728     766=    768     769     770     780     781     788     789     819
            836     838     838     842     899=    901     902     903     904     905     906     907     936     948     948     954     954
            959     984=    986     986     988
IPJA    -I  350=    352     353     354
IPJB    -I  349=    352     353     355
IPJM    -I  127=    135     136     137     138     139     173     335=    340     370     376     395     397
IPJP    -I   25=     35     188=    192     196     220     265=    270     271     272     273     282     285     405=    408     409     419
            429=    463     472=    478     479     480     481     482     524     558     558     565     565     571     571     574     589=
            590     593     594     597     606=    610     611     612     632     636     667     679=    685     686     687     688     689
            715     719     726     729     767=    771     772     773     782     783     790     791     843     900=    908     909     910
            911     912     913     914     937     951     951     957     957     960     985=    986     986     987
IP1     -I    4CO   126DO   132     232DO   426DO   444     743DO   752DO   872DO   877     878     888DO   973DO
IP2     -I    4CO   873
ISCF2   -I    4CO   577DO   963DO
ISC2    -I    4CO   577DO   963DO
IX1     ()I   8DI     9EQ   207=    216AG   217AG   233=    238     238     240AG   241AG   388=    391AG   392AG   393AG   406=    415AG   416AG
IX2     ()I   8DI     9EQ   209=    217AG   218AG   235=    238=    238     240AG   391AG   408=    416AG   417AG
IX3     -I  211=    215AG   218AG   410=    414AG   417AG
IX4     -I  213=    215AG   216AG   412=    414AG   415AG
IY1     ()I   8DI     9EQ   208=    216AG   217AG   234=    238     238     240AG   241AG   389=    391AG   392AG   393AG   407=    415AG   416AG
IY2     ()I   8DI     9EQ   210=    217AG   218AG   236=    237     238     239=    240AG   391AG   409=    416AG   417AG
IY3     -I  212=    215AG   218AG   411=    414AG   417AG
IY4     -I  214=    215AG   216AG   413=    414AG   415AG
J       -I    4CO    22DO    28      29      34     125DO   130     132     157WR   164PR   185DO   216     231DO   253DO   262DO   292DO   331DO
            402DO   415     417     425DO   438     450     469DO   546     576     579     586DO   602DO   655     658     676DO   722     725
            742DO   751DO   763DO   820     824     834     856DO   860     861     871=    877     878     879     880     887DO   897DO   962
            965     972DO   982DO
JBAR    -I    4CO    29      93     248     331DO
JDTC    -I   43WR    45PR   834=
JDTV    -I   43WR    45PR   546=
JJ      -I  347DO   870DO   871
JNM     -I   10CO    13AG   161WR   169PR   226WR   247WR   329WR
JNSC    -I   94=     95RD
JP1     -I    4CO    22DO   185DO   253DO   262DO   292DO   402DO   417     469DO   579     586DO   602DO   655     676DO   725     763DO   820
            856DO   861     897DO   965     982DO
JP2     -I    4CO   125DO   132     231DO   425DO   450     742DO   751DO   870DO   878     879     887DO   972DO
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JP4        -I     4CO    871
JTD        -I     93=     96     102PR   105WR
K          -I    301=    302     304=    305     306=    309     311=    311     317DO   318     318     319=    328WR   337DO   393
KK         -I    33700   339     340     341     342     387     392     393
KRET       -I     72AS    74AS    77AS    79AS    91     112     176     178
KRF        -I    113AS   117AS   122=    159     163
KRFP       -I    115AS   118AS   122
KRP        -I    114AS   123AS   166     171
KRI        -I    364AS   371AS   378AS   385AS   390
KXI        -I     4CO    531     532     542
K1         -I    338=    339=    343     343     359     366
K2         -I    338=    340=    343     343     366     373
K3         -I    338=    341=    343     343     359     380
K4         -I    338=    342=    343     343     373     380
L          -I    249=    250=    250     251     255     322
LAM        -R     4CO     6RL    537     543
LAMD       -R     6RL    537=    548     549     551
LINCNT     -     119SU   224SU   245SU   321SU
LINESF     -I    158=    158     159     160=
LINESP     -I    165=    165     166     167=
LJP2       -I     4CO    58000   966DO
LL         -I    358=    386=    386     388     389     390     394=
LOCF       -      94SU    94SU
LOOP       -      37SU   174SU   221SU   243SU   257SU   286SU   297SU   332SU   420SU   465SU   582SU   598SU   669SU   731SU   747SU   757SU   845SU
                 866SU   893SU   968SU   978SU   989SU
LPR        -I     4CO     43      83     104     112     116     156     176     180     738=
M          ()R    5EQ     6RL     7DI
MB         -R     6RL    647=    659=    664     664
MC         -R     6RL    647=    661     661     662     662     663     663     664     664     665
ML         -R     6RL    647=    653=    663     663
MP         ()R    5EQ     6RL     7DI    836=    838     858     877     878     879     880
MPAR       ()R    5EQ     6RL     7DI
MR         -R     6RL    647=    650=    661     661
MT         -R     6RL    647=    656=    662     662
MU         -R     4CO     6RL    538     543
MU02       -R     6RL    538=    539     548     549
MU04       -R     6RL    539=    550     551
MUSTIT     -I    673=    707=    735     736=
N          -I     84WR    84WR    85WR    85WR    86WR    86WR    95RD    95RD    97RD    97RD    98RD    98RD   336=    344     351=    351     352
                 353
NAME       ()I    4CO    103PR   106WR   161WR   169PR   226WR   247WR   329WR
NCYC       -I     4CO     34      43WR    45PR    47      51=     51      52      53      82PR    83WR   103PR   106WR   161WR   169PR   181     190
                 223     226WR   247WR   329WR
NLC        -I     4CO     85WR    97RD
NPS        -I     4CO     86WR    98RD
NPT        -I     4CO     86      98     179     992
NQ         -I     4CO     24      25     127     128     187     188     242     256     264     265     296     334     335     349     350     399
                 404     405     427     428     429     464     471     472     577DO   58000   588     589     604     605     606     668     678
                 679     746     756     765     766     767     844     862     862     863     864     865     874     875     892     899     900
                 963DO   966DO   977     984     985
NQIB       -I     4CO    575     575     730     730     961     961
NSC        -I     4CO     84WR
NUMIT      -I     4CO     43WR    45PR    47     672=    734=    734     737
NUMTD      -I     4CO     82PR    83WR    90=     90      96     100=    100
OM         -R     4CO    703
OMAL13     -R    945=    950     956
OMAL24     -R    946=    947     953
OMANC      -R     4CO    543
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     INDEX  01/12/73                     SUBROUTINE YAQUI2                           PAGE  64
OMCYL    -R     4CO   755
OPAL13   -R   943=    950     956
OPAL24   -R   944=    947     953
P        ()R    5EQ     7DI    31=     33=     34=    157WR   164PR   553     557     560     648     651     654     657     660
PB       -R   648=    660=    664
PC       -R   648=    661     662     663     664
PITH     -R   551=    554     555     558     559
PIXX     -R   548=    552     556     567     570
PIXY     -R   550=    552     556     561     564     567     567     570     570
PIYY     -R   549=    560     567     570
PL       ()R    5EQ     7DI   705     708=    708
PLE      -R   648=    654=    663
PLMAX    -R   674=    705=    705     706
PLT      -    241SU   392SU   393SU
PMX      ()R    5EQ     7DI
PMY      ()R    5EQ     7DI
PM0      ()R    5EQ     7DI
PR       -R   648=    651=    661
PRINT    -     45F     82F    102F    103F    108F    164F    168F    169F    170F    739F
PRM      -R   129=    131=    157WR   164PR
PRSIE    -R   129=    133=    157WR   164PR
PRV      -R   129=    134=    157WR   164PR
PT       -R   648=    657=    662
PU       ()R    5EQ     7DI
PV       ()R    5EQ     7DI
PYYMP    -R   560=    561     564
P12      -R   661=    665
P23      -R   662=    665
P34      -R   663=    665
P41      -R   664=    665
Q        ()R    5EQ     7DI   461=    568=    568     569=    569     571=    571     572=    572     590     590     590     590
QMN      -R   289=    290     294=    294     299     304     308     314     315     318     328WR
QMX      -R   290=    295=    295     299     310     314     315     328WR
R        ()R    5EQ     7DI   137     142     147     152     282     282     282     282     475     480     485     490     609     612     615
              618     682     687     692     697     755=    770     773     776     779     903     910     917     924
RA       -R   702=    703
RCSQ     ()R    5EQ     7DI   592=    702     704
RDT      -R     4CO    58=    424     701     702
READ     -     95F     97F     98F
RETURN   -     81F    111SU
RIBJB    -R     4CO    42
RM       ()R    5EQ     7DI   131     131     523     524     525     526     714     715     716     717     889     976=
RMP      ()R    5EQ     7DI   881=    889     936     937     938     939     976
RO       ()R    5EQ     7DI    31      31      33     157WR   164PR   255     532     536     542     543     591     647     650     653     656
              659     701     836     837     838     838     838     838     858=    860=    861=    862=
ROE      -R   837=    838     838     838     838     838
ROL      ()R    5EQ     7DI    33     591=    701     701     704=    704     836     836     836     836     836     836     836     836     860
              861     862     929     940
RON      -R     4CO    31      33      34
RVOL     ()R    5EQ     7DI   134     134     155     282     528     548     549     550     551     647     650     653     656     659     700
              817     818     819     820     832     841=    850     853     858     940
R1       -R   137=    155     155     282=    283     475=    505     508     509     554     609=    627     630     682=    700     700     711
              718     770=    805     808     841     841     903=    934
R12      -R   505=    528     548     549     550     627=    665     805=    817     827
R2       -R   142=    155     155     480=    505     506     510     558     612=    627     628     687=    700     700     712     719     773=
              805     806     841     910=    935
R23      -R   506=    528     548     549     550     628=    665     806=    817     829
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     INDEX  01/12/73                   SUBROUTINE YAQUI2                                           PAGE  65
R3         -R  147=   155    155    485=   506    507    509    555    615=   628    629    692=   700    700    711    720    776=
               806    807    841    841    917=   934
R34        -R  507=   528    548    549    550    629=   665    807=   817    849
R4         -R  152=   155    155    490=   507    508    510    559    618=   629    630    697=   700    700    712    721    779=
               807    808    841    924=   935
R41        -R  508=   528    548    549    550    630=   665    808=   817    852
S          -R  701=   703
SECOND     -    11SU   41SU
SIE       ()R    5EQ    7DI   30     133    592    986=
SIFT       -R   30=   31     33
SIGN       -   828SU  830SU  850SU  853SU  941SU  942SU
SQRT       -   199SU  200SU  203SU  204SU
START      -    20SU  124SU  184SU  230SU  252SU  261SU  291SU  330SU  401SU  423SU  468SU  585SU  601SU  675SU  741SU  750SU  762SU
               855SU  886SU  896SU  971SU  981SU
T          -R    4CO   43WR   45PR  46     50     56     56     57=    57     69     82PR   83WR  103PR  106WR  161WR  169PR  226WR
               247WR  329WR
TRASE      -R   11AG  12     49
TLIM       -R   16=    19=   19     49     101=   101
TLIMD      -R    4CO  19     101
TOLD       -R   40=   42
TOUT       -R    4CO  46     56     56     68=    68     70=
TWFIN      -R    4CO  50
T1         -R   12=   48     76=
T2         -R   40    41AG   42     43WR   45PR   48     49     76
T2OMD      -R    4CO  48
U         ()R    5EQ    7DI  28     28     29     29     138    143    148    153    157WR  164PR  189    235    268    272    276
               280    433    439    445    451    457    459    461    476    481    486    491    974=   986    986    986    986
UD1        -R  788=   827    852
UD2        -R  790=   827    829
UD3        -R  792=   829    849
UD4        -R  794=   849    852
UG        ()R    5EQ    7DI  744=   753    788    790    792    794    905    912    919    926
UG1        -R  905=   934
UG2        -R  912=   935
UG3        -R  919=   934
UG4        -R  926=   935
UL        ()R    5EQ    7DI  683    688    693    698    718=   719=   720=   721=   730=   730=   730=   730=   744    780    782
               784    786    890    904    911    918    925
UL1        -R  780=   788    809    812    904=   930    947
UL13       -R  930=   934
UL2        -R  782=   790    809    810    911=   932    950
UL24       -R  932=   935
UL3        -R  784=   792    810    811    918=   930    947
UL4        -R  786=   794    811    812    925=   932    950
UP        ()R    5EQ    7DI  890=   948=   948    949=   949    951=   951    952=   952    961=   961=   961=   961=   974
UTIL      ()R    5EQ    7DI  459=   554=   554    555=   555    558=   558    559=   559    575=   575=   575=   575=   631    632
               633    634
U1         -R  138=   155    155    268=   283    283    431=   433=   439=   439    445=   445    451=   451    457    476=   511
               514    516    631=   639    642    683=   700    700    718
U12        -R  511=   528    548    548    550    551    639=   665    809=   817
U13        -R  516=   570
U2         -R  143=   155    155    272=   283    283    481=   511    512    515    632=   639    640    688=   700    700    719
U23        -R  512=   528    548    550    640=   665    810=   817
U24        -R  515=   567
U3         -R  148=   155    155    276=   283    283    486=   512    513    516    633=   640    641    693=   700    700    720
U34        -R  513=   528    548    548    550    551    641=   665    811=   817
U4         -R  153=   155    155    280=   283    283    491=   513    514    515    534    535    634=   641    642    698=   700
               700    721
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 INDEX  01/12/73                         SUBROUTINE YAQUI2                                        PAGE  66
U41       -R   514=    528     548     550     642=    665     812=    817
V         ()R    5EQ     7DI   26      26      27      27      139     144     149     154     157WR   164PR   189     236     269     273     277
               281     434     440     446     452     458     460     461     477     482     487     492     975=    986     986     986     986
VD1       -R   789=    827     852
VD2       -R   791=    827     829
VD3       -R   793=    829     849
VD4       -R   795=    849     852
VELIJ     -R   534=    536     542
VELMX     -R   535=    536     542
VG        ()R    5EQ     7DI   745=    754     789     791     793     795     907     914     921     928
VG1       -R   907=    934
VG2       -R   914=    935
VG3       -R   921=    934
VG4       -R   928=    935
VL        ()R    5EQ     7DI   684     689     694     699     723=    724=    726=    727=    745     781     783     785     787     891     906
               913     920     927
VL1       -R   781=    789     813     816     906=    931     953
VL13      -R   931=    934
VL2       -R   783=    791     813     814     913=    933     956
VL24      -R   933=    935
VL3       -R   785=    793     814     815     920=    931     953
VL4       -R   787=    795     815     816     927=    933     956
VMAX      -R   183=    189=    189     227     228     246WR
VOLC      -R   818=    828     830     836     838
VOLR      -R   818=    819=    828
VOLT      -R   818=    820=    830
VP        ()R    5EQ     7DI   891=    954=    954     955=    955     957=    957     958=    958     964=    967=    975
VTIL      ()R    5EQ     7DI   460=    562=    562     563=    563     565=    565     566=    566     578=    581=    635     636     637     638
VV        -R     4CO   228
V1        -R   139=    155     155     269=    283     283     431=    434=    440=    440     446=    446     452=    452     458     477=    517
               520     522     635=    643     646     684=    700     700     723
V12       -R   517=    528     549     550     550     643=    665     813=    817
V13       -R   522=    570
V2        -R   144=    155     155     273=    283     283     482=    517     518     521     636=    643     644     689=    700     700     726
V23       -R   518=    528     549     550     644=    665     814=    817
V24       -R   521=    567
V3        -R   149=    155     155     277=    283     283     487=    518     519     522     637=    644     645     694=    700     700     727
V34       -R   519=    528     549     550     550     645=    665     815=    817
V4        -R   154=    155     155     281=    283     283     492=    519     520     521     534     535     638=    645     646     699=    700
               700     724
V41       -R   520=    528     549     550     646=    665     816=    817
WRITE     -      43F     83F    84F     85F     86F    105F    106F    109F    157F    161F    162F    225F    226F    246F    247F    323F    325F
               327F    328F    329F
X         ()R    5EQ     7DI   28      28      29      29      135     140     145     150     157WR   164PR   191     192     193     194     233
               235     266     270     274     278     352     352     352     352     406     408     410     412     473     478     483     488
               593     593     593     593     607     610     613     616     680     685     690     695     753=    753     755     768     771
               774     777     901     908     915     922
XCO       ()R    8DI     9EQ   352=    388     388     388
XCONV     -R     4CO   207     209     211     213     233     235     388     406     408     410     412
XL        -R     4CO   207     209     211     213     233     235     388     406     408     410     412
XPAR      ()R    5EQ     7DI
XR        -R     4CO   225WR
XR13      -R   711=    724     726
XR24      -R   712=    723     727
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      INDEX  01/12/73                           SUBROUTINE YAQUI2                                                PAGE  67
XX        -R    42=     43WR    45PR    299=    300     301     302=    303     305=    307=    307     308     309     310     312=    312     314=
                315     316     387=    388     389     430=    437=    449=    459     529=    535     540=    540     540     543     543     552=
                554     555     556=    558     559     561=    562     563     564=    565     566     567=    568     569     570=    571     572
                593=    595     595     713=    714     715     716     717     831=    832     876=    877=    878=    878     879=    879     880=
                880     881     889=    890     891     929=    934     935     940=    941     942     947=    948     949     950=    951     952
                953=    954     955     956=    957     958
XY        -R    527=    548     550     551     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=    436=    442=    442     448=    448     454=
                454     456=    456     457     458     473=    493     496     498     529     607=    619     622     680=    700     700     711
                768=    796     799     839     840     901=    934
X12       -R    493=    528     549     550     619=    665     796=    817     827
X2        -R    140=    155     155     192=    200     203     209     270=    283     283     478=    493     494     497     529     610=    619
                620     685=    700     700     712     771=    796     797     839     908=    935
X23       -R    494=    528     549     550     620=    665     797=    817     829
X24       -R    497=    527     552     561     567     567
X3        -R    145=    155     155     193=    200     204     211     274=    283     283     483=    494     495     498     529     613=    620
                621     690=    700     700     711     774=    797     798     839     840     915=    934
X31       -R    498=    527     556     564     570     570
X34       -R    495=    528     549     550     621=    665     798=    817     849
X4        -R    150=    155     155     194=    199     204     213     278=    283     283     488=    495     496     497     529     616=    621
                622     695=    700     700     712     777=    798     799     840     922=    935
X41       -R    496=    528     549     550     622=    665     799=    817     852
Y         ()R     5EQ     7DI   26      26      27      27     136     141     146     151     157WR   164PR   195     196     197     198     234
                236     267     271     275     279     353     353     353     353     407     409     411     413     474     479     484     489
                594     594     594     594     608     611     614     617     681     686     691     696     754=    754     769     772     775
                778     902     909     916     923
YB        -R      4CO   34      208     210     212     214     225WR   234     236     389     407     409     411     413
YCO       ()R     8DI     9EQ   353=    389     389     389
YCONV     -R      4CO   208     210     212     214     234     236     389     407     409     411     413
YPAR      ()R     5EQ     7DI
YT        -R      4CO   34      225WR
YY        -R    430=    443=    455=    460     530=    535     541=    541     541     543     543     553=    554     555     557=    558     559
                594=    595     595
Y1        -R    136=    155     155     195=    199     203     208     267=    283     283     424=    457     458     474=    499     502     504
                530     608=    623     626     681=    700     700     710     769=    800     803     804     902=    934
Y14       -R    502=    528     548     550     626=    665     803=    817     840     852
Y2        -R    141=    155     155     196=    200     203     210     271=    283     283     479=    499     500     503     530     611=    623
                624     686=    700     700     709     772=    800     801     909=    935
Y21       -R    499=    528     548     550     623=    665     800=    817     827     839
Y24       -R    503=    527     552     553     561     567     567     709=    718     720
Y3        -R    146=    155     155     197=    200     204     212     275=    283     283     484=    500     501     504     530     614=    624
                625     691=    700     700     710     775=    801     802     804     916=    934
Y31       -R    504=    527     556     557     564     570     570     710=    719     721     804=    839     840
Y32       -R    500=    528     548     550     624=    665     801=    817     829     839
Y4        -R    151=    155     155     198=    199     204     214     279=    283     283     489=    501     502     503     530     617=    625
                626     696=    700     700     709     778=    802     803     923=    935
Y43       -R    501=    528     548     550     625=    665     802=    817     840     849
ZZ        -R      4CO   94
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INDEX  01/12/73                   SUBROUTINE PARTMOV                             PAGE  68
                   SUBROUTINE PARTMOV                                           YAQUI1  01056
                   COMMON /YSC1/ AASC(4242)                                     COMMON2 00002
                   COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,B0,COLAMU,CYL,      COMMON2 00003
                  1       DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTO(10),DTOC(10),     COMMON2 00004
                  2       DTO16,DTO2,DTO4,DTOR,DTPOS,DTV,DT8,DZ,EM10,EPS,FIBP,  COMMON2 00005
                  3       FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,     COMMON2 00006
                  4       FREZ,GGM1,GM1,GR,GRDVEL,GZ,G7P,I,IBAR,IBP,IBP1,ICOLOR, COMMON2 00007
                  5       IDTO,IJ,IJM,IJP,IJPS,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,NQI,NQIB,NQI2,NSC, COMMON2 00012
                  1       NUMIT,NUMTD,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV, COMMON2 00013
                  2       PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE, COMMON2 00014
                  3       REZUE,REZVE,REZVT,REZY0,RIBAR,RIRJB,RIBP,RJBP,ROMFR,  COMMON2 00015
                  4       RON,RPDR,RPDRDZ,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,T20MD,  COMMON2 00016
                  5       VV,XCONV,XL,XR,YB,YCONV,YT,ZZ                         COMMON2 00017
                   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),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,PM0),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL, EQVREAL 00006
                  5             VL,PMY,PV),(AASC(14),Q,ROL)                      EQVREAL 00007
                   REAL LAM,LAMD,M,MB,MC,ML,MP,MPAR,MR,MT,MTE,MU,MU02,MU04      EQVREAL 00008
                   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),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          PMY(1),PV(1),Q(1),ROL(1),PM0(1)                    DIMEN   00006
                   DIMENSION X1(4)                                              YAQUI1  01060
                   EQUIVALENCE (X1(2),X2),(X1(3),X3),(X1(4),X4)                 YAQUI1  01061
                    COMMON /YSC3/ JNM                                           YAQUI1  01062
                   CALL START                                                   YAQUI1  01063
                   DO 1019 J=2,JP2                                              YAQUI1  01064
                   DO 1009 I=1,IP1                                              YAQUI1  01065
                   PMX(IJ) = PMY(IJ) = PM0(IJ) = 0.0                            YAQUI1  01066
             1009  IJ = IJ+NQ                                                   YAQUI1  01067
                   CALL LOOP                                                    YAQUI1  01068
             1019  CONTINUE                                                     YAQUI1  01069
                   CALL DONE                                                    YAQUI1  01070
                   DO 1099 J=2,JP2                                              YAQUI1  01071
                   IEC = (J-1)*NQI                                              YAQUI1  01072
                   CALL ECRD (AASC,IEC,NQI,NE)                                  YAQUI1  01073
                   IJ = 1                                                       YAQUI1  01074
                   DO 1089 I=1,IP1                                              YAQUI1  01075
                   IF (X(IJ).GT.PXRP .OR. Y(IJ).LT.PYBM) GO TO 1099             YAQUI1  01076
                   IF (Y(IJ).GT.PYTP) GO TO 1100                                YAQUI1  01077
                   KI =  X(IJ)      *RPDR + OPEM10                              YAQUI1  01078
                   KJ = (Y(IJ)-PYB)*RPDZ + OPEM10                               YAQUI1  01079
                   IEC = KJ*NQI                                                 YAQUI1  01080
                   CALL ECRD (AASC(ISC2),IEC,NQI2,NE)                           YAQUI1  01081
                   KIJ = (KI-1)*NQ+ISC2                                         YAQUI1  01082
                   KIJP = KIJ+NQI                                               YAQUI1  01083
                   W =  X(IJ)      -FLOAT(KI-1)*PDR                             YAQUI1  01084
                   H = (Y(IJ)-PYB)-FLOAT(KJ-1)*PDZ                              YAQUI1  01085
                   XX = RPDRDZ/RM(IJ)                                           YAQUI1  01086
                   HTE = PDZ-H                                                  YAQUI1  01087
                   DO 1049 JJ=1,2                                               YAQUI1  01088
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            WTE = PDR-W                                                   YAQUI1  01089
            DO 1039 II=1,2                                                YAQUI1  01090
            X1 = XX*WTE*HTE                                               YAQUI1  01091
            PMX(KIJ) = PMX(KIJ) +X1*U(IJ)                                 YAQUI1  01092
            PMY(KIJ) = PMY(KIJ) +X1*V(IJ)                                 YAQUI1  01093
            PMO(KIJ) = PMO(KIJ) +X1                                       YAQUI1  01094
            WTE = W                                                       YAQUI1  01095
      1039  KIJ = KIJ+NQ                                                  YAQUI1  01096
            HTE = H                                                       YAQUI1  01097
      1049  KIJ = KIJP                                                    YAQUI1  01098
            CALL ECWR (AASC(ISC2),IEC,NQI2,NE)                            YAQUI1  01099
      1089  IJ = IJ+NQ                                                    YAQUI1  01100
      1099  CONTINUE                                                      YAQUI1  01101
      1100  CALL START                                                    YAQUI1  01102
            KK = 0                                                        YAQUI1  01103
            DO 1199 J=2,JBP2                                              YAQUI1  01104
            DO 1189 I=1,IBP1                                              YAQUI1  01105
            RPMO = PMO(IJ)                                                YAQUI1  01106
            IF (RPMO.NE.0.) PMO(IJ) = RPMO = 1./RPMO                      YAQUI1  01107
            IF (RPMO.EQ.0.) KK = 1                                        YAQUI1  01108
            PU(IJ) = PMX(IJ)*RPMO                                         YAQUI1  01109
            PV(IJ) = PMY(IJ)*RPMO                                         YAQUI1  01110
            IF (I.EQ.1) PU(IJ) = 0.                                       YAQUI1  01111
      1189  IJ = IJ + NQ                                                  YAQUI1  01112
            CALL LOOP                                                     YAQUI1  01113
      1199  CONTINUE                                                      YAQUI1  01114
            CALL DONE                                                     YAQUI1  01115
      1200  IF (KK.EQ.0) GO TO 1400                                       YAQUI1  01116
            CALL START                                                    YAQUI1  01117
            DO 1299 J=2,JBP2                                              YAQUI1  01118
            DO 1289 I=1,IBP1                                              YAQUI1  01119
            IF (PMO(IJ).GT.0.) GO TO 1289                                 YAQUI1  01120
            ITESTL = ITESTR = I                                           YAQUI1  01121
            PUL = PVL = PUR = PVR = 0.                                    YAQUI1  01122
            XWL = XWR = 1.                                                YAQUI1  01123
            IL = IR = IJ                                                  YAQUI1  01124
      1210  ITESTL = ITESTL-1                                             YAQUI1  01125
            IF (ITESTL.LT.1) GO TO 1230                                   YAQUI1  01126
            IL = IL-NQ                                                    YAQUI1  01127
            IF (PMO(IL).GT.0.) GO TO 1220                                 YAQUI1  01128
            XWL = XWL + 1.                                                YAQUI1  01129
            GO TO 1210                                                    YAQUI1  01130
      1220  PUL = PU(IL)                                                  YAQUI1  01131
            PVL = PV(IL)                                                  YAQUI1  01132
      1230  ITESTR = ITESTR+1                                             YAQUI1  01133
            IF (ITESTR.GT.IBP1) GO TO 1250                                YAQUI1  01134
            IR = IR+NQ                                                    YAQUI1  01135
            IF (PMO(IR).GT.0.) GO TO 1240                                 YAQUI1  01136
            XWR = XWR + 1.                                                YAQUI1  01137
            GO TO 1230                                                    YAQUI1  01138
      1240  PUR = PU(IR)                                                  YAQUI1  01139
            PVR = PV(IR)                                                  YAQUI1  01140
      1250  DEN = 1./(XWL+XWR)                                            YAQUI1  01141
            WTL = XWR*DEN                                                 YAQUI1  01142
            WTR = XWL*DEN                                                 YAQUI1  01143
            PU(IJ) = PUL*WTL + PUR*WTR                                    YAQUI1  01144
            PV(IJ) = PVL*WTL + PVR*WTR                                    YAQUI1  01145
      1289  IJ = IJ+NQ                                                    YAQUI1  01146
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            CALL LOOP                                                          YAQUI1  01147
      1299  CONTINUE                                                           YAQUI1  01148
            CALL DONE                                                          YAQUI1  01149
      1300  DO 1399 J=2,JBP2                                                   YAQUI1  01150
            IEC = (J-1)*NQI                                                    YAQUI1  01151
            CALL ECRD (AASC,IEC,NQI,NE)                                        YAQUI1  01152
            IJ = 1                                                             YAQUI1  01153
            DO 1389 I=1,IBP1                                                   YAQUI1  01154
            IF (PMO(IJ).GT.0. .OR. PU(IJ).NE.0. .OR. PV(IJ).NE.0.) GO TO 1389  YAQUI1  01155
            JTESTB = JTESTT = J                                                YAQUI1  01156
            PUB = PVB = PUT = PVT = 0.                                         YAQUI1  01157
            XWB = XWT = 1.                                                     YAQUI1  01158
            IB = IT = IJ+NQI                                                   YAQUI1  01159
            IECB = IECT = IEC                                                  YAQUI1  01160
      1310  JTESTB = JTESTB - 1                                                YAQUI1  01161
            IF (JTESTB.LT.2) GO TO 1330                                        YAQUI1  01162
            IECB = IECB - NQI                                                  YAQUI1  01163
            CALL ECRD (AASC(ISC2),IECB,NQI,NE)                                 YAQUI1  01164
            IF (PMO(IB).GT.0.) GO TO 1320                                      YAQUI1  01165
            XWB = XWB + 1.                                                     YAQUI1  01166
            GO TO 1310                                                         YAQUI1  01167
      1320  PUB = PU(IB)                                                       YAQUI1  01168
            PVB = PV(IB)                                                       YAQUI1  01169
      1330  JTESTT = JTESTT + 1                                                YAQUI1  01170
            IF (JTESTT.GT.JBP2) GO TO 1350                                     YAQUI1  01171
            IECT = IECT + NQI                                                  YAQUI1  01172
            CALL ECRD (AASC(ISC2),IECT,NQI,NE)                                 YAQUI1  01173
            IF (PMO(IT).GT.0.) GO TO 1340                                      YAQUI1  01174
            XWT = XWT + 1.                                                     YAQUI1  01175
            GO TO 1330                                                         YAQUI1  01176
      1340  PUT = PU(IT)                                                       YAQUI1  01177
            PVT = PV(IT)                                                       YAQUI1  01178
      1350  DEN = 1./(XWT+XWB)                                                 YAQUI1  01179
            WTB = XWT*DEN                                                      YAQUI1  01180
            WTT = XWB*DEN                                                      YAQUI1  01181
            PU(IJ) = PUB*WTB + PUT*WTT                                         YAQUI1  01182
            PV(IJ) = PVB*WTB + PVT*WTT                                         YAQUI1  01183
      1389  IJ = IJ + NQ                                                       YAQUI1  01184
      1399  CALL ECWR (AASC,IEC,NQI,NE)                                        YAQUI1  01185
      1400  IF (IMOMX.EQ.0) GO TO 2000                                         YAQUI1  01186
            CALL START                                                         YAQUI1  01187
            DO 1499 J=2,JBP2                                                   YAQUI1  01188
            DO 1489 I=1,IBP1                                                   YAQUI1  01189
            PU(IJ) = PU(IJ).AND..NOT.7777777777B                               YAQUI1  01190
            PV(IJ) = PV(IJ).AND..NOT.7777777777B                               YAQUI1  01191
      1489  IJ = IJ + NQ                                                       YAQUI1  01192
            CALL LOOP                                                          YAQUI1  01193
      1499  CONTINUE                                                           YAQUI1  01194
            CALL DONE                                                          YAQUI1  01195
      2000  IECP = IPAR                                                        YAQUI1  01196
            NPMT = JOLD = 0                                                    YAQUI1  01197
      2010  CALL ECRD (AASC,IECP,LPB,NE)                                       YAQUI1  01198
            KP = 1                                                             YAQUI1  01199
      2020  XTE = XPAR(KP)                                                     YAQUI1  01200
            YTE = YPAR(KP)                                                     YAQUI1  01201
            DRAG = MPAR(KP)                                                    YAQUI1  01202
            I =  XTE     *RPDR + OPEM10                                        YAQUI1  01203
            J = (YTE-PYB)*RPDZ + OPEM10                                        YAQUI1  01204
```

```
      IF (J.LT.1 .OR. J.GT.JBP .OR. I.LT.1 .OR. I.GT.IBP) GO TO 2180      YAQUI1  01205
      IF (J.EQ.JOLD) GO TO 2030                                           YAQUI1  01206
      JOLD = J + IMOME3                                                   YAQUI1  01207
      IEC = J*NQI                                                         YAQUI1  01208
      CALL ECRD (AASC(ISC2),IEC,NQI2,NE)                                  YAQUI1  01209
 2030 IJ = (I-1)*NQ+ISC2                                                  YAQUI1  01210
      IPJ  = IJ+NQ                                                        YAQUI1  01211
      IJP  = IJ+NQI                                                       YAQUI1  01212
      IPJP = IPJ + NQI                                                    YAQUI1  01213
      W =  XTE       - FLOAT(I-1)*PDR                                     YAQUI1  01214
      H = (YTE-PYB) - FLOAT(J-1)*PDZ                                      YAQUI1  01215
      PDRMW = PDR-W                                                       YAQUI1  01216
      PDZMH = PDZ-H                                                       YAQUI1  01217
      X1 = PDRMW*PDZMH                                                    YAQUI1  01218
      X2 =     W*PDZMH                                                    YAQUI1  01219
      X3 = PDRMW*    H                                                    YAQUI1  01220
      X4 =     W*    H                                                    YAQUI1  01221
      UK = (PU(IJ)*X1 + PU(IPJ)*X2 + PU(IJP)*X3 + PU(IPJP)*X4) * RPDRDZ  YAQUI1  01222
      VK = (PV(IJ)*X1 + PV(IPJ)*X2 + PV(IJP)*X3 + PV(IPJP)*X4) * RPDRDZ  YAQUI1  01223
      UPAR = SHIFT(XTE,30)                                                YAQUI1  01224
      VPAR = SHIFT(YTE,30)                                                YAQUI1  01225
      DTDRAG = DT*DRAG                                                    YAQUI1  01226
      RDTDRG = 1./(1.+DTDRAG)                                             YAQUI1  01227
      URAND = VRAND = 0.0                                                 YAQUI1  01228
      UPAR = (UPAR + DTDRAG*(UK+URAND) + DTGR) * RDTDRG                   YAQUI1  01229
      VPAR = (VPAR + DTDRAG*(VK+VRAND) + DTGZP) * RDTDRG                  YAQUI1  01230
      XTE  = XTE + DT*UPAR                                                YAQUI1  01231
      YTE  = YTE + DT*VPAR                                                YAQUI1  01232
      USH  =  SHIFT(UPAR,30).AND.7777777777B                              YAQUI1  01233
      VSH  =  SHIFT(VPAR,30).AND.7777777777B                              YAQUI1  01234
      XPAR(KP) = (XTE.AND. .NOT. 7777777777B) .OR. USH                    YAQUI1  01235
      YPAR(KP) = (YTE.AND. .NOT. 7777777777B) .OR. VSH                    YAQUI1  01236
      IF (IMOMX.EQ.0) GO TO 2150                                          YAQUI1  01237
      MTE = SHIFT(DRAG,30)                                                YAQUI1  01238
      H = MTE*RPDRDZ*DTDRAG                                               YAQUI1  01239
      KIJ = IJ                                                            YAQUI1  01240
      KK = 0                                                              YAQUI1  01241
      DO 2149 JJ=1,2                                                      YAQUI1  01242
      DO 2139 II=1,2                                                      YAQUI1  01243
      KK = KK+1                                                           YAQUI1  01244
      X1 = X1(KK)*H                                                       YAQUI1  01245
      PUL = PU(KIJ)                                                       YAQUI1  01246
      PVL = PV(KIJ)                                                       YAQUI1  01247
      XX = (SHIFT(PUL,30))+X1*(UK-UPAR+URAND)                             YAQUI1  01248
      YY = (SHIFT(PVL,30))+X1*(VK-VPAR+VRAND)                             YAQUI1  01249
      PU(KIJ)  = (PUL.AND..NOT.7777777777B).OR.                           YAQUI1  01250
     1         (SHIFT(XX,30).AND.7777777777B)                             YAQUI1  01251
      PV(KIJ)  = (PVL.AND..NOT.7777777777B).OR.                           YAQUI1  01252
     1         (SHIFT(YY,30).AND.7777777777B)                             YAQUI1  01253
 2139 KIJ = KIJ+NQ                                                        YAQUI1  01254
 2149 KIJ = IJP                                                           YAQUI1  01255
      CALL ECWR (AASC(ISC2),IEC,NQI2,NE)                                  YAQUI1  01256
 2150 NPMT = NPMT+1                                                       YAQUI1  01257
      IF (NPMT.EQ.NPT) GO TO 2190                                         YAQUI1  01258
      KP = KP+3                                                           YAQUI1  01259
      IF (KP.LT.LPB) GO TO 2020                                           YAQUI1  01260
      CALL ECWR (AASC,IECP,LPB,NE)                                        YAQUI1  01261
      IECP = IECP+LPB                                                     YAQUI1  01262
```

```
           GO TO 2010
      2180 XPAR(KP) = -1.E+3
           GO TO 2150
      2190 CALL ECWR (AASC,IECP,LPB,NE)
      2500 IF (IMOMX.EQ.0) RETURN
           DO 2599 J=2,JP2
           IEC = (J-1)*NQI
           CALL ECRD (AASC,IEC,NQI,NE)
           IJ = 1
           DO 2589 I=1,IP1
           IF (X(IJ).GT.PXRP .OR. Y(IJ).LT.PYBM) GO TO 2599
           IF (Y(IJ).GT.PYTP) RETURN
           KI =  X(IJ)      *RPDR + OPEM10
           KJ = (Y(IJ)-PYB)*RPDZ + OPEM10
           IECP = KJ*NQI
           CALL ECRD (AASC(ISC2),IECP,NQI2,NE)
           KIJ = (KI-1)*NQ+ISC2
           KIJP = KIJ+NQI
           W =  X(IJ)       - FLOAT(KI-1)*PDR
           H = (Y(IJ)-PYB) - FLOAT(KJ-1)*PDZ
           HTE = PDZ-H
           DO 2549 JJ=1,2
           WTE = PDR-W
           DO 2539 II=1,2
           XX = RPDRDZ*WTE*HTE*PMO(KIJ)
           U(IJ) = U(IJ) -XX*(SHIFT(PU(KIJ),30))
           V(IJ) = V(IJ) -XX*(SHIFT(PV(KIJ),30))
           WTE = W
      2539 KIJ = KIJ+NQ
           HTE = H
      2549 KIJ = KIJP
      2589 IJ = IJ+NQ
      2599 CALL ECWR (AASC,IEC,NQI,NE)
           RETURN
           ENTRY PARPLOT
           CALL ADV(1)
           CALL FRAME (IPXL,IPXR,IPYT,IPYB)
           CALL FRAME (IPXL,IPXR,IPYT,IPYB)
           IF (LPR.EQ.0) GO TO 3000
           CALL LINCNT(59)
           WRITE(12,3090) PDR,PDZ,PXR,PYB,PYT
           WRITE (12,3095) JNM,NAME,T,NCYC
      3000 IECP = IPAR
           IF (ICOLOR.GT.0) CALL COLOR(1)
           IF (ICOLOR.GT.0) CALL COLOR(1)
           NPPT = 0
      3010 CALL ECRD (AASC,IECP,LPB,NE)
           KP = 1
      3020 IF (XPAR(KP).LT.0.) GO TO 3050
           IX1 = FIPXL + (XPAR(KP)-PXL)*PXCONV
           IY1 = FIPYB + (YPAR(KP)-PYB)*PYCONV
           CALL PLT (IX1,IY1,42)
      3050 NPPT = NPPT + 1
           IF (NPPT.EQ.NPT) GO TO 3060
           KP = KP+3
           IF (KP.LT.LPB) GO TO 3020
           IECP = IECP+LPB
           GO TO 3010
```

```
      3060 IF (ICOLOR.GT.0) CALL COLOR(0)
           RETURN
      C
      3090 FORMAT(* PARTICLES*/11X*PDR=*1PE12.5* PDZ=*E12.5* PXR=*E12.5
          1 * PYB=*E12.5* PYT=*E12.5)
      3095 FORMAT(5X,A10,10A8*   T=*1PE12.5* CYCLE=*I5)
           END
```

```
SINGLY REFERENCED VARIABLES
   1200 -    63*    DTOC    ()R    3CO    FIYT     -R    3CO    ISC3     -I    3CO    LINCNT   -  247SU   OMEM10  -R    3CO    THIRD    -R    3CO
   1300 -    97*    DT016    -R    3CO    FJBP     -R    3CO    ITV      -I    3CO    LJP2     -I    3CO   PARPLOT -  242SU    TLIMD    -R    3CO
   2500 -   212*    DT02     -R    3CO    FREZ     -R    3CO    IUNF     -I    3CO    MB       -R    5RL   PARTMOV -    1SU    TOUT     -R    3CO
 AA       ()R   3CO    DT04     -R    3CO    GGM1     -R    3CO    IXL      -I    3CO    MC       -R    5RL   PLT     -  259SU    TWFIN    -R    3CO
 ADV       -  243SU    DT08     -R    3CO    GM1      -R    3CO    IXR      -I    3CO    ML       -R    5RL   RDT     -R    3CO    T20MD    -R    3CO
 ANC      -R    3CO    DTPOS    -R    3CO    GR       -R    3CO    IYB      -I    3CO    MR       -R    5RL   REAL    -      5F    VV       -R    3CO
 ASQ      -R    3CO    DTV      -R    3CO    GRDVEL   -R    3CO    IYT      -I    3CO    MT       -R    5RL   REZRON  -R    3CO    XCONV    -R    3CO
 A0       -R    3CO    DT8      -R    3CO    GZ       -R    3CO    JBAR     -I    3CO    MU02     -R    5RL   REZSIE  -R    3CO    XL       -R    3CO
 A0FAC    -R    3CO    D7       -R    3CO    GZP      -R    3CO    JCEN     -I    3CO    MU04     -R    5RL   REZUE   -R    3CO    XR       -R    3CO
 A0M      -R    3CO    EM10     -R    3CO    IBAR     -I    3CO    JM10     -I    3CO    NLC      -I    3CO   REZVE   -R    3CO    YB       -R    3CO
 BO       -R    3CO    ENTRY    -  242F       IDTO     -I    3CO    JM14     -I    3CO    NPS      -I    3CO   REZVT   -R    3CO    YCONV    -R    3CO
 COLAMU   -R    3CO    EPS      -R    3CO    IJM      -I    3CO    JP1      -I    3CO    NQIB     -I    3CO   REZY0   -R    3CO    YSC1     -     2CN
 CYL      -R    3CO    FIBP     -R    3CO    IJPS     -I    3CO    JP4      -I    3CO    NSC      -I    3CO   RIBAR   -R    3CO    YSC2     -     3CN
 DR       -R    3CO    FIPXR    -R    3CO    IM1      -I    3CO    JP402    -I    3CO    NUMIT    -I    3CO   RIBJB   -R    3CO    YSC3     -     9CN
 DTC      -R    3CO    FIPYT    -R    3CO    IM6      -I    3CO    JUNF     -I    3CO    NUMTD    -I    3CO   RIBP    -R    3CO    YT       -R    3CO
 DTFAC    -R    3CO    FIXL     -R    3CO    IP2      -I    3CO    JUNF02   -I    3CO    OM       -R    3CO   RJBP    -R    3CO    ZZ       -R    3CO
 DTGZ     -R    3CO    FIXR     -R    3CO    ISCF1    -I    3CO    KXI      -I    3CO    OMANC    -R    3CO   ROMFR   -R    3CO
 DTO      ()R   3CO    FIYB     -R    3CO    ISCF2    -I    3CO    LAMD     -R    5RL    OMCYL    -R    3CO   RON     -R    3CO
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
MULTIPLY-REFERENCED VARIABLES
  1009 -     12DO    14*
  1019 -     11DO    16*
  1039 -     37DO    43*
  1049 -     35DO    45*
  1089 -     22DO    47*
  1099 -     18DO    23       48*
  1100 -     24      49*
  1189 -     57DO    59*
  1199 -     51DO    61*
  1210 -     72*     77
  1220 -     75      78*
  1230 -     73      80*      85
  1240 -     83      86*
  1250 -     81      88*
  1289 -     66DO    67       93*
  1299 -     65DO    95*
  1310 -    108*    114
  1320 -    112     115*
  1330 -    109     117*     123
  1340 -    121     124*
  1350 -    118     126*
  1389 -    101DO   102      131*
  1399 -     97DO   132*
  1400 -     63     133*
  1489 -    136DO   139*
  1499 -    135DO   141*
  2000 -    133     143*
  2010 -    145*    208
  2020 -    147*    205
  2030 -    153     157*
  2139 -    190DO   199*
  2149 -    189DO   200*
  2150 -    184     202*     210
  2180 -    152     209*
  2190 -    203     211*
  2539 -    231DO   236*
  2549 -    229DO   238*
```

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     INDEX  01/12/73                    SUBROUTINE PARTMOV                       PAGE  75
   2589 -   217DO  239*
   2599 -   213DO  218     240*
   3000 -   246    250*
   3010 -   254*   265
   3020 -   256*   263
   3050 -   256    260*
   3060 -   261    266*
   3090 -   248WR  268*
   3095 -   249WR  269*
AASC    ()R    2CO    4EQ     4EQ     4EQ     4EQ     4EQ     4EQ     4EQ     4EQ     4EQ     4EQ     4EQ     4EQ     4EQ     4EQ    20AG    28AG
              46AG   99AG   111AG   120AG   132AG   145AG   156AG   201AG   206AG   211AG   215AG   223AG   240AG   254AG
COLOR    -   251SU  252SU   266SU
COMMON   -     2F     3F      9F
CQ      ()R    4EQ    6DI
DELSM   ()R    4EQ    6DI
DEN     -R    88=    89      90     126=    127     128
DIMENSI  -     6F     7F
DONE     -    17SU   62SU    96SU   142SU
DRAG    -R   149=   173     185
DT      -R     3CO  173     178     179
DTDRAG  -R   173=   174     176     177     186
DTGR    -R     3CO  176
DTGZP   -R     3CO  177
E       ()R    4EQ    6DI
ECRD     -    20SU   28SU    99SU   111SU   120SU   145SU   156SU   215SU   223SU   254SU
ECWR     -    46SU  132SU   201SU   206SU   211SU   240SU
EP      ()R    4EQ    6DI
EQUIVAL  -     4F     8F
ETIL    ()R    4EQ    6DI
FIPXL   -R     3CO  257
FIPYR   -R     3CO  258
FLOAT    -    31SU   32SU   161SU   162SU   226SU   227SU
FRAME    -   244SU  245SU
H       -R    32=    34      44     162=    164     167     168     186=    192     227=    228     237
HTE     -R    34=    38      44=    228=    232     237=
I       -I     3CO  12DO    22DO    52DO    58      66DO    68     101DO   136DO   150=    152     152     157     161     217DO
IB      -I   106=   112     115     116
IBP     -I     3CO  152
IBP1    -I     3CO  52DO    66DO    81     101DO   136DO
ICOLOR  -I     3CO  251     252     266
IEC     -I    19=   20AG    27=     28AG    46AG    98=     99AG   107     132AG   155=    156AG   201AG   214=    215AG   240AG
IECR    -I   107=   110=    110     111AG
IECP    -I   143=   145AG   206AG   207=    207     211AG   222=    223AG   250=    254AG   264=    264
IECT    -I   107=   119=    119     120AG
II      -I    37DO  190DO   231DO
IJ      -I     3CO   13      13      13      14=     14      21=     23      23      24      25      26      31      32      33      39      40
              47=    47      53      54      56      56      57      57      58      59=     59      67      71      91      92      93=     93
             100=   102     102     102     106     129     130     131=    131     137     137     138     138     139=    139     157=    158
             159    169     170     187     216=    218     218     219     220     221     226     227     233     233     234     234     239=
             239
IJP     -I     3CO  159=    169     170     200
IL      -I    71=    74=     74      75      78      79
IMOME3  -I     3CO  154
IMOMX   -I     3CO  133     184     212
IPAR    -I     3CO  143     250
IPJ     -I   158=   160     169     170
IPJP    -I   160=   169     170
IPXL    -I     3CO  244AG   245AG
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     INDEX  01/12/73                        SUBROUTINE PARTMOV                                   PAGE  76
IPXR     -I     3CO   244AG   245AG
IPYR     -I     3CO   244AG   245AG
IPYT     -I     3CO   244AG   245AG
IPI      -I     3CO    12DO    22DO   217DO
IR       -I    71=     82=     82      83      86      87
ISC2     -I     3CO    28AG    29      46AG   111AG   120AG   156AG   157     201AG   223AG   224
IT       -I   106=    121     124     125
ITESTL   -I    68=     72=     72      73
ITESTR   -I    68=     80=     80      81
IX1      -I   257=    259AG
IY1      -I   258=    259AG
J        -I     3CO    11DO    18DO    19      51DO    65DO    97DO    98     103     135DO   151=    152     152     153     154     155     162
              213DO   214
JBP      -I     3CO   152
JBP2     -I     3CO    51DO    65DO    97DO   118     135DO
JJ       -I    35DO   189DO   229DO
JNM      -I     9CO   249WR
JOLD     -I   144=    153     154=
JP2      -I     3CO    11DO    18DO   213DO
JTESTB   -I   103=    108=    108     109
JTESTT   -I   103=    117=    117     118
KI       -I    25=     29      31     220=    224     226
KIJ      -I    29=     30      39      39      40      40      41      41      43=     43      45=    187=    193     194     197     198     199=
              199     200=    224=    225     232     233     234     236=    236     238=
KIJP     -I    30=     45     225=    238
KJ       -I    26=     27      32     221=    222     227
KK       -I    50=     55=     63     188=    191=    191     192
KP       -I   146=    147     148     149     182     183     204=    204     205     209     255=    256     257     258     262=    262     263
LAM      -R     3CO     5RL
LOOP     -     15SU    60SU    94SU   140SU
LPB      -I     3CO   145AG   205     206AG   207     211AG   254AG   263     264
LPR      -I     3CO   246
M       ()R     4EQ     5RL     6DI
MP      ()R     4EQ     5RL     6DI
MPAR    ()R     4EQ     5RL     6DI   149
MTE      -R     5RL   185=    186
MU       -R     3CO     5RL
NAME    ()I     3CO   249WR
NCYC     -I     3CO   249WR
NE       -I    20AG    28AG    46AG    99AG   111AG   120AG   132AG   145AG   156AG   201AG   206AG   211AG   215AG   223AG   240AG   254AG
NPMT     -I   144=    202=    202     203
NPPT     -I   253=    260=    260     261
NPT      -I     3CO   203     261
NQ       -I     3CO    14      29      43      47      59      74      82      93     131     139     157     158     199     224     236     239
NQI      -I     3CO    19      20AG    27      30      98      99AG   106     110     111AG   119     120AG   132AG   155     159     160     214
              215AG   222     225     240AG
NQI2     -I     3CO    28AG    46AG   156AG   201AG   223AG
OPEMI0   -R     3CO    25      26     150     151     220     221
P       ()R     4EQ     6DI
PDR      -R     3CO    31      36     161     163     226     230     248WR
PDRMW    -R   163=    165     167
PDZ      -R     3CO    32      34     162     164     227     228     248WR
PDZMH    -R   164=    165     166
PL      ()R     4EQ     6DI
PMX     ()R     4EQ     6DI    13=     39=     39      56
PMY     ()R     4EQ     6DI    13=     40=     40      57
PM0     ()R     4EQ     6DI    13=     41=     41      53      54=     67      75      83     102     112     121     232
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      INDEX  01/12/73                              SUBROUTINE PARTMOV                              PAGE  77
PU      ()R     4EQ     6DI     56=     58=      78      86     91=     102     115     124    129=    137=     137     169     169     169     169
               193     197=     233
PUB      -R    104=    115=     129
PUL      -R     69=     78=      91    193=     195     197
PUR      -R     69=     86=      91
PUT      -R    104=    124=     129
PV      ()R     4EQ     6DI     57=      79      87     92=     102     116     125    130=    138=     138     170     170     170     170     194
               198=     234
PVB      -R    104=    116=     130
PVL      -R     69=     79=      92    194=     196     198
PVR      -R     69=     87=      92
PVT      -R    104=    125=     130
PXCONV   -R     3CO     257
PXL      -R     3CO     257
PXR      -R     3CO   248WR
PXRP     -R     3CO      23     218
PYB      -R     3CO      26      32     151     162     221     227   248WR     258
PYBM     -R     3CO      23     218
PYCONV   -R     3CO     258
PYT      -R     3CO   248WR
PYTP     -R     3CO      24     219
Q       ()R     4EQ     6DI
R       ()R     4EQ     6DI
RCSQ    ()R     4EQ     6DI
RDTDRG   -R    174=     176     177
RETURN   -     212F    219F    241F    267F
RM      ()R     4EQ     6DI      33
RMP     ()R     4EQ     6DI
RO      ()R     4EQ     6DI
ROL     ()R     4EQ     6DI
RPDR     -R     3CO      25     150     220
RPDRDZ   -R     3CO      33     169     170     186     232
RPDZ     -R     3CO      26     151     221
RPMO     -R     53=      54     54=      54      55      56      57
RVOL    ()R     4EQ     6DI
SHIFT    -    171SU   172SU   180SU   181SU   185SU   195SU   196SU   197SU   198SU   233SU   234SU
SIE     ()R     4EQ     6DI
START    -     10SU    49SU    64SU   134SU
T        -R     3CO   249WR
U       ()R     4EQ     6DI      39    233=     233
UG      ()R     4EQ     6DI
UK       -R    169=     176     195
UL      ()R     4EQ     6DI
UP      ()R     4EQ     6DI
UPAR     -R    171=    176=     176     178     180     195
URAND    -R    175=     176     195
USH      -R    180=     182
UTIL    ()R     4EQ     6DI
V       ()R     4EQ     6DI      40    234=     234
VG      ()R     4EQ     6DI
VK       -R    170=     177     196
VL      ()R     4EQ     6DI
VP      ()R     4EQ     6DI
VPAR     -R    172=    177=     177     179     181     196
VRAND    -R    175=     177     196
VSH      -R    181=     183
VTIL    ()R     4EQ     6DI
W        -R     31=      36      42    161=     163     166     168    226=     230     235
```

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    INDEX  01/12/73                        SUBROUTINE PARTMOV                                PAGE  78
WRITE    -    248F   249F
WTB      -R   127=   129    130
WTE      -R    36=    38     42=    230=   232    235=
WTL      -R    89=    91     92
WTR      -R    90=    91     92
WTT      -R   128=   129    130
X       ()R     4EQ    6DI   23     25     31     218    220    226
XPAR    ()R     4EQ    6DI  147    182=   209=   256    257
XTE      -R   147=   150    161    171    178=   178    182
XWB      -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     7DI    8EQ    8EQ    8EQ    38=    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    6DI   23     24     26     32     218    219    221    227
YPAR    ()R     4EQ    6DI  148    183=   258
YTE      -R   148=   151    162    172    179=   179    183
YY       -R   196=   198
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      SUBROUTINE REZONE                                              YAQUI1  01328
      COMMON /YSC1/ AASC(4242)                                       COMMON2 00002
      COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,AOM,R0,COLAMU,CYL,        COMMON2 00003
     1       DR,DT,DTC,DTFAC,DTGR,DTGZ,DTGZP,DTO(10),DTOC(10),       COMMON2 00004
     2       DTO16,DTO2,DTO4,DTO8,DTPOS,DTV,DT8,DZ,EM10,EPS,FIBP,    COMMON2 00005
     3       FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,       COMMON2 00006
     4       FREZ,GGM1,GM1,GR,GRDVEL,GZ,GZP,I,IBAR,IBP,IBP1,ICOLOR,  COMMON2 00007
     5       IDTO,IJ,IJM,IJP,IJPS,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,LPB,    COMMON2 00011
     9       LPR,MU,NAME(10),NCYC,NLC,NPS,NPT,NQ,NQI,NQIB,NQI2,NSC,  COMMON2 00012
     1       NUMIT,NUMTO,OM,OMANC,OMCYL,OMEM10,OPEM10,PDR,PDZ,PXCONV, COMMON2 00013
     2       PXL,PXR,PXRP,PYB,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIE, COMMON2 00014
     3       REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJB,RIBP,RJBP,ROMFR,    COMMON2 00015
     4       RON,RPDR,RPDRDZ,RPDZ,T,THIRD,TLIMD,TOUT,TWFIN,T20MD,    COMMON2 00016
     5       VV,XCONV,XL,XR,YB,YCONV,YT,ZZ                           COMMON2 00017
      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),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,PMO),(AASC(12),UTIL,UL,CQ,PMX,PU),(AASC(13),VTIL, EQVREAL 00006
     5           VL,PMY,PV),(AASC(14),Q,ROL)                          EQVREAL 00007
      REAL LAM,LAMD,M,MR,MC,ML,MP,MPAR,MR,MT,MTE,MU,MU02,MU04        EQVREAL 00008
      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),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         PMY(1),PV(1),Q(1),ROL(1),PMO(1)                        DIMEN   00006
      DIMENSION UGTE(100)                                            YAQUI1  01332
      REZOMG = 0.15*ROT                                              YAQUI1  01333
      REZBTA = 0.002                                                 YAQUI1  01334
      XX = -1.E+6                                                    YAQUI1  01335
      CALL START                                                     YAQUI1  01336
      FCR = FCT = FCB = XXX = XOMSUM = YOMSUM = OMSUM = 0.           YAQUI1  01337
      DO 1049 J=2,JP2                                                YAQUI1  01338
      DO 1039 I=1,IP1                                                YAQUI1  01339
      AVEL = AMAX1(ABS(UL(IJ)),ABS(VL(IJ)))                          YAQUI1  01340
      XXX = AMAX1(XXX,AVEL)                                          YAQUI1  01341
      IF (I.EQ.IM6 ) FCR = AMAX1(FCR,AVEL)                           YAQUI1  01342
      IF (J.EQ.JM14) FCT = AMAX1(FCT,AVEL)                           YAQUI1  01343
      IF (J.EQ.9   ) FCB = AMAX1(FCR,AVEL)                           YAQUI1  01344
 1039 IJ = IJ + NQ                                                   YAQUI1  01345
      CALL LOOP                                                      YAQUI1  01346
 1049 CONTINUE                                                       YAQUI1  01347
      FCR = SQRT(FCR*XXX)                                            YAQUI1  01348
      FCT = SQRT(FCT*XXX)                                            YAQUI1  01349
      FCB = SQRT(FCB*XXX)                                            YAQUI1  01350
      CALL START                                                     YAQUI1  01351
      DO 1069 J=2,JP1                                                YAQUI1  01352
      IF (J.EQ.JP402) YCEN = Y(IJ)                                   YAQUI1  01353
      DO 1059 I=1,IBAR                                               YAQUI1  01354
      IPJ = IJ+NQ                                                    YAQUI1  01355
      IPJP = IJP+NQ                                                  YAQUI1  01356
      IF (J.LT.10.OR.J.GT.JM10.OR.I.GT.IM6) GO TO 1055               YAQUI1  01357
      X1 = X(IPJ)                                                    YAQUI1  01358
      Y1 = Y(IPJ)                                                    YAQUI1  01359
      U1 = UL(IPJ)                                                   YAQUI1  01360
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      V1 = VL(IPJ)                                                      YAQUI1  01361
      X2 = X(IPJP)                                                      YAQUI1  01362
      Y2 = Y(IPJP)                                                      YAQUI1  01363
      U2 = UL(IPJP)                                                     YAQUI1  01364
      V2 = VL(IPJP)                                                     YAQUI1  01365
      X3 = X(IJP)                                                       YAQUI1  01366
      Y3 = Y(IJP)                                                       YAQUI1  01367
      U3 = UL(IJP)                                                      YAQUI1  01368
      V3 = VL(IJP)                                                      YAQUI1  01369
      X4 = X(IJ)                                                        YAQUI1  01370
      Y4 = Y(IJ)                                                        YAQUI1  01371
      U4 = UL(IJ)                                                       YAQUI1  01372
      V4 = VL(IJ)                                                       YAQUI1  01373
      R1 = .125*RVOL(IJ)*(R(IPJ)+R(IPJP)+R(IJP)+R(IJ))                  YAQUI1  01374
      YY = R1*((U1+U4)*(X1-X4)+(V1+V4)*(Y1-Y4)                          YAQUI1  01375
     1          +(U2+U1)*(X2-X1)+(V2+V1)*(Y2-Y1)                        YAQUI1  01376
     2          +(U3+U2)*(X3-X2)+(V3+V2)*(Y3-Y2)                        YAQUI1  01377
     3          +(U4+U3)*(X4-X3)+(V4+V3)*(Y4-Y3))                       YAQUI1  01378
      IF (YY.GT.0.) GO TO 1055                                          YAQUI1  01379
      YY = YY*YY                                                        YAQUI1  01380
      XOMSUM = XOMSUM + YY*X4                                           YAQUI1  01381
      YOMSUM = YOMSUM + YY*Y4                                           YAQUI1  01382
      OMSUM  =  OMSUM + YY                                              YAQUI1  01383
 1055 IJ = IPJ                                                          YAQUI1  01384
 1059 IJP = IPJP                                                        YAQUI1  01385
      CALL LOOP                                                         YAQUI1  01386
 1069 CONTINUE                                                          YAQUI1  01387
      XC = XOMSUM/OMSUM                                                 YAQUI1  01388
      YC = YOMSUM/OMSUM                                                 YAQUI1  01389
      REZVT = AMAX1(0.,(REZOMG*.5*(YC-YCEN)))                           YAQUI1  01390
      CALL START                                                        YAQUI1  01391
      DO 1099 J=2,JP2                                                   YAQUI1  01392
      YBAR = .5*(Y(IJP)+Y(IJM))+REZBTA*(YC-Y(IJ))                       YAQUI1  01393
      VGTE = REZOMG*(YBAR-Y(IJ))+REZVT                                  YAQUI1  01394
      IF (J.EQ.2  ) VGTE = -FCB                                         YAQUI1  01395
      IF (J.EQ.JP2) VGTE = FCT                                          YAQUI1  01396
      DO 1089 I=1,IP1                                                   YAQUI1  01397
      IPJ = IJ+NQ                                                       YAQUI1  01398
      IF (J.GT.2) GO TO 1080                                            YAQUI1  01399
      XBAR = .5*(X(IPJ)+X(IJ-NQ))+REZBTA*(XC-X(IJ))                     YAQUI1  01400
      UGTE(I) = REZOMG*(XBAR-X(IJ))                                     YAQUI1  01401
      IF (I.EQ.1) UGTE = 0.0                                            YAQUI1  01402
      IF (I.EQ.IP1) UGTE(I) = FCR                                       YAQUI1  01403
 1080 UG(IJ) = UGTE(I)                                                  YAQUI1  01404
      VG(IJ) = VGTE                                                     YAQUI1  01405
 1089 IJ = IPJ                                                          YAQUI1  01406
      CALL LOOP                                                         YAQUI1  01407
 1099 CONTINUE                                                          YAQUI1  01408
      CALL DONE                                                         YAQUI1  01409
 1200 CALL START                                                        YAQUI1  01410
      XIP1 = YJP2 = 0.                                                  YAQUI1  01411
      Y2 = 1.E+20                                                       YAQUI1  01412
      DO 1289 J=2,JP2                                                   YAQUI1  01413
      DO 1279 I=1,IP1                                                   YAQUI1  01414
      X(IJ) = X(IJ)+UG(IJ)*DT                                           YAQUI1  01415
      Y(IJ) = Y(IJ)+VG(IJ)*DT                                           YAQUI1  01416
      R(IJ) = X(IJ)*CYL+OMCYL                                           YAQUI1  01417
      IF (J.EQ.2)   Y2    = AMIN1(Y(IJ),Y2)                             YAQUI1  01418
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INDEX  01/12/73                     SUBROUTINE REZONE                                   PAGE  81
                IF (J.EQ.JP2) YJP2 = AMAX1(Y(IJ),YJP2)                              YAQUI1  01419
                IF (I.EQ.IP1) XIP1 = AMAX1(X(IJ),XIP1)                              YAQUI1  01420
          1279  IJ = IJ+NQ                                                          YAQUI1  01421
                CALL LOOP                                                           YAQUI1  01422
          1289  CONTINUE                                                            YAQUI1  01423
                CALL DONE                                                           YAQUI1  01424
                PDR = XIP1*RIBP                                                     YAQUI1  01425
                PDZ = (YJP2-Y2)*RJBP                                                YAQUI1  01426
                PYB = 0.0                                                           YAQUI1  01427
                CALL FILMCO                                                         YAQUI1  01428
                CALL START                                                          YAQUI1  01429
                YY = ABS(GZ)/(GM1*REZSIE)                                           YAQUI1  01430
                DO 1399 J=2,JP1                                                     YAQUI1  01431
                DO 1389 I=1,IBAR                                                    YAQUI1  01432
                IPJ = IJ + NQ                                                       YAQUI1  01433
                IPJP = IJP + NQ                                                     YAQUI1  01434
                Y4 = REZY0 + 0.25*(Y(IJP)+Y(IPJP)+Y(IJ)+Y(IPJ))                     YAQUI1  01435
                IF (J.EQ.2   ) ROL(IJM) = REZRON*EXP((Y4-Y(IJ) -Y(IPJ) )*YY)        YAQUI1  01436
                IF (I.EQ.IBAR) ROL(IPJ) = REZRON*EXP((Y4-Y(IPJ)-Y(IPJP))*YY)        YAQUI1  01437
                IF (J.EQ.JP1 ) ROL(IJP) = REZRON*EXP((Y4-Y(IJP)-Y(IPJP))*YY)        YAQUI1  01438
                IJM = IJM + NQ                                                      YAQUI1  01439
                IJP = IJP + NQ                                                      YAQUI1  01440
          1389  IJ = IPJ                                                            YAQUI1  01441
                CALL LOOP                                                           YAQUI1  01442
          1399  CONTINUE                                                            YAQUI1  01443
                CALL DONE                                                           YAQUI1  01444
                RETURN                                                              YAQUI1  01445
                END                                                                 YAQUI1  01446
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 INDEX  01/12/73                          SUBROUTINE REZONE                                  PAGE  82
SINGLY REFERENCED VARIABLES
   1200 -    82*    DTO8    -R   3CO   GR      -R   3CO   ITV     -I   3CO   MR      -R   5RL   PXL     -R   3CO   TLIMD   -R   3CO
 AA     ()R   3CO   DTPOS   -R   3CO   GRDVEL  -R   3CO   IUNF    -I   3CO   MT      -R   5RL   PXR     -R   3CO   TOUT    -R   3CO
 AMINI   -   90SU   DTV     -R   3CO   GZP     -R   3CO   IXL     -I   3CO   MTE     -R   5RL   PXRP    -R   3CO   TWFIN   -R   3CO
 ANC    -R    3CO   DT8     -R   3CO   IBP     -I   3CO   IXR     -I   3CO   MUO2    -R   5RL   PYRM    -R   3CO   T20MD   -R   3CO
 ASQ    -R    3CO   DZ      -R   3CO   IBPI    -I   3CO   IYB     -I   3CO   MUO4    -R   5RL   PYCONV  -R   3CO   VV      -R   3CO
 A0     -R    3CO   EM10    -R   3CO   ICOLOR  -I   3CO   IYT     -I   3CO   NAME    ()I  3CO   PYT     -R   3CO   XCONV   -R   3CO
 A0FAC  -R    3CO   EPS     -R   3CO   IDTO    -I   3CO   JBAR    -I   3CO   NCYC    -I   3CO   PYTP    -R   3CO   XL      -R   3CO
 A0M    -R    3CO   EQUIVAL -    4F    IJPS    -I   3CO   JBP     -I   3CO   NLC     -I   3CO   REAL    -    5F    XR      -R   3CO
 B0     -R    3CO   FIBP    -R   3CO   IMOME3  -I   3CO   JBP2    -I   3CO   NPS     -I   3CO   RETURN  -  117F    XX      -R  10=
 COLAMU -R    3CO   FILMCO  -  100SU  IMOMX   -I   3CO   JCEN    -I   3CO   NPT     -I   3CO   REZONE  -    1SU   YB      -R   3CO
 DR     -R    3CO   FIPXL   -R   3CO   IM1     -I   3CO   JP4     -I   3CO   NQI     -I   3CO   REZUE   -R   3CO   YCONV   -R   3CO
 DTC    -R    3CO   FIPXR   -R   3CO   IPAR    -I   3CO   JUNF    -I   3CO   NQIB    -I   3CO   REZVE   -R   3CO   YSC1    -    2CN
 DTFAC  -R    3CO   FIPYB   -R   3CO   IPXL    -I   3CO   JUNF02  -I   3CO   NQI2    -I   3CO   RIBAR   -R   3CO   YSC2    -    3CN
 DTGR   -R    3CO   FIPYT   -R   3CO   IPXR    -I   3CO   KXI     -I   3CO   NSC     -I   3CO   RIBJB   -R   3CO   YT      -R   3CO
 DTGZ   -R    3CO   FIXL    -R   3CO   IPYB    -I   3CO   LAMD    -R   5RL   NUMIT   -I   3CO   ROMFR   -R   3CO   ZZ      -R   3CO
 DTGZP  -R    3CO   FIXR    -R   3CO   IPYT    -I   3CO   LJP2    -I   3CO   NUMTD   -I   3CO   RON     -R   3CO
 DTO    ()R   3CO   FIYB    -R   3CO   IP2     -I   3CO   LPB     -I   3CO   OM      -R   3CO   RPDR    -R   3CO
 DTOC   ()R   3CO   FIYT    -R   3CO   ISCF1   -I   3CO   LPR     -I   3CO   OMANC   -R   3CO   RPDRDZ  -R   3CO
 DTO16  -R    3CO   FJBP    -R   3CO   ISCF2   -I   3CO   MR      -R   5RL   OMEM10  -R   3CO   RPDZ    -R   3CO
 DTO2   -R    3CO   FREZ    -R   3CO   ISC2    -I   3CO   MC      -R   5RL   OPEM10  -R   3CO   T       -R   3CO
 DTO4   -R    3CO   GGM1    -R   3CO   ISC3    -I   3CO   ML      -R   5RL   PXCONV  -R   3CO   THIRD   -R   3CO
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
MULTIPLY-REFERENCED VARIABLES
   1039 -    14DO   20*
   1049 -    13DO   22*
   1055 -    32     51     56*
   1059 -    29DO   57*
   1069 -    27DO   59*
   1080 -    71     76*
   1089 -    69DO   78*
   1099 -    64DO   80*
   1279 -    86DO   93*
   1289 -    85DO   95*
   1389 -   104DO  113*
   1399 -   103DO  115*
AASC    ()R   2CO   4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ
ABS      -   15SU   15SU  102SU
AMAX1    -   15SU   16SU   17SU   18SU   19SU   62SU   91SU   92SU
AVEL    -R   15=    16     17     18     19
COMMON   -    2F     3F
CQ      ()R   4EQ    6DI
CYL     -R    3CO   89
DELSM   ()R   4EQ    6DI
DIMENSI  -    6F     7F
DONE     -   81SU   96SU  116SU
DT      -R    3CO   87     88
E       ()R   4EQ    6DI
FP      ()R   4EQ    6DI
FTIL    ()R   4EQ    6DI
EXP      -  108SU  109SU  110SU
FCB     -R   12=    19=    19     25=    25     67
FCR     -R   12=    17=    17     23=    23     75
FCT     -R   12=    18=    18     24=    24     68
GM1     -R    3CO  102
GZ      -R    3CO  102
I       -I    3CO   14DO   17     29DO   32     69DO   73     74     75     75     76     86DO   92    104DO  109
IBAR    -I    3CO   29DO  104DO  109
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         INDEX  01/12/73                                SUBROUTINE REZONE                                          PAGE  83
IJ       -I    3CO    15     15     20=    20     28     30     45     46     47     48     49     49     56=    65     66     70
              72     72     73     76     77     78=    87     87     87     88     88     88     89     89     90     91     92
              93=    93     105    107    108    113=
IJM      -I    3CO    65     108    111=   111
IJP      -I    3CO    31     41     42     43     44     49     57=    65     106    107    110    110    112=   112
IM6      -I    3CO    17     32
IPJ      -I   30=     33     34     35     36     49     56     70=    72     78     105=   107    108    109    109    113
IPJP     -I   31=     37     38     39     40     49     57     106=   107    109    110
IP1      -I    3CO    1400   6900   75     8600   92
J        -I    3CO    1300   18     19     2700   28     32     32     6400   67     68     71     8500   90     91     10300  108
             110
JM10     -I    3CO    32
JM14     -I    3CO    18
JP1      -I    3CO    2700   10300  110
JP2      -I    3CO    1300   6400   68     8500   91
JP402    -I    3CO    28
LAM      -R    3CO     5PL
LOOP     -    21SU    58SU   79SU   94SU   114SU
M       ()R    4EQ     5RL    6DI
MP      ()R    4EQ     5RL    6DI
MPAR    ()R    4EQ     5RL    6DI
MU       -R    3CO     5RL
NQ       -I    3CO    20     30     31     70     72     93     105    106    111    112
OMCYL    -R    3CO    89
OMSUM    -R   12=     55=    55     60     61
P       ()R    4EQ     6D
PDR      -R    3CO    97=
PDZ      -R    3CO    98=
PL      ()R    4EQ     6DI
PMX     ()R    4EQ     6DI
PMY     ()R    4EQ     6DI
PMO     ()R    4EQ     6DI
PU      ()R    4EQ     6DI
PV      ()R    4EQ     6DI
PYB      -R    3CO    99=
Q       ()R    4EQ     6DI
R       ()R    4EQ     6DI   49     49     49     49     89=
RCSQ    ()R    4EQ     6DI
RDT      -R    3CO     8
REZBTA   -R    9=     65     72
REZOMG   -R    8=     62     66     73
REZRON   -R    3CO   108    109    110
REZSIE   -R    3CO   102
REZVT    -R    3CO    62=    66
REZYO    -R    3CO   107
RIRP     -R    3CO    97
RJRP     -R    3CO    98
RM      ()R    4EQ     6DI
RMP     ()R    4EQ     6DI
RO      ()R    4EQ     6DI
ROL     ()R    4EQ     6DI   108=   109=   110=
RVOL    ()R    4EQ     6DI   49
R1       -R   49=     50
SIE     ()R    4EQ     6DI
SQRT     -    23SU    24SU   25SU
START    -    11SU    26SU   63SU   82SU   101SU
U       ()R    4EQ     6DI
UG      ()R    4EQ     6DI   76=    87
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    INDEX  01/12/73                           SUBROUTINE REZONE                                       PAGE  84
UGTE     ()R    7DI     73=     74=     75=     76
UL       ()R    4EQ     6DI     15      35      39      43      47
UP       ()R    4EQ     6DI
UTIL     ()R    4EQ     6DI
U1        =R   35=      50      50
U2        =R   39=      50      50
U3        =R   43=      50      50
U4        =R   47=      50      50
V        ()R    4EQ     6DI
VG       ()R    4EQ     6DI     77=     88
VGTE      =R   66=      67=     68=     77
VL       ()R    4EQ     6DI     15      36      40      44      48
VP       ()R    4EQ     6DI
VTIL     ()R    4EQ     6DI
V1        =R   36=      50      50
V2        =R   40=      50      50
V3        =R   44=      50      50
V4        =R   48=      50      50
X        ()R    4EQ     6DI     33      37      41      45      72      72      72      73      87=     87      89      92
XBAR      =R   72=      73
XC        =R   60=      72
XIP1      =R   83=      92=     92      97
XOMSUM    =R   12=      53=     53      60
XPAR     ()R    4EQ     6DI
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        ()R    4EQ     6DI     28      34      38      42      46      65      65      65      66      88=     88      90      91      107     107
               107      107     108     108     109     109     110     110
YBAR      =R   65=      66
YC        =R   61=      62      65
YCEN      =R   28=      62
YJP2      =R   83=      91=     91      98
YOMSUM    =R   12=      54=     54      61
YPAR     ()R    4EQ     6DI
YY        =R   50=      51      52=     52      52      53      54      55      102=    108     109     110
Y1        =R   34=      50      50
Y2        =R   38=      50      50      84=     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-BLANK 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

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
  AASC     YAQUI   CD    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
  AA2      YAQUI    D    YASET1   D    PARTGEN 2D    YAQUI2  2D
  AB       YAQUI2  6
  ABL      YASET1  2     YAQUI2  2
S ABS      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
  ASO      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
  A0       YAQUI   1C    LOOP     C    FILMCO   C    YASET1  1C    PARTGEN  C    MESHMKR  C    YAQUI2  2C    PARTMOV  C    REZONE   C
  A0FAC    YAQUI    C    LOOP     C    FILMCO   C    YASET1  1C    PARTGEN  C    MESHMKR  C    YAQUI2  1C    PARTMOV  C    REZONE   C
  A0M      YAQUI   1C    LOOP     C    FILMCO   C    YASET1  3C    PARTGEN  C    MESHMKR  C    YAQUI2  4C    PARTMOV  C    REZONE   C
  B0       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    YASET1   D    PARTGEN  D    MESHMKR  D    YAQUI2  2D    PARTMOV  D    REZONE   D
  DEN      PARTMOV 6
F DIMENSI  FILMCO  1     YASET1   1    PARTGEN  1    MESHMKR  1    YAQUI2   2    PARTMOV  2    REZONE   2
S DONE     LOOP    1     YASET1   1    MESHMKR  5    YAQUI2  16    PARTMOV  4    REZONE   3
  DP       YAQUI2  5
  DQ       YAQUI2  8
  DR       YAQUI   1C    LOOP     C    FILMCO   C    YASET1  1C    PARTGEN 1C    MESHMKR 1C    YAQUI2   C    PARTMOV  C    REZONE   C
  DRAG     PARTGEN 6     PARTMOV  3
  DRMAX    YAQUI2  4
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  INDEX   01/12/73                        MASTER INDEX                                    PAGE  86
  DRMIN   YAQUI2   4
  DROU    YAQUI2   3
  DRPAR   PARTGEN  6
S DRV     YAQUI2  10
  DT      YAQUI     C  LOOP      C  FILMCO    C  YASET1   4C  PARTGEN   C  MESHMKR   C  YAQUI2  24C  PARTMOV  3C  REZONE   2C
  DTC     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
  DTO     YAQUI     C  LOOP      C  FILMCO    C  YASET1   3C  PARTGEN   C  MESHMKR   C  YAQUI2   2C  PARTMOV   C  REZONE    C
  DTOC    YAQUI     C  LOOP      C  FILMCO    C  YASET1   2C  PARTGEN   C  MESHMKR   C  YAQUI2   2C  PARTMOV   C  REZONE    C
  DTO16   YAQUI     C  LOOP      C  FILMCO    C  YASET1    C  PARTGEN   C  MESHMKR   C  YAQUI2   2C  PARTMOV   C  REZONE    C
  DTO2    YAQUI     C  LOOP      C  FILMCO    C  YASET1    C  PARTGEN   C  MESHMKR   C  YAQUI2   7C  PARTMOV   C  REZONE    C
  DTO2M1  YAQUI2   7
  DTO2M2  YAQUI2   7
  DTO2M3  YAQUI2   7
  DTO2M4  YAQUI2   7
  DTO4    YAQUI     C  LOOP      C  FILMCO    C  YASET1    C  PARTGEN   C  MESHMKR   C  YAQUI2   2C  PARTMOV   C  REZONE    C
  DTO8    YAQUI     C  LOOP      C  FILMCO    C  YASET1    C  PARTGEN   C  MESHMKR   C  YAQUI2   5C  PARTMOV   C  REZONE    C
  DTPOS   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
  DT8     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  10
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 EXP     MESHMKR  1   REZONE    3
  FB      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
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  INDEX     01/12/73                              MASTER INDEX                              PAGE  87
  FL        YAQUI2    7
S FLOAT     YASET1    2    PARTGEN   3    MESHMKR   1    YAQUI2    2    PARTMOV   6
  FM1       YAQUI2    3
  FM2       YAQUI2    3
  FM3       YAQUI2    3
  FM4       YAQUI2    3
  FNUM      MESHMKR   8
  FR        YAQUI2    7
S FRAME     PARTMOV   2
  FREZ      YAQUI     C    LOOP      C    FILMCO    C    YASET1   4C    PARTGEN  8C    MESHMKR  9C    YAQUI2    C    PARTMOV   C    REZONE    C
  FSET12    YAQUI     1
  FSET7     YAQUI     1
  FSET8     YAQUI     1
  FSET9     YAQUI     1
  FT        YAQUI2   7D
  F13       YAQUI2    5
  F24       YAQUI2    5
S GETQ      YAQUI2    2
  GGM1      YAQUI     C    LOOP      C    FILMCO    C    YASET1   1C    PARTGEN   C    MESHMKR   C    YAQUI2   1C    PARTMOV   C    REZONE    C
  GM1       YAQUI     C    LOOP      C    FILMCO    C    YASET1   4C    PARTGEN   C    MESHMKR  1C    YAQUI2   2C    PARTMOV   C    REZONE   1C
  GR        YAQUI     C    LOOP      C    FILMCO    C    YASET1   2C    PARTGEN   C    MESHMKR   C    YAQUI2   2C    PARTMOV   C    REZONE    C
  GRDVEL    YAQUI    1C    LOOP      C    FILMCO    C    YASET1   1C    PARTGEN   C    MESHMKR   C    YAQUI2   6C    PARTMOV   C    REZONE    C
  GZ        YAQUI     C    LOOP      C    FILMCO    C    YASET1   2C    PARTGEN   C    MESHMKR  2C    YAQUI2   3C    PARTMOV   C    REZONE   1C
  GZP       YAQUI     C    LOOP      C    FILMCO    C    YASET1   2C    PARTGEN   C    MESHMKR   C    YAQUI2   1C    PARTMOV   C    REZONE    C
  H         PARTMOV  12
  HR13      YAQUI2    4
  HR24      YAQUI2    4
  HTE       PARTMOV   6
S H4020     YAQUI2    1
  I         YAQUI     C    LOOP     1C    FILMCO   1C    YASET1   6C    PARTGEN   C    MESHMKR 16C    YAQUI2  57C    PARTMOV 14C    REZONE  14C
S IABS      MESHMKR   2
  IB        PARTMOV   4
  IBAR      YAQUI    2C    LOOP      C    FILMCO    C    YASET1   9C    PARTGEN  2C    MESHMKR   C    YAQUI2  20C    PARTMOV   C    REZONE   3C
  IBP       YAQUI     C    LOOP      C    FILMCO    C    YASET1   2C    PARTGEN  4C    MESHMKR   C    YAQUI2    C    PARTMOV  1C    REZONE    C
  IBP1      YAQUI     C    LOOP      C    FILMCO    C    YASET1    C    PARTGEN  1C    MESHMKR   C    YAQUI2    C    PARTMOV  5C    REZONE    C
  IBUF      LOOP      9
  ICOLOR    YAQUI     C    LOOP      C    FILMCO    C    YASET1   2C    PARTGEN   C    MESHMKR   C    YAQUI2    C    PARTMOV  3C    REZONE    C
  IC1       YAQUI2    8
  IC2       YAQUI2    6
  IDTC      YAQUI2    3
  IDTO      YAQUI     C    LOOP      C    FILMCO    C    YASET1   1C    PARTGEN   C    MESHMKR   C    YAQUI2   6C    PARTMOV   C    REZONE    C
  IDTV      YAQUI2    3
  IEC       LOOP      4    PARTMOV  15
  IECA      PARTMOV   4
  IECP      PARTGEN   5    PARTMOV  12
  IECR      LOOP     18
  IECT      PARTMOV   4
  IECW      LOOP     12
  II        YASET1    2    YAQUI2    5    PARTMOV   3
  IJ        YAQUI     C    LOOP     6C    FILMCO   5C    YASET1  18C    PARTGEN   C    MESHMKR 47C    YAQUI2  99C    PARTMOV 68C    REZONE  39C
  IJA       YAQUI2    6
  IJB       YAQUI2    6
  IJM       YAQUI     C    LOOP     5C    FILMCO    C    YASET1   3C    PARTGEN   C    MESHMKR  7C    YAQUI2  52C    PARTMOV   C    REZONE   4C
  IJMS      LOOP     14
  IJP       YAQUI     C    LOOP     3C    FILMCO    C    YASET1   7C    PARTGEN   C    MESHMKR  7C    YAQUI2  99C    PARTMOV  4C    REZONE  14C
  IJPS      YAQUI     C    LOOP     8C    FILMCO    C    YASET1    C    PARTGEN   C    MESHMKR   C    YAQUI2   2C    PARTMOV   C    REZONE    C
  IJS       LOOP      3
  IJ1       YAQUI2    6
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INDEX     01/12/73                                MASTER INDEX                                    PAGE  88
IJ2       YAQUI2     6
IL        PARTMOV    6
IMJ       YASET1     3    MESHMKR    4    YAQUI2    14
IMJM      YASET1     3    YAQUI2     3
IMOME3    YAQUI      C    LOOP       C    FILMCO     C    YASET1     C    PARTGEN   1C    MESHMKR    C    YAQUI2     C    PARTMOV   1C    REZONE     C
IMOMX     YAQUI      C    LOOP       C    FILMCO     C    YASET1    2C    PARTGEN   1C    MESHMKR    C    YAQUI2     C    PARTMOV   3C    REZONE     C
IM1       YAQUI      C    LOOP       C    FILMCO     C    YASET1    1C    PARTGEN    C    MESHMKR   1C    YAQUI2    2C    PARTMOV    C    REZONE     C
IM6       YAQUI      C    LOOP       C    FILMCO     C    YASET1    1C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE    2C
INP       YAQUI      1
IPAR      YAQUI      C    LOOP       C    FILMCO     C    YASET1     C    PARTGEN   2C    MESHMKR    C    YAQUI2     C    PARTMOV   2C    REZONE     C
IPJ       YASET1     7    MESHMKR    3    YAQUI2    99    PARTMOV    4    REZONE    16
IPJA      YAQUI2     4
IPJB      YAQUI2     4
IPJM      YAQUI2    13
IPJP      YASET1     7    MESHMKR    4    YAQUI2    82    PARTMOV    3    REZONE    11
IPXL      YAQUI      C    LOOP       C    FILMCO    1C    YASET1     C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV   2C    REZONE     C
IPXR      YAQUI      C    LOOP       C    FILMCO    1C    YASET1     C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV   2C    REZONE     C
IPYB      YAQUI      C    LOOP       C    FILMCO    1C    YASET1     C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV   2C    REZONE     C
IPYT      YAQUI      C    LOOP       C    FILMCO    1C    YASET1     C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV   2C    REZONE     C
IP1       YAQUI      C    LOOP       C    FILMCO    1C    YASET1    5C    PARTGEN    C    MESHMKR   6C    YAQUI2   12C    PARTMOV   3C    REZONE    5C
IP2       YAQUI      C    LOOP       C    FILMCO     C    YASET1    2C    PARTGEN    C    MESHMKR    C    YAQUI2    1C    PARTMOV    C    REZONE     C
IR        PARTMOV    6
ISCF1     YAQUI      C    LOOP      2C    FILMCO     C    YASET1    2C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE     C
ISCF2     YAQUI      C    LOOP      2C    FILMCO     C    YASET1    1C    PARTGEN    C    MESHMKR    C    YAQUI2    2C    PARTMOV    C    REZONE     C
ISC2      YAQUI      C    LOOP      8C    FILMCO     C    YASET1    3C    PARTGEN    C    MESHMKR    C    YAQUI2    2C    PARTMOV  10C    REZONE     C
ISC3      YAQUI      C    LOOP      4C    FILMCO     C    YASET1    1C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE     C
IT        PARTMOV    4
ITESTL    PARTMOV    4
ITESTR    PARTMOV    4
ITV       YAQUI      C    LOOP      1C    FILMCO     C    YASET1    1C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE     C
IUNF      YAQUI     1C    LOOP       C    FILMCO     C    YASET1    3C    PARTGEN   2C    MESHMKR   1C    YAQUI2     C    PARTMOV    C    REZONE     C
IXL       YAQUI      C    LOOP       C    FILMCO    1C    YASET1     C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE     C
IXR       YAQUI      C    LOOP       C    FILMCO    1C    YASET1     C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE     C
IX1       YAQUI2   15D    PARTMOV    2
IX2       YAQUI2   11D
IX3       YAQUI2     6
IX4       YAQUI2     6
IYB       YAQUI      C    LOOP       C    FILMCO    1C    YASET1     C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE     C
IYT       YAQUI      C    LOOP       C    FILMCO    1C    YASET1     C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE     C
IY1       YAQUI2   15D    PARTMOV    2
IY2       YAQUI2   12D
IY3       YAQUI2     6
IY4       YAQUI2     6
J         YAQUI      C    LOOP      2C    FILMCO    1C    YASET1    6C    PARTGEN    C    MESHMKR  19C    YAQUI2   53C    PARTMOV  18C    REZONE   17C
JBAR      YAQUI     1C    LOOP       C    FILMCO     C    YASET1    8C    PARTGEN   2C    MESHMKR   1C    YAQUI2    4C    PARTMOV    C    REZONE     C
JBOT      MESHMKR    3
JBP       YAQUI      C    LOOP       C    FILMCO     C    YASET1    2C    PARTGEN   3C    MESHMKR    C    YAQUI2     C    PARTMOV   1C    REZONE     C
JBP2      YAQUI      C    LOOP       C    FILMCO     C    YASET1     C    PARTGEN   1C    MESHMKR    C    YAQUI2     C    PARTMOV   5C    REZONE     C
JCEN      YAQUI     1C    LOOP       C    FILMCO     C    YASET1    3C    PARTGEN   2C    MESHMKR   4C    YAQUI2     C    PARTMOV    C    REZONE     C
JDB       MESHMKR    2
JDT       MESHMKR    2
JDTC      YAQUI2     3
JDTV      YAQUI2     3
JJ        YASET1     2    MESHMKR    3    YAQUI2     3    PARTMOV    3
JM10      YAQUI      C    LOOP       C    FILMCO     C    YASET1    1C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE    1C
JM14      YAQUI      C    LOOP       C    FILMCO     C    YASET1    1C    PARTGEN    C    MESHMKR    C    YAQUI2     C    PARTMOV    C    REZONE    1C
JNM       YAQUI2    6C    PARTMOV   1C
JNSC      YAQUI2     2
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   INDEX   01/12/73                       MASTER INDEX                                    PAGE  89
  JOLD     PARTMOV   3
  JP1      YAQUI     C   LOOP      C   FILMCO    C   YASET1   3C   PARTGEN   C   MESHMKR  1C   YAQUI2  21C   PARTMOV   C   REZONE   3C
  JP2      YAQUI     C   LOOP      C   FILMCO   1C   YASET1   6C   PARTGEN   C   MESHMKR  3C   YAQUI2  12C   PARTMOV  3C   REZONE   5C
  JP4      YAQUI     C   LOOP      C   FILMCO    C   YASET1   4C   PARTGEN   C   MESHMKR  1C   YAQUI2   1C   PARTMOV   C   REZONE    C
  JP402    YAQUI     C   LOOP      C   FILMCO    C   YASET1   1C   PARTGEN   C   MESHMKR   C   YAQUI2    C   PARTMOV   C   REZONE   1C
  JTD      YAQUI2    4
  JTESTB   PARTMOV   4
  JTESTT   PARTMOV   4
  JTOP     MESHMKR   3
  JUNF     YAQUI    1C   LOOP      C   FILMCO    C   YASET1   4C   PARTGEN   C   MESHMKR   C   YAQUI2    C   PARTMOV   C   REZONE    C
  JUNFO2   YAQUI     C   LOOP      C   FILMCO    C   YASET1   1C   PARTGEN  4C   MESHMKR  3C   YAQUI2    C   PARTMOV   C   REZONE    C
  K        MESHMKR   2   YAQUI2   15
  KI       PARTMOV   6
  KIJ      PARTMOV  27
  KIJP     PARTMOV   4
  KJ       PARTMOV   6
  KK       YAQUI2    8   PARTMOV   7
  KP       PARTGEN   8   PARTMOV  17
  KRET     YASET1    3   YAQUI2    6
  KRF      YAQUI2    5
  KRFP     YAQUI2    3
  KRP      YAQUI2    4
  KRI      YAQUI2    5
  KT       YASET1   10
  KXI      YAQUI    1C   LOOP      C   FILMCO    C   YASET1   1C   PARTGEN   C   MESHMKR   C   YAQUI2   3C   PARTMOV   C   REZONE    C
  K1       YAQUI2    6
  K2       YAQUI2    6
  K3       YAQUI2    6
  K4       YAQUI2    6
  L        YAQUI2    6
  LAM      YAQUI    CD   LOOP      C   FILMCO   CD   YASET1  3CD   PARTGEN  CD   MESHMKR  CD   YAQUI2  2CD   PARTMOV  CD   REZONE   CD
  LAMD     YAQUI     D   FILMCO    D   YASET1    D   PARTGEN   D   MESHMKR   D   YAQUI2   4D   PARTMOV   D   REZONE    D
F LCM      YAQUI     1   YASET1    1   PARTGEN   1   YAQUI2    1
S LINCNT   YAQUI     1   YAQUI2    4   PARTMOV   1
  LINESF   YAQUI2    4
  LINESP   YAQUI2    4
  LJP2     YAQUI     C   LOOP      C   FILMCO    C   YASET1   5C   PARTGEN   C   MESHMKR   C   YAQUI2   2C   PARTMOV   C   REZONE    C
  LL       YAQUI2    7
S LOCF     YASET1    4   PARTGEN   2   YAQUI2    2
S LOOP     LOOP      1   FILMCO    1   YASET1    1   MESHMKR   6   YAQUI2   22   PARTMOV   4   REZONE    5
S LOOPD    LOOP      1   YASET1    1   YAQUI2    1
  LPB      YAQUI     C   LOOP      C   FILMCO    C   YASET1    C   PARTGEN  5C   MESHMKR   C   YAQUI2    C   PARTMOV  8C   REZONE    C
  LPR      YAQUI     C   LOOP      C   FILMCO    C   YASET1   3C   PARTGEN  2C   MESHMKR  1C   YAQUI2   9C   PARTMOV  1C   REZONE    C
  M        YAQUI     D   FILMCO    D   YASET1   6D   PARTGEN   D   MESHMKR   D   YAQUI2    D   PARTMOV   D   REZONE    D
S MAXO     YASET1    2
  MB       YAQUI     D   FILMCO    D   YASET1    D   PARTGEN   D   MESHMKR   D   YAQUI2   4D   PARTMOV   D   REZONE    D
  MC       YAQUI     D   FILMCO    D   YASET1    D   PARTGEN  3D   MESHMKR   D   YAQUI2  10D   PARTMOV   D   REZONE    D
S MESHMKR  YASET1    1   MESHMKR   1
  ML       YAQUI     D   FILMCO    D   YASET1    D   PARTGEN   D   MESHMKR   D   YAQUI2   4D   PARTMOV   D   REZONE    D
  MP       YAQUI     D   FILMCO    D   YASET1    D   PARTGEN   D   MESHMKR   D   YAQUI2   7D   PARTMOV   D   REZONE    D
  MPAR     YAQUI     D   FILMCO    D   YASET1    D   PARTGEN  1D   MESHMKR   D   YAQUI2    D   PARTMOV  1D   REZONE    D
  MR       YAQUI     D   FILMCO    D   YASET1    D   PARTGEN   D   MESHMKR   D   YAQUI2   4D   PARTMOV   D   REZONE    D
  MT       YAQUI     D   FILMCO    D   YASET1    D   PARTGEN  5D   MESHMKR   D   YAQUI2   4D   PARTMOV   D   REZONE    D
  MTE      YAQUI     D   FILMCO    D   YASET1    D   PARTGEN  4D   MESHMKR   D   YAQUI2    D   PARTMOV  2D   REZONE    D
  MU       YAQUI    CD   LOOP      C   FILMCO   CD   YASET1  4CD   PARTGEN  CD   MESHMKR  CD   YAQUI2  2CD   PARTMOV  CD   REZONE   CD
  MUO2     YAQUI     D   FILMCO    D   YASET1    D   PARTGEN   D   MESHMKR   D   YAQUI2   4D   PARTMOV   D   REZONE    D
  MUO4     YAQUI     D   FILMCO    D   YASET1    D   PARTGEN   D   MESHMKR   D   YAQUI2   3D   PARTMOV   D   REZONE    D
  MUSTIT   YAQUI2    4
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  N         YASET1     8  YAQUI2    18
  NAME      YAQUI      C  LOOP       C  FILMCO     C  YASET1    2C  PARTGEN    C  MESHMKR    C  YAQUI2    7C  PARTMOV   1C  REZONE     C
  NB        MESHMKR    4
  NB2       MESHMKR    2
  NCYC      YAQUI      C  LOOP       C  FILMCO     C  YASET1    1C  PARTGEN    C  MESHMKR    C  YAQUI2   20C  PARTMOV   1C  REZONE     C
  NE        LOOP      11  PARTGEN    2  PARTMOV   16
  NL        MESHMKR    4
  NLC       YAQUI      C  LOOP       C  FILMCO     C  YASET1    1C  PARTGEN    C  MESHMKR    C  YAQUI2    2C  PARTMOV    C  REZONE     C
  NL1       MESHMKR    2
  NPMT      PARTMOV    4
  NPPT      PARTMOV    4
  NPS       YAQUI      C  LOOP       C  FILMCO     C  YASET1     C  PARTGEN   1C  MESHMKR    C  YAQUI2    2C  PARTMOV    C  REZONE     C
  NPT       YAQUI      C  LOOP       C  FILMCO    1C  YASET1     C  PARTGEN   6C  MESHMKR    C  YAQUI2    4C  PARTMOV   2C  REZONE     C
  NQ        YAQUI     1C  LOOP      1C  FILMCO    1C  YASET1    8C  PARTGEN    C  MESHMKR  10C  YAQUI2   55C  PARTMOV  16C  REZONE   10C
  NQI       YAQUI      C  LOOP     21C  FILMCO     C  YASET1    7C  PARTGEN   2C  MESHMKR   1C  YAQUI2     C  PARTMOV  20C  REZONE     C
  NQIB      YAQUI      C  LOOP       C  FILMCO     C  YASET1    1C  PARTGEN    C  MESHMKR    C  YAQUI2    6C  PARTMOV    C  REZONE     C
  NQIM      MESHMKR    2
  NQI2      YAQUI      C  LOOP       C  FILMCO     C  YASET1     C  PARTGEN   1C  MESHMKR    C  YAQUI2     C  PARTMOV   5C  REZONE     C
  NR        MESHMKR    6
  NR1       MESHMKR    3
  NSC       YAQUI      C  LOOP       C  FILMCO     C  YASET1    1C  PARTGEN    C  MESHMKR    C  YAQUI2    1C  PARTMOV    C  REZONE     C
  NT        MESHMKR    5
  NT2       MESHMKR    3
  NUMIT     YAQUI      C  LOOP       C  FILMCO     C  YASET1     C  PARTGEN    C  MESHMKR    C  YAQUI2    7C  PARTMOV    C  REZONE     C
  NUMTD     YAQUI      C  LOOP       C  FILMCO     C  YASET1    1C  PARTGEN    C  MESHMKR    C  YAQUI2    7C  PARTMOV    C  REZONE     C
  OM        YAQUI      C  LOOP       C  FILMCO     C  YASET1    2C  PARTGEN    C  MESHMKR    C  YAQUI2    1C  PARTMOV    C  REZONE     C
  OMAL13    YAQUI2     3
  OMAL24    YAQUI2     3
  OMANC     YAQUI      C  LOOP       C  FILMCO     C  YASET1    1C  PARTGEN    C  MESHMKR    C  YAQUI2    1C  PARTMOV    C  REZONE     C
  OMCYL     YAQUI      C  LOOP       C  FILMCO     C  YASET1    1C  PARTGEN   1C  MESHMKR   2C  YAQUI2    1C  PARTMOV    C  REZONE    1C
  OMEM10    YAQUI      C  LOOP       C  FILMCO    1C  YASET1    1C  PARTGEN    C  MESHMKR    C  YAQUI2     C  PARTMOV    C  REZONE     C
  OMSUM     REZONE     5
  OPAL13    YAQUI2     3
  OPAL24    YAQUI2     3
  OPEM10    YAQUI      C  LOOP       C  FILMCO    2C  YASET1    1C  PARTGEN    C  MESHMKR    C  YAQUI2     C  PARTMOV   6C  REZONE     C
  OUT       YAQUI      2
S OVERLAY   YAQUI      2
  P         YAQUI      D  FILMCO     D  YASET1     D  PARTGEN    D  MESHMKR    D  YAQUI2   13D  PARTMOV    D  REZONE     D
S PARPLOT   YAQUI2     1  PARTMOV    1
S PARTGEN   YASET1     1  PARTGEN    1
S PARTMOV   YAQUI2     1  PARTMOV    1
  PB        YAQUI2     3
  PC        YAQUI2     5
  PDR       YAQUI      C  LOOP       C  FILMCO    2C  YASET1    2C  PARTGEN   1C  MESHMKR    C  YAQUI2     C  PARTMOV   7C  REZONE    1C
  PDRMW     PARTMOV    3
  PDZ       YAQUI      C  LOOP       C  FILMCO    2C  YASET1    2C  PARTGEN   1C  MESHMKR    C  YAQUI2     C  PARTMOV   7C  REZONE    1C
  PDZMH     PARTMOV    3
  PITH      YAQUI2     5
  PIXX      YAQUI2     5
  PIXY      YAQUI2     9
  PIYY      YAQUI2     4
  PL        YAQUI      D  FILMCO     D  YASET1     D  PARTGEN    D  MESHMKR    D  YAQUI2    3D  PARTMOV    D  REZONE     D
  PLE       YAQUI2     3
  PLMAX     YAQUI2     4
S PLT       YAQUI2     3  PARTMOV    1
  PMX       YAQUI      D  FILMCO     D  YASET1     D  PARTGEN    D  MESHMKR    D  YAQUI2     D  PARTMOV   4D  REZONE     D
  PMY       YAQUI      D  FILMCO     D  YASET1     D  PARTGEN    D  MESHMKR    D  YAQUI2     D  PARTMOV   4D  REZONE     D
  PM0       YAQUI      D  FILMCO     D  YASET1     D  PARTGEN    D  MESHMKR    D  YAQUI2     D  PARTMOV  12D  REZONE     D
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   INDEX  01/12/73                          MASTER INDEX                                         PAGE  91
  PR      YAQUI2     3
F PRINT   YAQUI      1   YASET      1   PARTGEN    3   MESHMKR    1   YAQUI1     1   YAQUI2    10
  PRM     YAQUI2     4
  PRSIE   YAQUI2     4
  PRV     YAQUI2     4
  PT      YAQUI2     3
  PU      YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2     D   PARTMOV  18D   REZONE     D
  PUB     PARTMOV    3
  PUL     PARTMOV    6
  PUR     PARTMOV    3
  PUT     PARTMOV    3
  PV      YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2     D   PARTMOV  17D   REZONE     D
  PVB     PARTMOV    3
  PVL     PARTMOV    6
  PVR     PARTMOV    3
  PVT     PARTMOV    3
  PXCONV  YAQUI      C   LOOP       C   FILMCO    1C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   1C   REZONE     C
  PXL     YAQUI      C   LOOP       C   FILMCO    2C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   1C   REZONE     C
  PXR     YAQUI      C   LOOP       C   FILMCO    4C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   1C   REZONE     C
  PXRP    YAQUI      C   LOOP       C   FILMCO    1C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   2C   REZONE     C
  PYR     YAQUI      C   LOOP       C   FILMCO    6C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   8C   REZONE    1C
  PYRM    YAQUI      C   LOOP       C   FILMCO    1C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   2C   REZONE     C
  PYCONV  YAQUI      C   LOOP       C   FILMCO    1C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   1C   REZONE     C
  PYT     YAQUI      C   LOOP       C   FILMCO    4C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   1C   REZONE     C
  PYTP    YAQUI      C   LOOP       C   FILMCO    1C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   2C   REZONE     C
  PYYMP   YAQUI2     3
  P12     YAQUI2     2
  P23     YAQUI2     2
  P34     YAQUI2     2
  P41     YAQUI2     2
  Q       YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2   13D   PARTMOV    D   REZONE     D
  QMN     YAQUI2    11
  QMX     YAQUI2     8
  R       YAQUI      D   FILMCO     D   YASET1    4D   PARTGEN    D   MESHMKR   2D   YAQUI2   29D   PARTMOV    D   REZONE    5D
  RA      YAQUI2     2
  RCSQ    YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2    3D   PARTMOV    D   REZONE     D
  RDT     YAQUI      C   LOOP       C   FILMCO     C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2    4C   PARTMOV    C   REZONE    1C
  RDTORG  PARTMOV    3
F READ    YAQUI      1   YASET1     7   PARTGEN    1   MESHMKR    2   YAQUI2     3
F REAL    YAQUI      1   FILMCO     1   YASET1     1   PARTGEN    1   MESHMKR    1   YAQUI2     1   PARTMOV    1   REZONE     1
F RETURN  LOOP       6   FILMCO     2   YASET1     1   PARTGEN    3   MESHMKR    2   YAQUI2     2   PARTMOV    4   REZONE     1
F REWIND  YAQUI2     1
  REZRTA  REZONE     3
  REZOMG  REZONE     4
S REZONE  YAQUI2     1   REZONE     1
  REZRON  YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR   1C   YAQUI2     C   PARTMOV    C   REZONE    3C
  REZSIE  YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR   4C   YAQUI2     C   PARTMOV    C   REZONE    1C
  REZUE   YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV    C   REZONE     C
  REZVE   YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV    C   REZONE     C
  REZVT   YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV    C   REZONE    2C
  REZYO   YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN   2C   MESHMKR   3C   YAQUI2     C   PARTMOV    C   REZONE    1C
  RIBAR   YAQUI      C   LOOP       C   FILMCO    1C   YASET1    1C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV    C   REZONE     C
  RIBJB   YAQUI      C   LOOP       C   FILMCO     C   YASET1    1C   PARTGEN    C   MESHMKR    C   YAQUI2    1C   PARTMOV    C   REZONE     C
  RIBP    YAQUI      C   LOOP       C   FILMCO     C   YASET1     C   PARTGEN   2C   MESHMKR    C   YAQUI2     C   PARTMOV    C   REZONE    1C
  RJBP    YAQUI      C   LOOP       C   FILMCO     C   YASET1     C   PARTGEN   2C   MESHMKR    C   YAQUI2     C   PARTMOV    C   REZONE    1C
  RM      YAQUI      D   FILMCO     D   YASET1    1D   PARTGEN    D   MESHMKR    D   YAQUI2   12D   PARTMOV   1D   REZONE     D
  RMP     YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2    7D   PARTMOV    D   REZONE     D
  RO      YAQUI      D   FILMCO     D   YASET1    2D   PARTGEN    D   MESHMKR   7D   YAQUI2   27D   PARTMOV    D   REZONE     D
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ROE       YAQUI2    6
ROI       MESHMKR   7
ROJP2     MESHMKR   2
ROJ1      MESHMKR   2
ROL       YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2   19D   PARTMOV    D   REZONE    3D
ROMFR     YAQUI      C   LOOP       C   FILMCO     C   YASET1    1C   PARTGEN   3C   MESHMKR   2C   YAQUI2     C   PARTMOV    C   REZONE     C
RON       YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2    3C   PARTMOV    C   REZONE     C
ROSAV     MESHMKR   7
RPDR      YAQUI      C   LOOP       C   FILMCO    2C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   3C   REZONE     C
RPDRDZ    YAQUI      C   LOOP       C   FILMCO    1C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   5C   REZONE     C
RPDZ      YAQUI      C   LOOP       C   FILMCO    2C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV   3C   REZONE     C
RPMO      PARTMOV   7
RVOL      YAQUI      D   FILMCO     D   YASET1    1D   PARTGEN    D   MESHMKR    D   YAQUI2   25D   PARTMOV    D   REZONE    1D
R1        YASET1    3    YAQUI2  25     REZONE    2
S R1ROW     LOOP      1    MESHMKR  4
R12       YAQUI2   10
R2        YASET1    2    YAQUI2  22
R23       YAQUI2   10
R3        YASET1    3    YAQUI2  23
R34       YAQUI2   10
R4        YASET1    2    YAQUI2  22
R41       YAQUI2   10
S         YAQUI2    2
S SECOND    YAQUI2    2
S SETIJ     LOOP      1    MESHMKR  4
S SHIFT     PARTGEN   3    PARTMOV 11
SIE       YAQUI      D   FILMCO     D   YASET1    1D   PARTGEN    D   MESHMKR   3D   YAQUI2    4D   PARTMOV    D   REZONE     D
SIEI      MESHMKR   7
SIET      YAQUI2    3
S SIGN      YAQUI2    6
S SQRT      YAQUI2    4    REZONE   3
S START     LOOP      1    FILMCO   1     YASET1     1   MESHMKR   5    YAQUI2   22    PARTMOV   4    REZONE    5
S STARTD    LOOP      1    YASET1   1     YAQUI2     1
T         YAQUI      C   LOOP       C   FILMCO     C   YASET1    3C   PARTGEN    C   MESHMKR    C   YAQUI2   18C   PARTMOV   1C   REZONE     C
TBASE     YAQUI2    3
THIRD     YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2     C   PARTMOV    C   REZONE     C
TJ        MESHMKR   3
TLIM      YAQUI2    6
TLIMD     YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2    2C   PARTMOV    C   REZONE     C
TOLD      YAQUI2    2
TOUT      YAQUI      C   LOOP       C   FILMCO     C   YASET1    1C   PARTGEN    C   MESHMKR    C   YAQUI2    6C   PARTMOV    C   REZONE     C
TWFIN     YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2    1C   PARTMOV    C   REZONE     C
T1        YAQUI2    3
T2        YAQUI2    8
T20MD     YAQUI      C   LOOP       C   FILMCO     C   YASET1    2C   PARTGEN    C   MESHMKR    C   YAQUI2    1C   PARTMOV    C   REZONE     C
U         YAQUI      D   FILMCO     D   YASET1    4D   PARTGEN    D   MESHMKR   2D   YAQUI2   32D   PARTMOV   3D   REZONE     D
UD1       YAQUI2    3
UD2       YAQUI2    3
UD3       YAQUI2    3
UD4       YAQUI2    3
UG        YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2   10D   PARTMOV    D   REZONE    2D
UGTE      REZONE   4D
UG1       YAQUI2    2
UG2       YAQUI2    2
UG3       YAQUI2    2
UG4       YAQUI2    2
UI        MESHMKR   7
UK        PARTMOV   3
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  INDEX  01/12/73                          MASTER INDEX                                            PAGE  93
UL       YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR   4D   YAQUI2  22D   PARTMOV    D   REZONE    5D
UL1      YAQUI2   7
UL13     YAQUI2   2
UL2      YAQUI2   7
UL24     YAQUI2   2
UL3      YAQUI2   7
UL4      YAQUI2   7
UP       YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2  14D   PARTMOV    D   REZONE     D
UPAR     PARTGEN  4     PARTMOV  6
URAND    PARTMOV  3
USH      PARTGEN  2     PARTMOV  2
UTIL     YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2  17D   PARTMOV    D   REZONE     D
U1       YAQUI2  26     REZONE   3
U12      YAQUI2  10
U13      YAQUI2   2
U2       YAQUI2  17     REZONE   3
U23      YAQUI2   8
U24      YAQUI2   2
U3       YAQUI2  17     REZONE   3
U34      YAQUI2  10
U4       YAQUI2  19     REZONE   3
U41      YAQUI2   8
V        YAQUI      D   FILMCO     D   YASET1    4D   PARTGEN    D   MESHMKR   3D   YAQUI2  32D   PARTMOV   3D   REZONE     D
VD1      YAQUI2   3
VD2      YAQUI2   3
VD3      YAQUI2   3
VD4      YAQUI2   3
VEL1J    YAQUI2   3
VELMX    YAQUI2   3
VG       YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2  10D   PARTMOV    D   REZONE    2D
VGTE     REZONE   4
VG1      YAQUI2   2
VG2      YAQUI2   2
VG3      YAQUI2   2
VG4      YAQUI2   2
VI       MESHMKR  7
VK       PARTMOV  3
VL       YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR   5D   YAQUI2  18D   PARTMOV    D   REZONE    5D
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
VOLT     YAQUI2   3
VP       YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2  12D   PARTMOV    D   REZONE     D
VPAR     PARTGEN  4     PARTMOV  6
VRAND    PARTMOV  3
VSH      PARTGEN  2     PARTMOV  2
VTIL     YAQUI      D   FILMCO     D   YASET1     D   PARTGEN    D   MESHMKR    D   YAQUI2  15D   PARTMOV    D   REZONE     D
VV       YAQUI      C   LOOP       C   FILMCO    1C   YASET1     C   PARTGEN    C   MESHMKR    C   YAQUI2   1C   PARTMOV    C   REZONE     C
V1       YAQUI2  26     REZONE   3
V12      YAQUI2   9
V13      YAQUI2   2
V2       YAQUI2  17     REZONE   3
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  INDEX  01/12/73                    MASTER INDEX                                   PAGE  94
 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
 WTB     PARTMOV  3
 WTE     PARTMOV  6
 WTL     PARTMOV  3
 WTR     PARTMOV  3
 WTT     PARTMOV  3
S WIROW   LOOP     1     MESHMKR  4
 X       YAQUI     D    FILMCO   1D    YASET1   4D   PARTGEN   D    MESHMKR  6D   YAQUI2  55D   PARTMOV  6D   REZONE  12D
 XBAR    REZONE   2
 XC      PARTGEN  4     REZONE   2
 XCO     YAQUI2  4D
 XCONV   YAQUI     C    LOOP      C    FILMCO   1C    YASET1    C   PARTGEN   C    MESHMKR   C   YAQUI2  11C   PARTMOV   C    REZONE    C
 XD      FILMCO  10     PARTGEN  8
 XIP1    REZONE   4
 XL      YAQUI     C    LOOP      C    FILMCO   2C    YASET1    C   PARTGEN   C    MESHMKR   C   YAQUI2  11C   PARTMOV   C    REZONE    C
 XMAX    PARTGEN  3
 XOMSUM  REZONE   4
 XPAR    YAQUI     D    FILMCO    D    YASET1    D   PARTGEN  1D    MESHMKR   D   YAQUI2    D   PARTMOV  5D   REZONE    D
 XR      YAQUI     C    LOOP      C    FILMCO   6C    YASET1    C   PARTGEN   C    MESHMKR   C   YAQUI2   1C   PARTMOV   C    REZONE    C
 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 11D   REZONE   3
 X12     YAQUI2   9
 X2      YASET1   2     YAQUI2  28     PARTMOV  3D   REZONE   3
 X23     YAQUI2   9
 X24     YAQUI2   6
 X3      YASET1   3     YAQUI2  29     PARTMOV  3D   REZONE   3
 X31     YAQUI2   6
 X34     YAQUI2   9
 X4      YASET1   2     YAQUI2  28     PARTMOV  3D   REZONE   4
 X41     YAQUI2   9
 Y       YAQUI     D    FILMCO   2D    YASET1   4D   PARTGEN   D    MESHMKR 12D   YAQUI2  54D   PARTMOV  8D   REZONE  23D
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    C
 YBAR    REZONE   2
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  YROT   PARTGEN   4
  YC     PARTGEN   7 REZONE    3
  YCEN   REZONE    2
  YCO    YAQUI2   4D
  YCONV  YAQUI     C LOOP      C FILMCO   1C YASET1    C PARTGEN   C MESHMKR   C YAQUI2  11C PARTMOV   C REZONE    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  10 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 REZONE    1
L YSC2   YAQUI     1 LOOP      1 FILMCO    1 YASET1    1 PARTGEN   1 MESHMKR   1 YAQUI2    1 PARTMOV   1 REZONE    1
L YSC3   YAQUI2    1 PARTMOV   1
  YT     YAQUI     C LOOP      C FILMCO   5C YASET1    C PARTGEN   C MESHMKR   C YAQUI2   2C PARTMOV   C REZONE    C
  YTE    PARTGEN   6 PARTMOV   7
  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   28 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 REZONE    C



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FILMCO     9 MESHMKR   29 PARTMOV   68 YAQUI      2 YAQUI2    38 YASET1    17
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
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