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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.

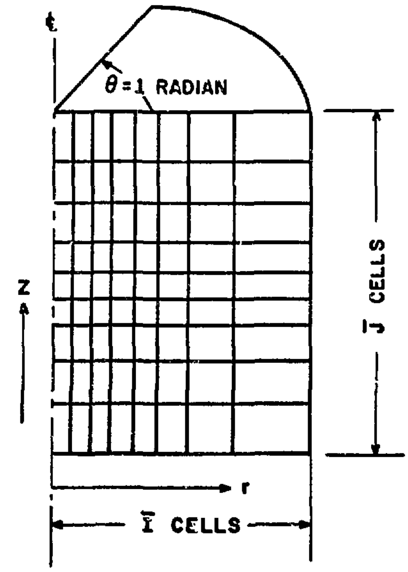


Fig. 1. A typical ICED-ALE mesh in cylindrical coordinates.

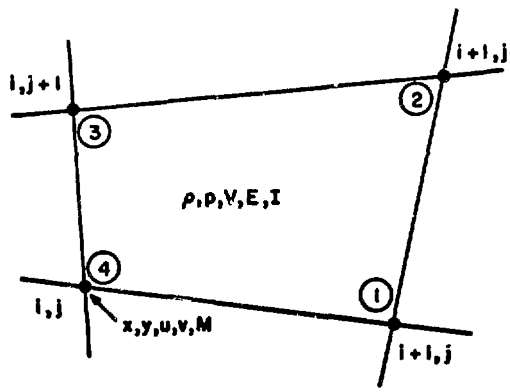


Fig. 2. A typical ICED-ALE cell showing the locations of the principal variables. The numbers are in the shorthand vertex notation used in the equations that follow and in the YAQUI code.

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

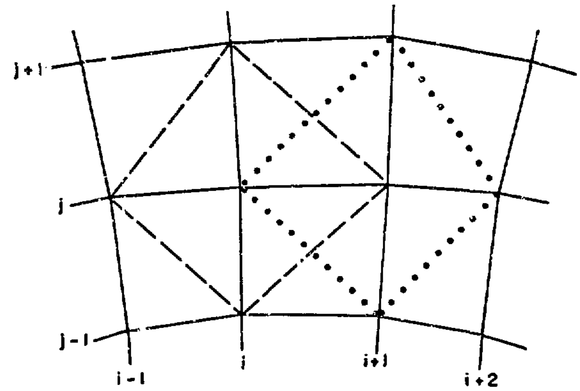


Fig. 3. Momentum-integration areas about cells $\binom{j}{i}$ and $\binom{j}{i+1}$, indicated by dashed lines and dotted lines, respectively.

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

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

and

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

where

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

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

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:

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

and

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

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

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

One might expect to see, instead,

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

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:

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

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

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

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

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

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:

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

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:

$$p_{12} = \frac{M^{j+\frac{1}{2}}_{i+3/2}\ {}^{n}p^{j+\frac{1}{2}}_{i+\frac{1}{2}} + M^{j+\frac{1}{2}}_{i+\frac{1}{2}}\ {}^{n}p^{j+\frac{1}{2}}_{i+3/2}}{M^{j+\frac{1}{2}}_{i+3/2} + M^{j+\frac{1}{2}}_{i+\frac{1}{2}}} \quad ,$$

$$p_{23} = \frac{M^{j+3/2}_{i+\frac{1}{2}}\ {}^{n}p^{j+\frac{1}{2}}_{i+\frac{1}{2}} + M^{j+\frac{1}{2}}_{i+\frac{1}{2}}\ {}^{n}p^{j+3/2}_{i+\frac{1}{2}}}{M^{j+3/2}_{i+\frac{1}{2}} + M^{j+\frac{1}{2}}_{i+\frac{1}{2}}} \quad ,$$

$$p_{34} = \frac{M^{j+\frac{1}{2}}_{i-\frac{1}{2}}\ {}^{n}p^{j+\frac{1}{2}}_{i+\frac{1}{2}} + M^{j+\frac{1}{2}}_{i+\frac{1}{2}}\ {}^{n}p^{j+\frac{1}{2}}_{i-\frac{1}{2}}}{M^{j+\frac{1}{2}}_{i-\frac{1}{2}} + M^{j+\frac{1}{2}}_{i+\frac{1}{2}}} \quad ,$$

$$p_{41} = \frac{M^{j-\frac{1}{2}}_{i+\frac{1}{2}}\ {}^{n}p^{j+\frac{1}{2}}_{i+\frac{1}{2}} + M^{j+\frac{1}{2}}_{i+\frac{1}{2}}\ {}^{n}p^{j-\frac{1}{2}}_{i+\frac{1}{2}}}{M^{j-\frac{1}{2}}_{i+\frac{1}{2}} + M^{j+\frac{1}{2}}_{i+\frac{1}{2}}} \quad .$$

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

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

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

$$(\text{New Total Energy}) = (\text{Old Total Energy}) + \sum_{\ell}\left(\frac{M_1 + M_2 + M_3 + M_4}{4}\right) Q_{\ell} \quad ,$$

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

$$u_L = \tilde{u} \quad ,$$
$$v_L = \tilde{v} \quad ,$$
$$\rho_L = {}^{n}\rho \quad ,$$
$$p_L = {}^{n}p \quad .$$

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

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

and

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

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

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

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.

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

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

(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 ${}^{n*}x$, not ${}^{n+1*}x$. 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 ${}^nx, {}^ny$ 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

${}^{n+1}r = {}^{n+1}x$ for cylindrical coordinates, or 1.0 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:

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

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

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

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

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

and the input constants allow these combinations:

$\alpha_o = 0$ 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

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

and

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

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

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

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

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

and

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

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:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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 swapt 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 LØØP and FILMCØ. LØØP 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. FILMCØ (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.

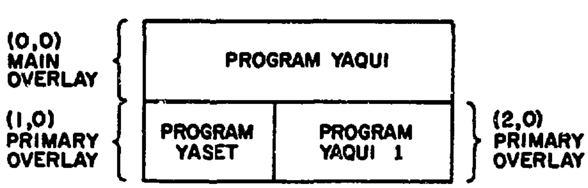


Fig. 4. The YAQUI 3 program overlay structure.

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: PARTMØV moves and plots particles, and REZØNE 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

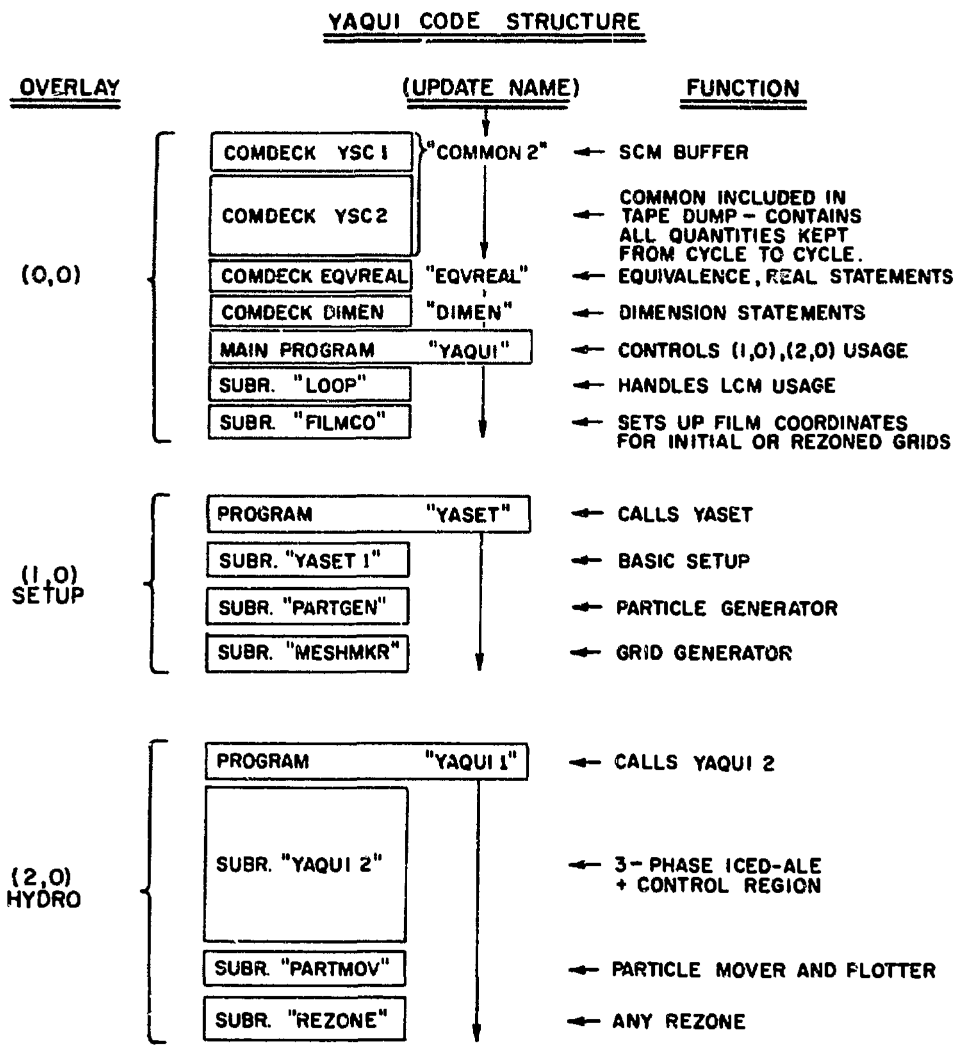


Fig. 5. Detailed breakdown of the YAQUI overlays, describing the functions of all sections and the UPDATE nomenclature.

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

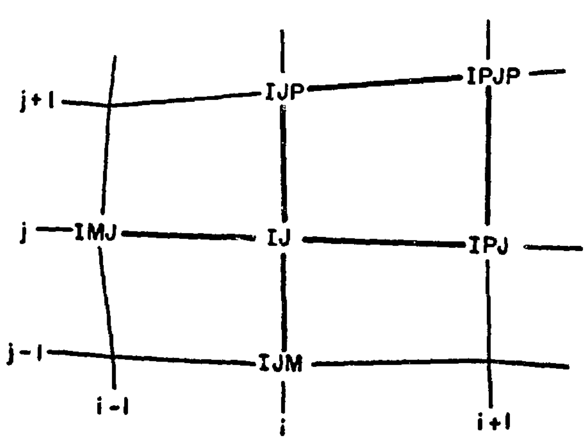


Fig. 6. Single subscript notation for vertex quantities.

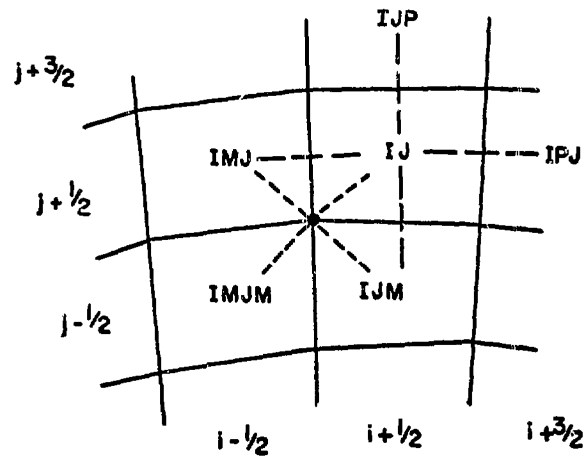


Fig. 7. Single subscript notation for cell quantities.

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

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

C. The Storage of Cell Data

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

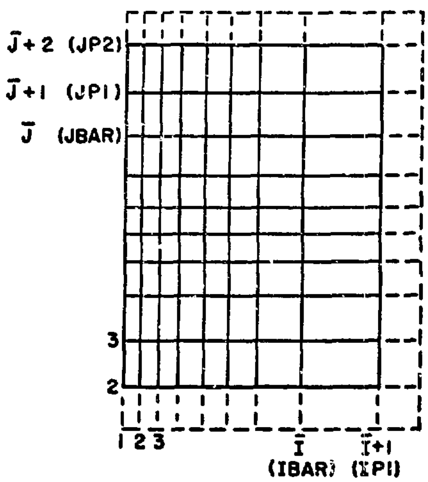


Fig. 8. An actual YAQUI mesh, corresponding to the conceptual mesh of Fig. 1, showing vertex notation. Fictitious cells are denoted by dashed lines.

inclusion of code to deal with other physical phenomena, such as magnetohydrodynamics, turbulence, and chemistry effects. Therefore, all cell data are maintained on LCM, and the code deals with only three rows of cells at a time in SCM processing. Clearly, the optimum procedure is that which requires the minimum number of read/write references to LCM. Accordingly, the cell variables are stored in an "interleaved" fashion, in which all the variables for a given cell are stored contiguously, followed by all the variables for the next cell, etc. (Contrast this with the traditional method of storing cell variables in individual $\bar{I}$ by $\bar{J}$ blocks for each variable. This scheme is appropriate when the computing code is designed for smaller meshes that will always fit in SCM.) In the version of YAQUI presented here, the full calculational cycle, including the optional particles, requires 35 different cell variables, but we are able to get by with using only 14 storage words per cell. This is made possible by retaining quantities during a cycle only as long as they are needed, and then using their storage words for other quantities. Figure 9 shows the allocation of the 14 storage words for a YAQUI cell in the (1,0) and (2,0) overlays. The ordering from left to right corresponds to the actual order in which quantities are calculated in the code. A black dot implies that the quantity currently in the given storage word is referenced to calculate the quantity specified at the top of the column. The open dots in the rezone imply that x, r, y, and V may be referenced, depending upon the particular rezone. Note that the vertex masses, M_v, and the cell volumes, V, are stored as reciprocals for increased computer efficiency. Because most references to M_v and V are in denominators of equations, the time-consuming divide operation is thus avoided much of the time.

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

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

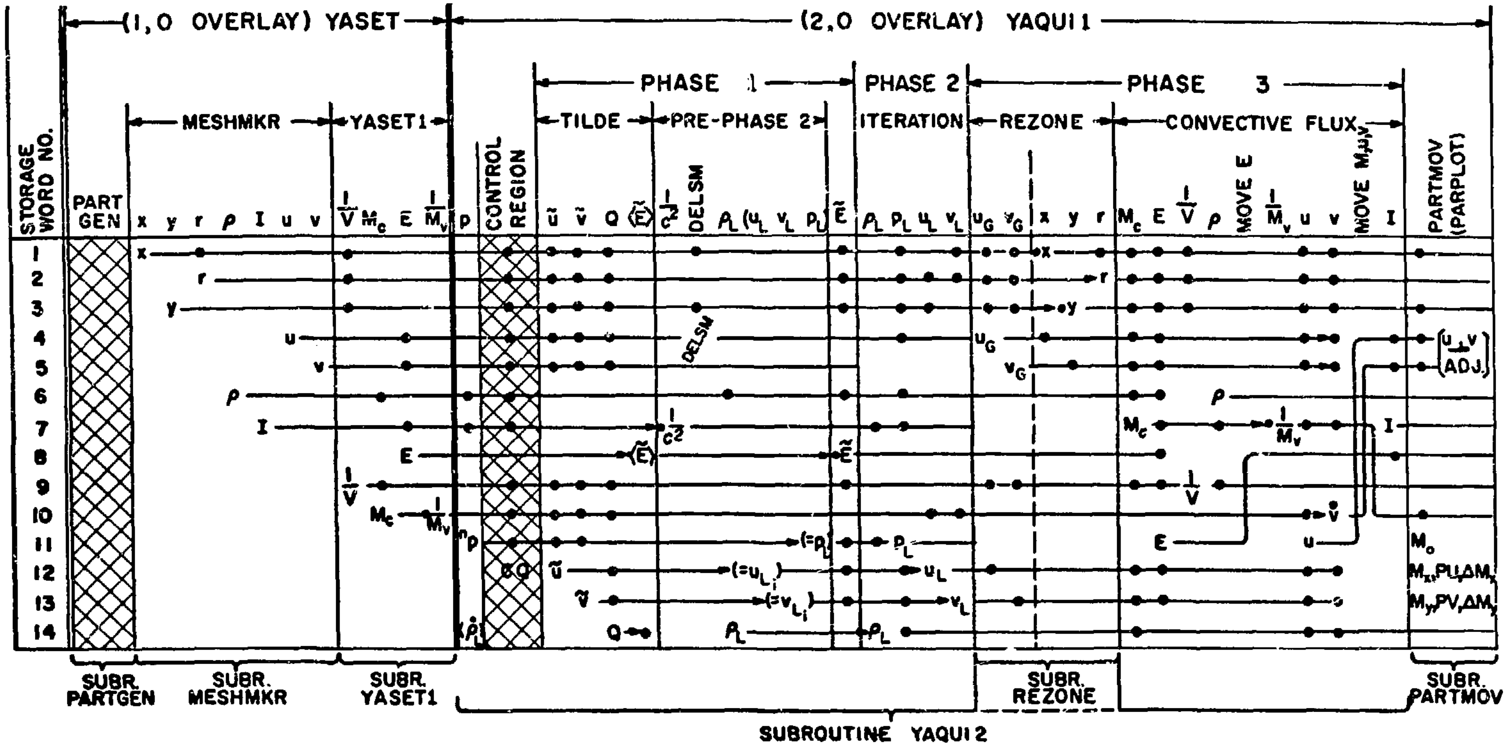
The contour quantity (CQ) in the control region denotes the field of some chosen cell variable for which a contour plot is drawn on microfilm. The quantities referred to in the PARTMØV subroutine are described in Sec. II E.

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

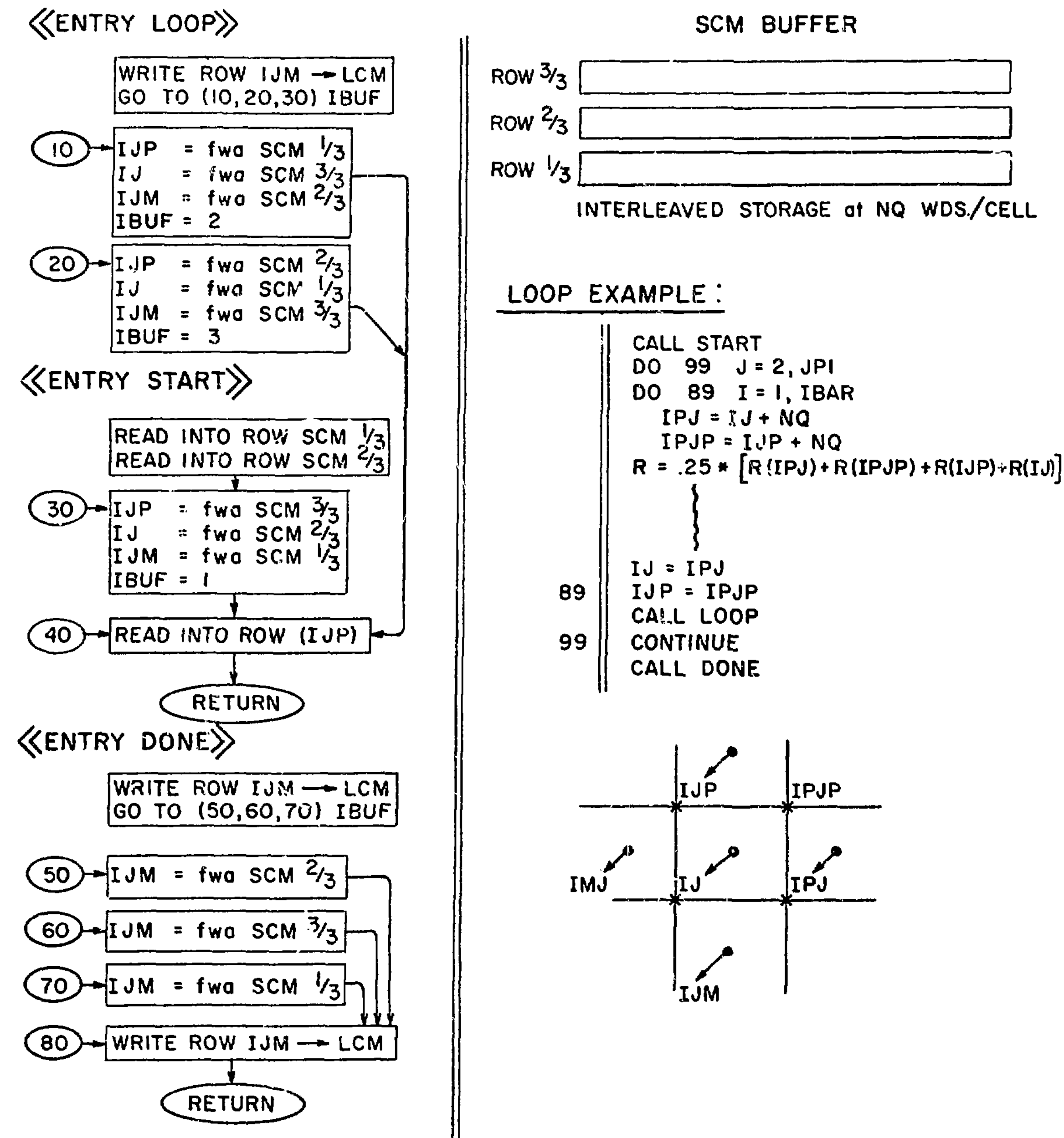
(4) LØØP returns to statement No. 99 in the sample calling program, and rows are processed similarly until all the rows specified by the J DØ-loop have been processed, at which time control passes to the "CALL DØNE" statement.

(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.



	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 $\bar{I} < 100$.

Other entry points in the LØØP subroutine, not shown in Fig. 10, allow the user to access any cell at random easily, and to perform DØ 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.

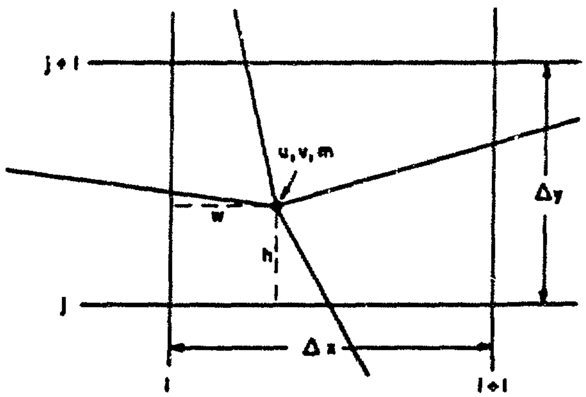


Fig. 11. Assigning YAQUI vertex quantities to the surrounding particle-grid cell.

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

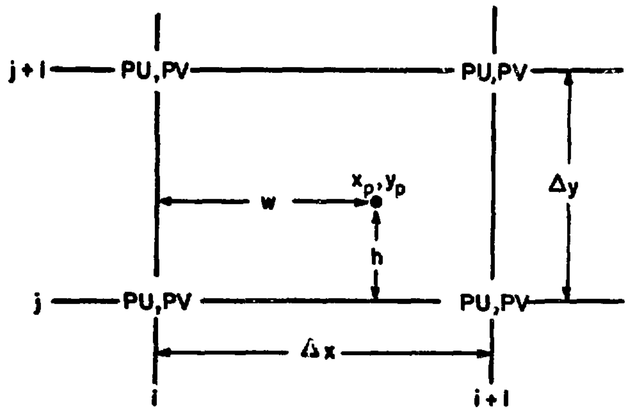


Fig. 12. Area weighting the particle p within the particle grid cell.

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

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

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

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

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

where m_p is the particle mass. This momentum change is distributed to the particle-grid vertices in much the same manner that u_{f1} 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

$$\left(\overline{\Delta M}_y\right)_p = m_p\ \delta t \eta_p \left(v_{f1} - {}^{n+1}v_p + v_{rand}\right) \quad .$$

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

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

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

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

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

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

Combining these two conditions, we obtain

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

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 $\text{JCEN} + \frac{\text{JUNF}}{2}$, and below $\text{JCEN} - \frac{\text{JUNF}}{2}$. 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.

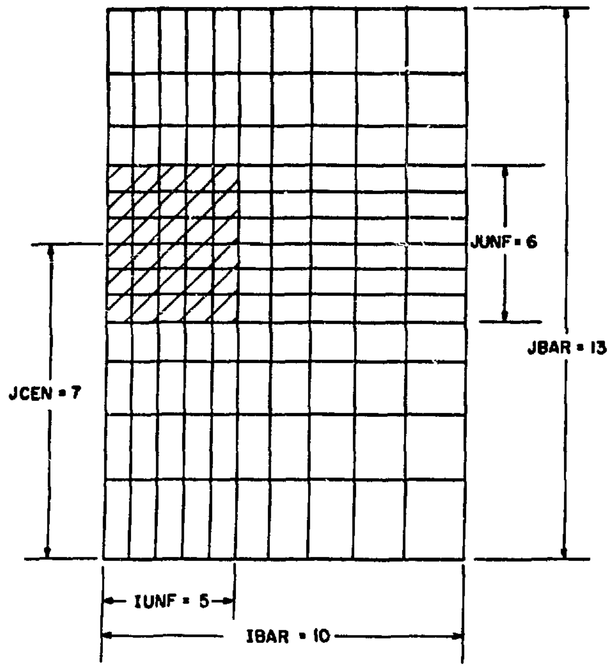


Fig. 13. An initial YAQUI grid with variable zoning. The region of uniform δr and δz zones (IUNF zones by JUNF zones, centered at JCEN zones up from the bottom) is denoted by shading.

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:

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

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

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

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

(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 underrelaxation 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 = μ_{input}, LAM = λ_{input} — Viscosity coefficients. Refer to Secs. I D and II F.

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.

<u>Card No. 4</u>: 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.

<u>Card No. 5</u>: 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 = $\bar{I}_{particles}$, JBP = $\bar{J}_{particles}$ } 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 } 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 = $YB_{particles}$, 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.

<u>Card No. 6</u>: 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.

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

Card No. 8: (DTØC(N), N=1,10)

(both are Format 10F8.3), where $DTØ_n$ specifies the problem-time output interval for both plots and prints. $DTØC_n$ specifies the time at which to change to $DTØ_{n+1}$. As an example, assume that t is in seconda, and that output is wanted every 1/4 sec for the first second, then every 1/2 sec up to 4 sec of problem time, then every 1 sec until t = 10, then every 2 sec until t = 50, and every 10 sec until t = 200. One would use

DTØ (1-10) = 0.25, 0.5, 1.0, 2.0, 10.0,

DTØC (1-10) = 1.0, 4.0, 10.0, 50.0, 200.0.

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

The above eight cards pertain to all YAQUI setups. They have defined a basic grid and provided the parameters for its use. What remains to be defined is the contents of this grid -- particle regions and fluid regions. Because these regions vary with the problem geometry, the number of cards in the rest of the input deck varies widely. The procedure beyond Card No. 8 is to define the particle regions first, if any exist, then finally to define fluid regions.

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

This is a particle-region card, to be expected only if IBP > 0 on Card No. 5. One card of the above format must be provided for each discrete particle region in the mesh. In the present version of PARTGEN, a particle region may be one of two shapes -- cylindrical or spherical (rectangular or circular in plane geometry). These two general shapes are shown in Fig. 14 with the named dimensions that specify them. The four dimensions (XC, YC, XD, and YD) are input in true distance units because the particle regions are not constrained to follow zone edges. For a cylinder, XC and YC specify the coordinates of the lower left corner, and XD and YD specify those of the upper right corner. For a sphere, YD must always be identically zero to enable PARTGEN to distinguish it from a cylinder. YC specifies the position of the center, measured up the axis, and XD specifies the sphere radius. Note that the y dimensions are defined relative to y = 0, not relative to the bottom of the mesh. (This was allowed so that particles might originally be placed outside an expanding mesh, but the user should not try to move any particle while it is still outside the mesh, as the present logic in 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.

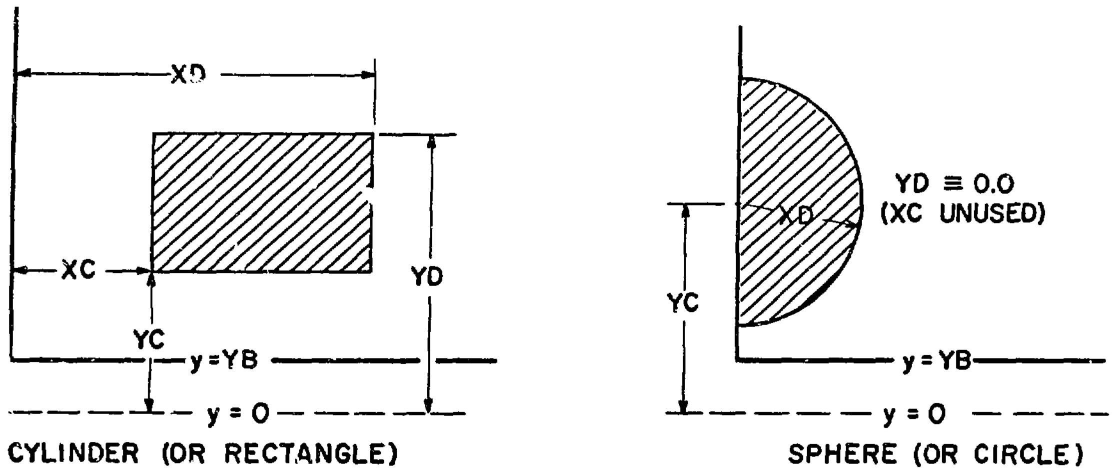


Fig. 14. Particle-region shapes available in PARTGEN. Note that the named dimensions are measured from x = 0 and y = 0.

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.

<u>Card No. 9</u>: if <u>no</u> particles are used. If particles <u>are</u> used, however, then this card follows the DRPAR = 0.0 card: NB, NR, NT, NL, UI, VI, RØ1, 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 = $\bar{J}$.

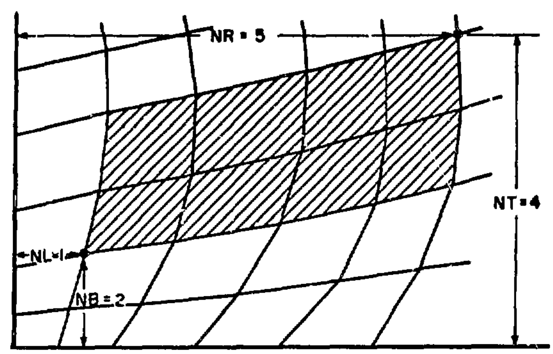


Fig. 15. The basic fluid region available in MESHMKR, defined by the number of zones over and up to two corners.

NB, NR, NT, NL — numbers of zones (integers only). Refer to Fig. 15.

UI = u_I, VI = 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

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

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 $\left(x_{i=IP1}/\bar{I}\right)$. 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 increments. 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 DTØ = 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 T2QMD 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 CØMMØN.	--
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)
CØLAMU	$(1 + \varepsilon)/(\lambda + 2\mu)$, 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
DTØ	Problem time interval between outputs (plots and prints).	I(S)
DTØC	Problem time at which to change to next DTØ in the set.	I(S)
DTØ16	$\delta t/16$.	2
DTØ2	$\delta t/2$.	2
DTØ4	$\delta t/4$.	2
DTØ8	$\delta t/8$.	2
DTPØS	δt possible for the cycle, but actual δt may be reduced to adjust to output time.	2
DTV	δt_v, competing δt based on Phase-1 viscous-stress considerations.	2
DT8	$\delta t{*}8$.	2
DZ	δz, the cell size in the axial direction if uniformly zoned.	I(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 CØMMØN because of ENTRY SETIJ in LØØP.	--
IBAR	$\bar{I}$, the number of interior fluid zones in the r direction.	I(0)
IBP	$\bar{I}_p$, the number of particle-grid zones in the r direction.	I(S)
IBP1	$\bar{I}_p$+1, index of rightmost column of particle-grid vertices.	P
ICØLØR	= 1 for color movie, = 0 for black and white processing.	I(S)
IDTØ	Index for DTØ and DTØC tables.	S,2
IJ	Index for cell (i,j), initialized by LØØP.	L
IJM	Index for cell (i,j-1), initialized by LØØP.	L
IJP	Index for cell (i,j+1), initialized by LØØP.	L
IJPS	Index for cell (i,j+1), saved for later reference to cell (1,j+1).	L
IMØME3	IMØMX*1000, forces resetting of J in statement No. 2020 in PARTMØV if IMØMX = 1.	P
IMØMX	= 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	LØCF(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 DØ 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 CØMMØN because of ENTRY R1RØW and W1RØW in LØØP.	--
JBAR	$\bar{J}$, the number of interior fluid zones in the z direction.	I(0)
JBP	$\bar{J}_p$, the number of particle-grid zones in the z direction.	I(S)
JBP2	$\bar{J}_p$+2, index of the topmost row of particle-grid vertices.	P
JCEN	Number of zones up to center of uniform-grid region.	I(0)
JM10	$\bar{J}$-10. In usual large grids, this row is down from the top.	S
JM14	$\bar{J}$-14. In usual large grids, this row is down from the top.	S
JP1	$\bar{J}$+1, index of topmost row of interior zones.	S
JP2	$\bar{J}$+2, index of topmost row of grid vertices.	S
JP4	$\bar{J}$+4, index used in reversed DØ loops and in LCM clearing.	S
JP4Ø2	($\bar{J}$+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)
JUNFØ2	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 > 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

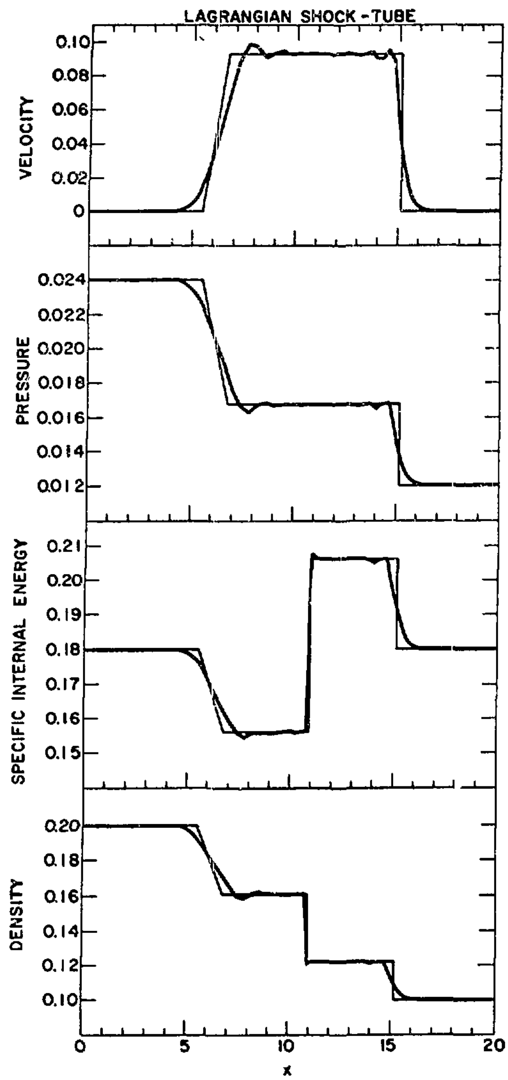


Fig. 16. One-dimensional YAQUI Lagrangian calculation of a 2:1-density-ratio shock tube.

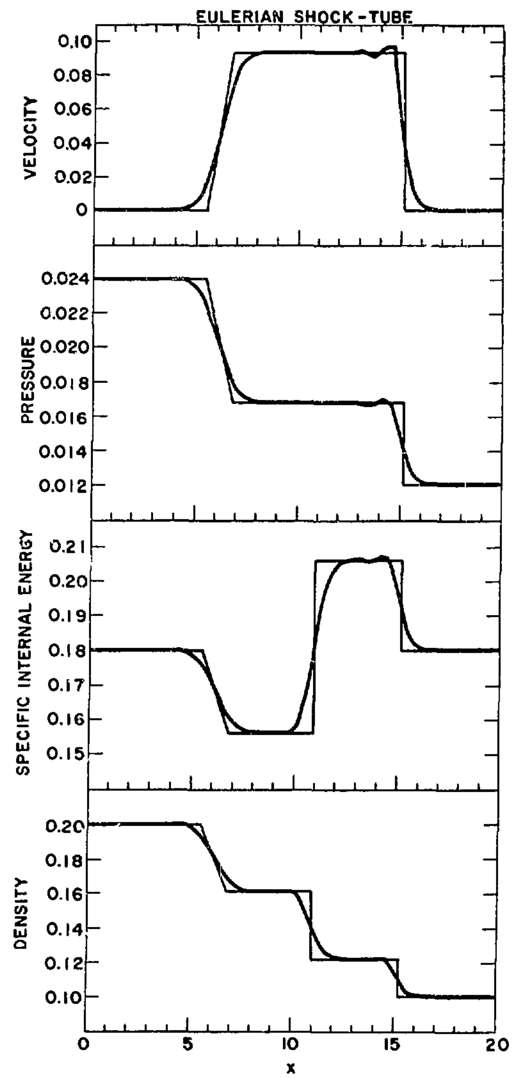


Fig. 17. One-dimensional YAQUI Eulerian calculation of a 2:1-density-ratio shock tube.

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.

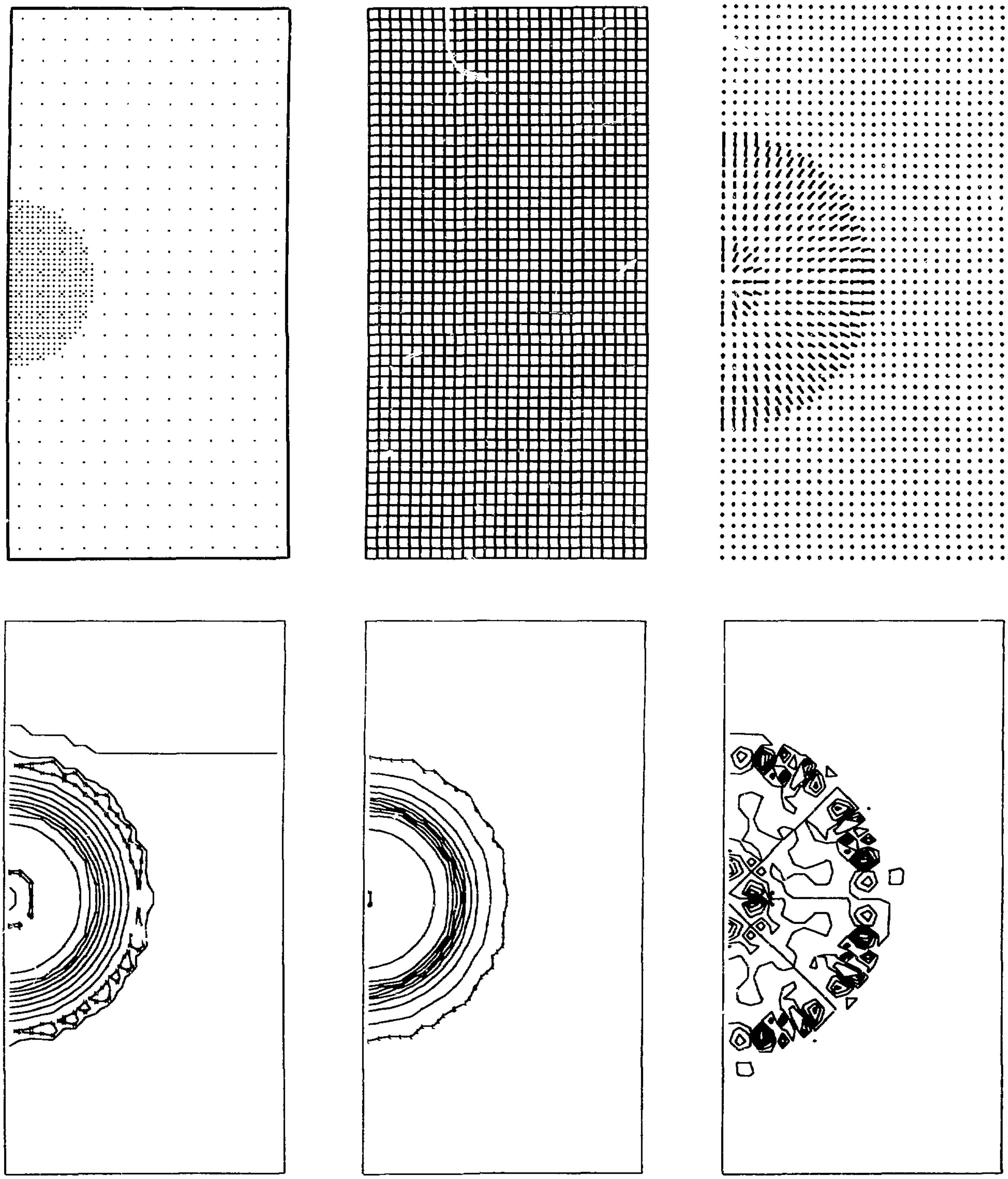


Fig. 18. YAQUI low-altitude explosion calculation at t = 0. The six plots represent the marker particles, computing mesh, and velocity vectors (top) and isopycnic, isotherm, and vorticity contour plots (bottom).

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

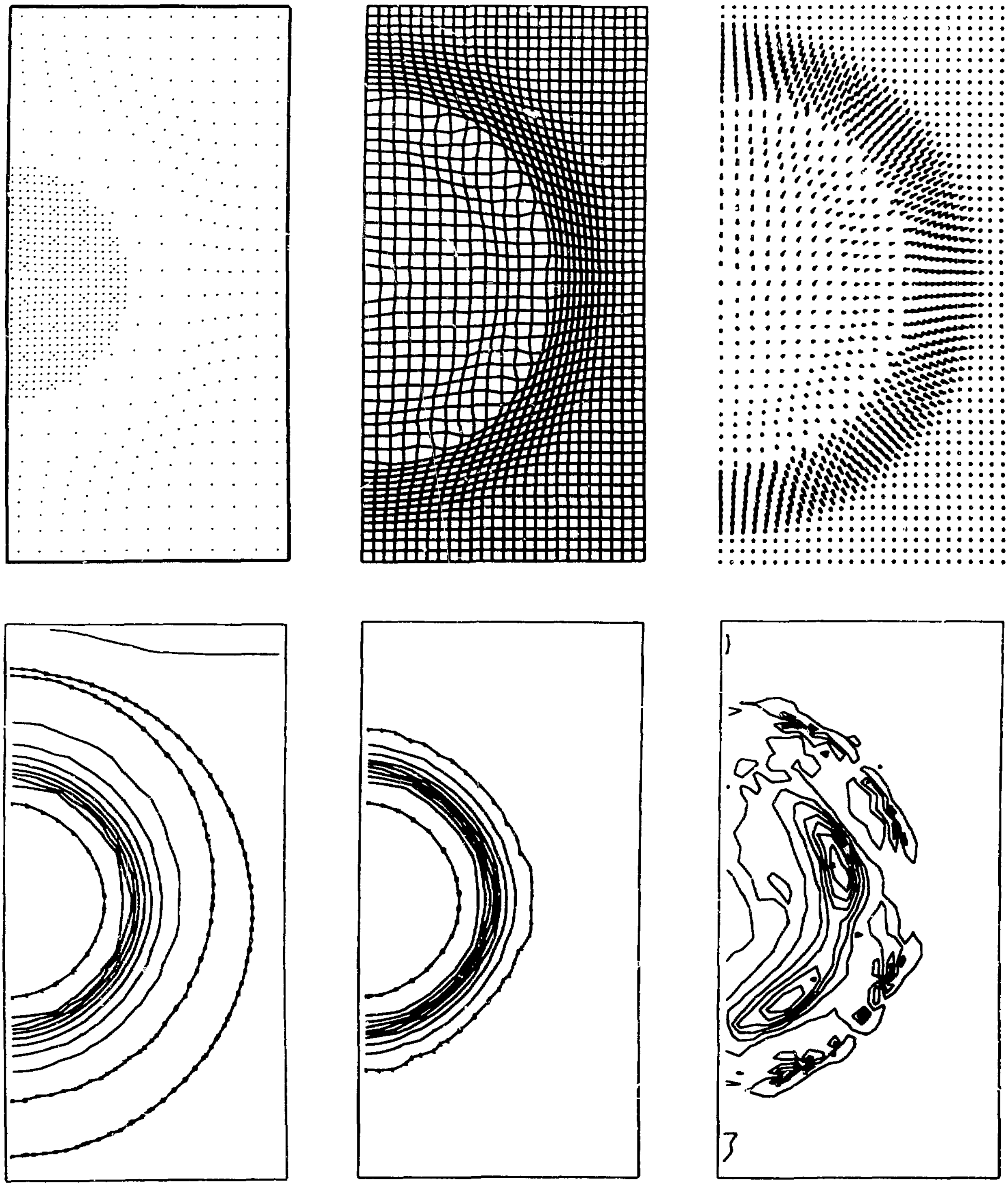


Fig. 19. A Lagrangian calculation at t = 1 sec of the problem setup of Fig. 18.

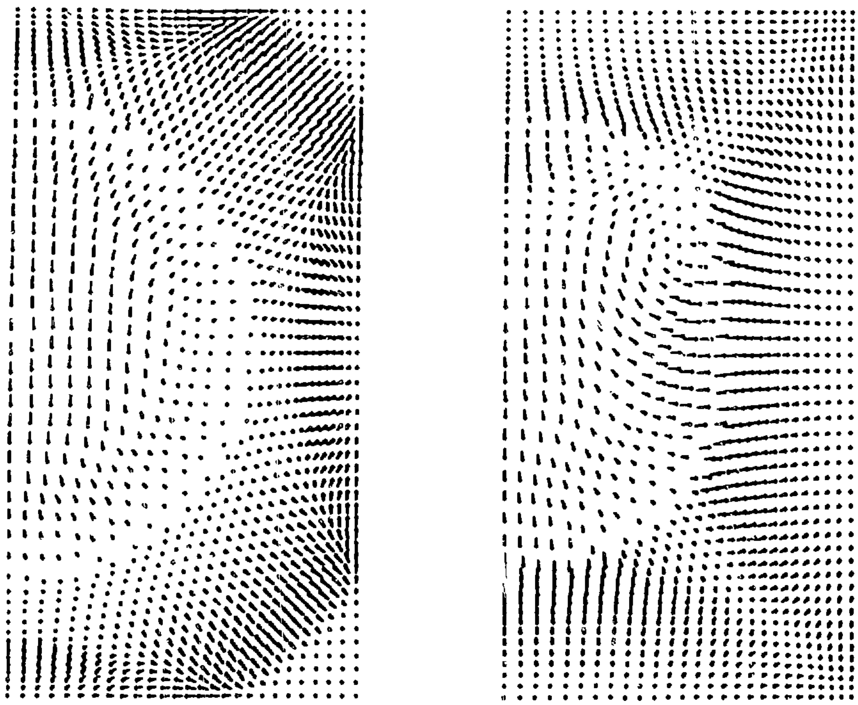


Fig. 20. Velocity-vector plots at t = 2 and t = 3 sec of the problem shown in Fig. 19, showing shock reflection from the boundaries.

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

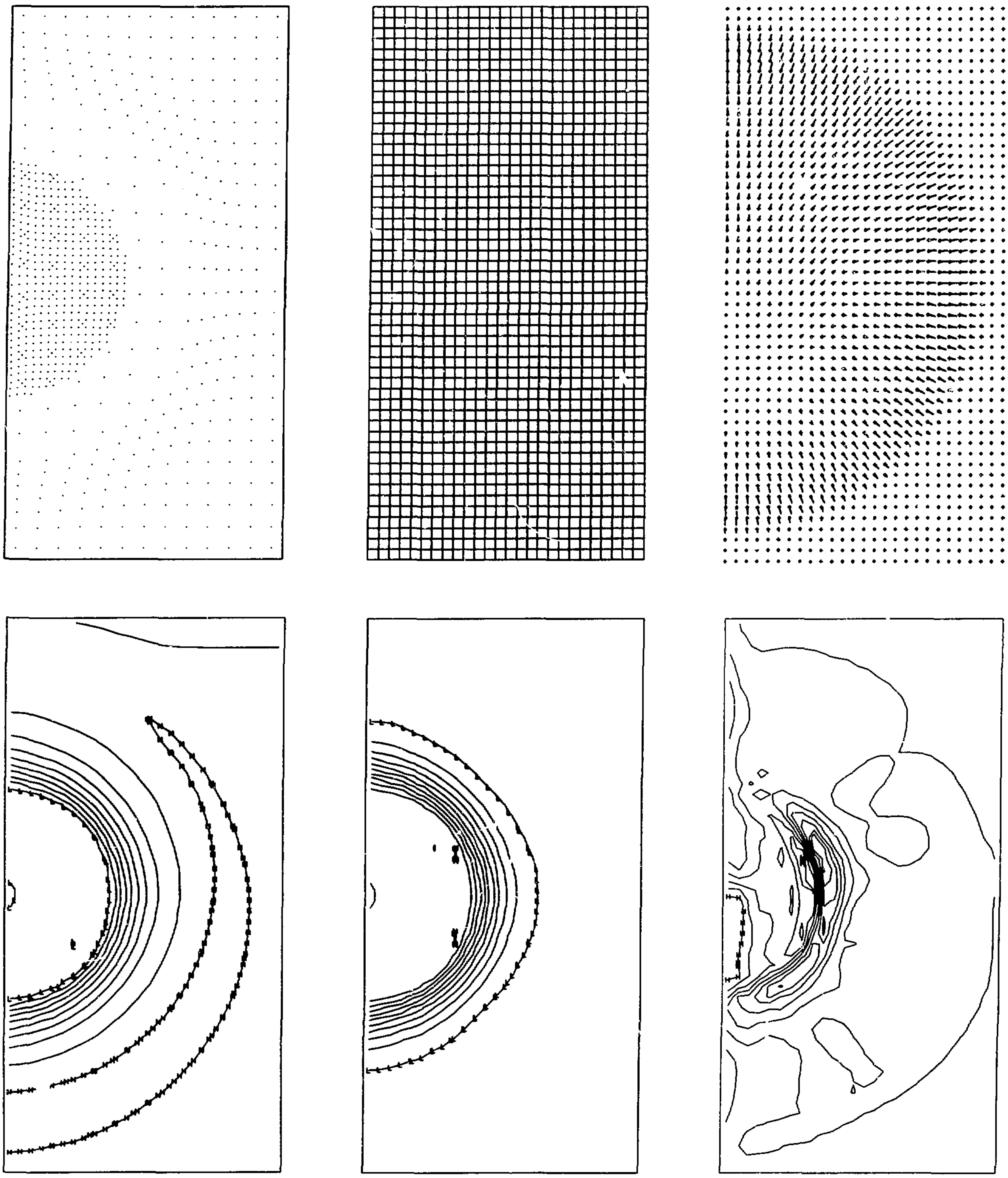


Fig. 21. An Eulerian calculation at t = 1 sec of the problem setup of Fig. 18.

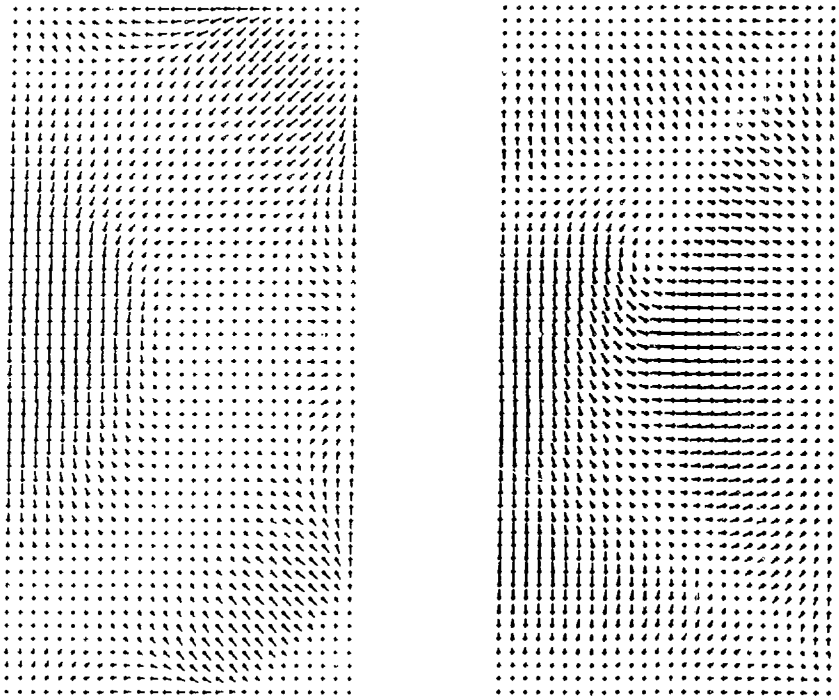


Fig. 22. Velocity-vector plots at t = 2 sec and t = 3 sec of the problem shown in Fig. 21, showing shock reflection from the boundaries.

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.

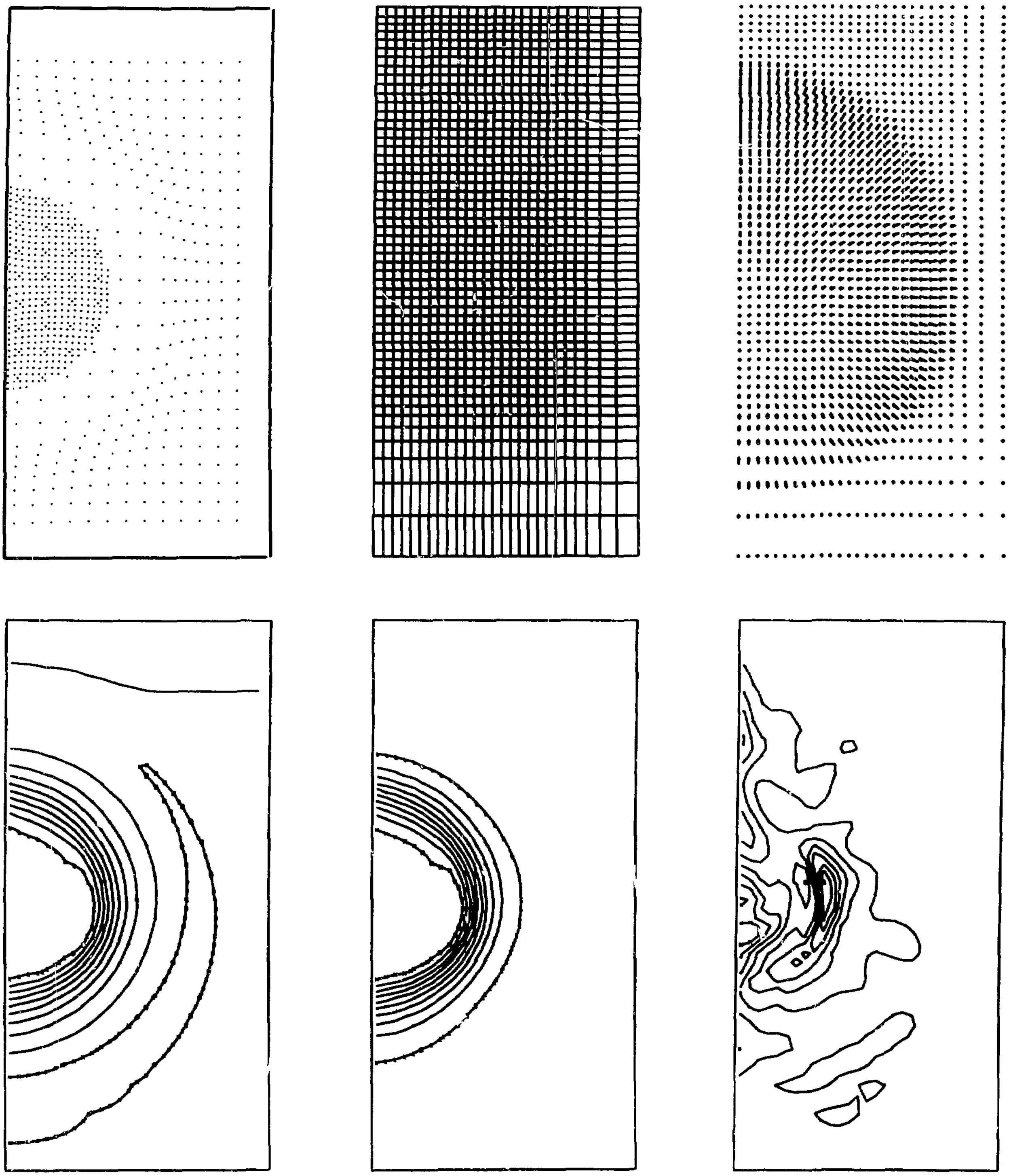


Fig. 23. A REZØNE calculation at t = 1 sec of the problem setup of Fig. 18.

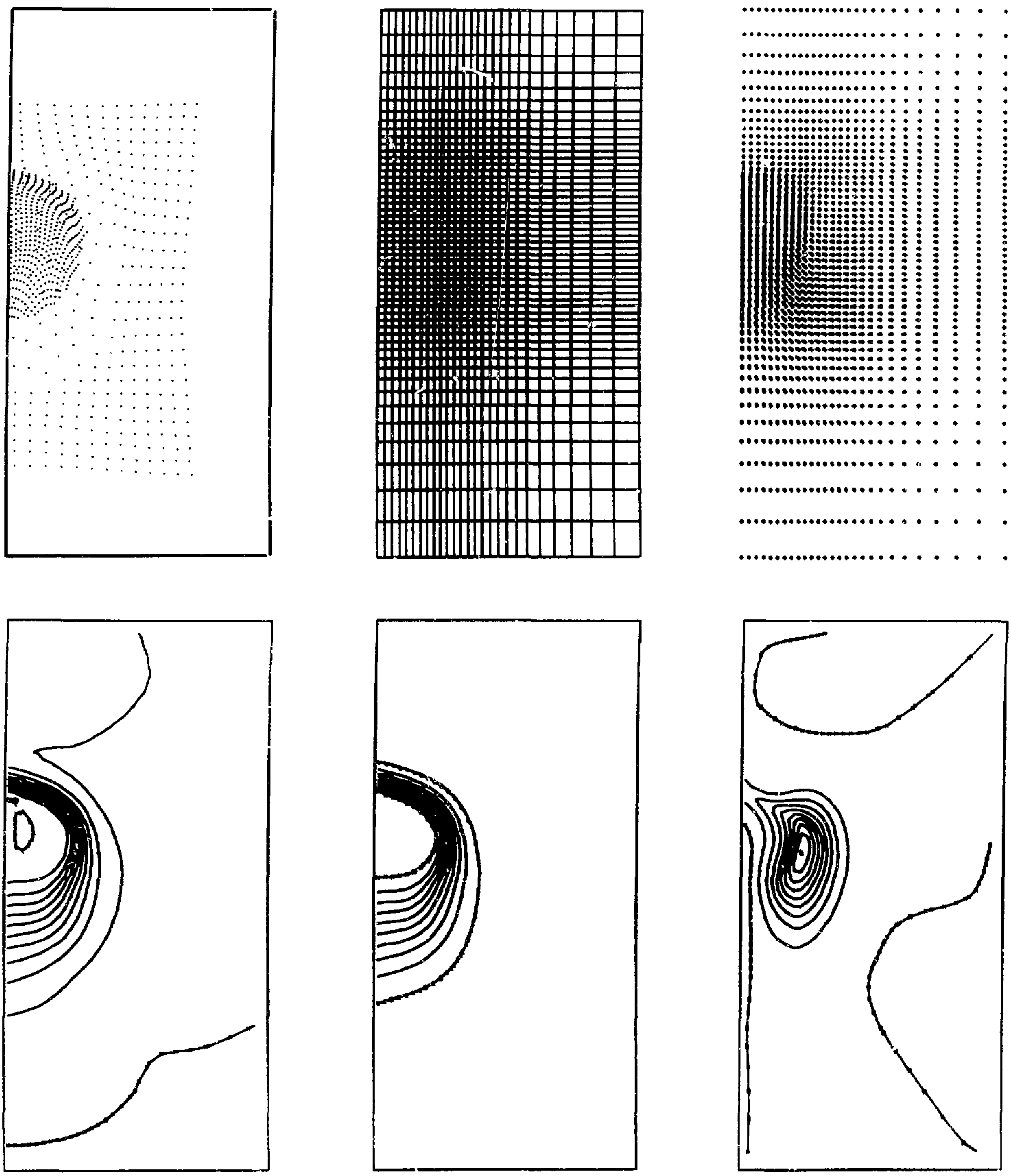


Fig. 24. The REZØNE calculation of the problem of Figs. 18 and 23 at t = 5 sec.

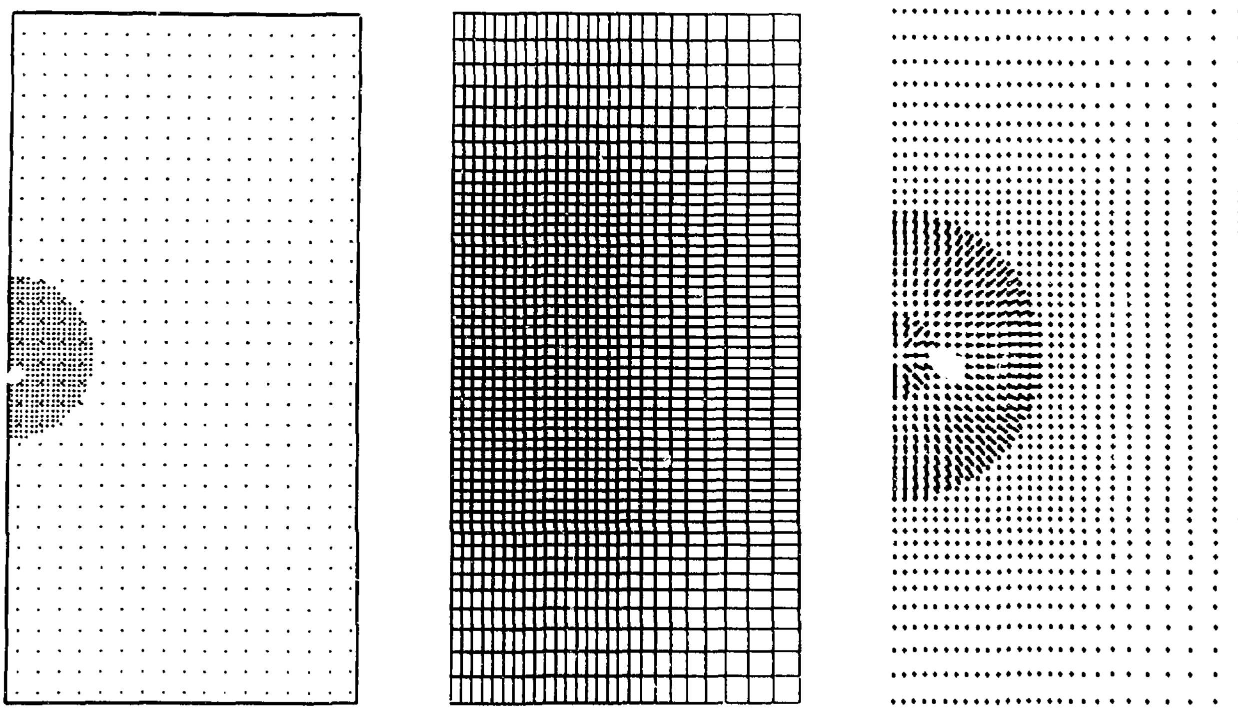


Fig. 25. A YAQUI setup with initial variable zoning for the problem shown in Fig. 18.

V. REFERENCES

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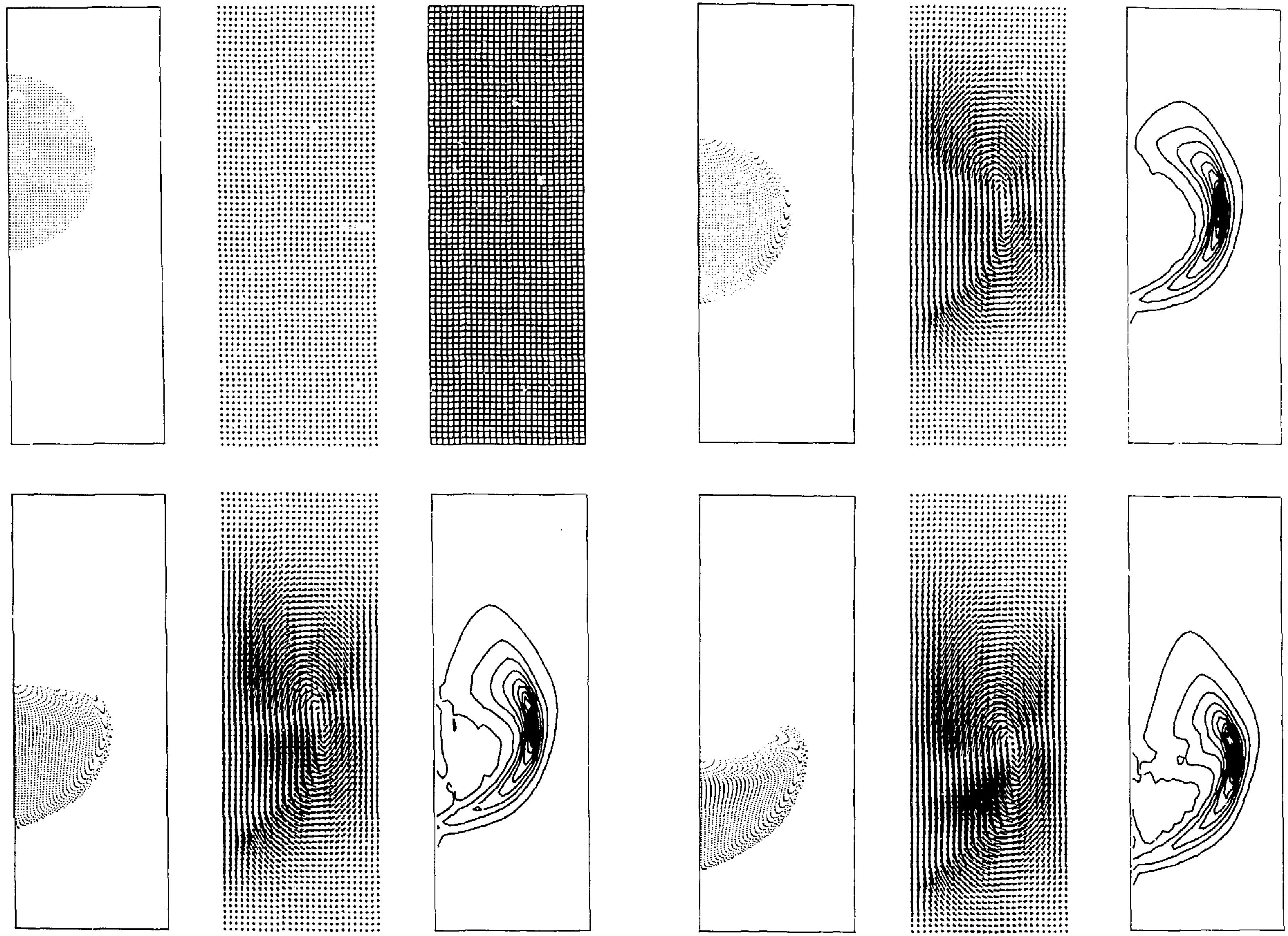

Fig. 26. YAQUI particle-fluid momentum-exchange calculation.

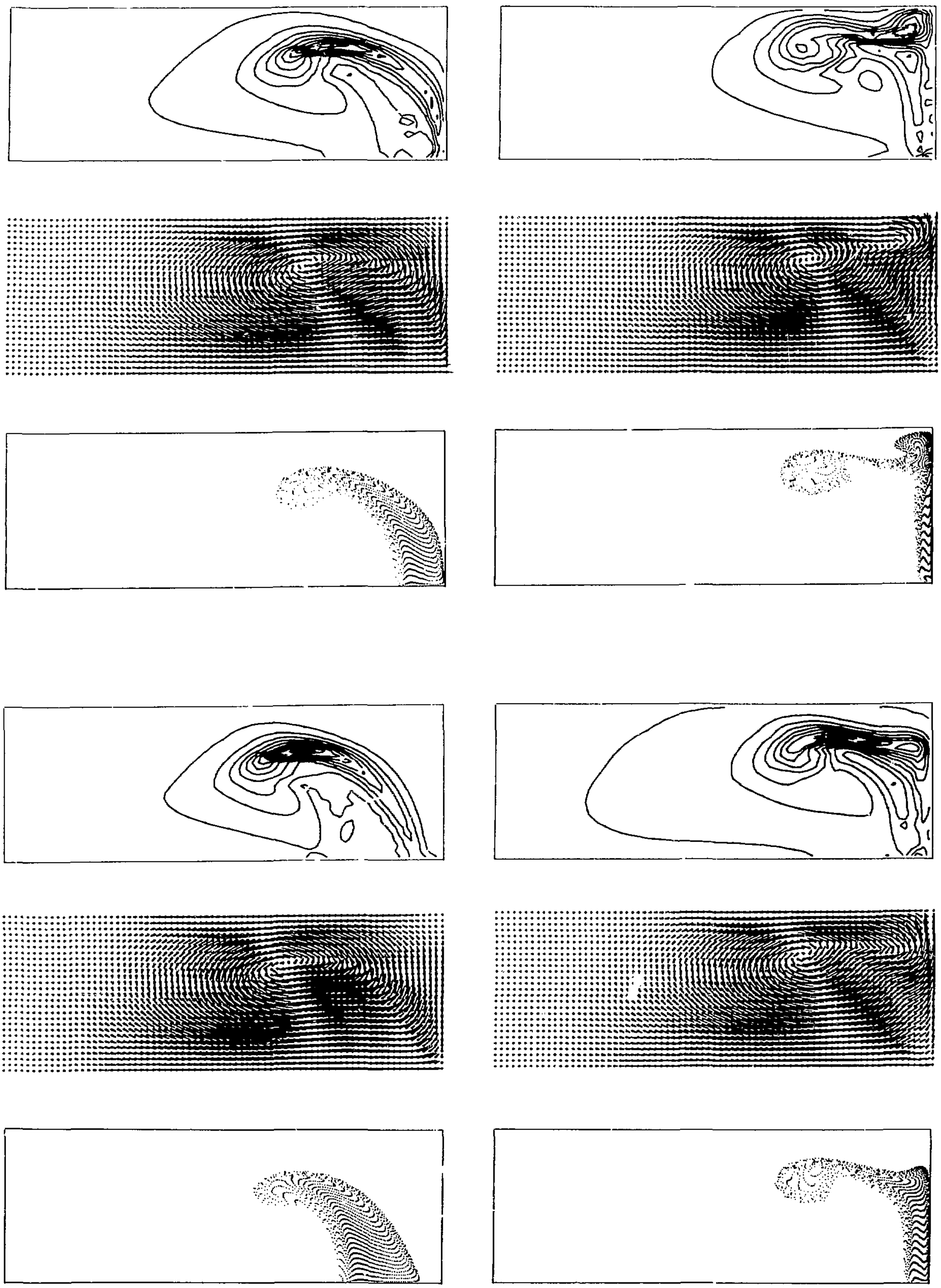

Fig. 26 (Contd)

```
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   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.
    ISP=  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
     406 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
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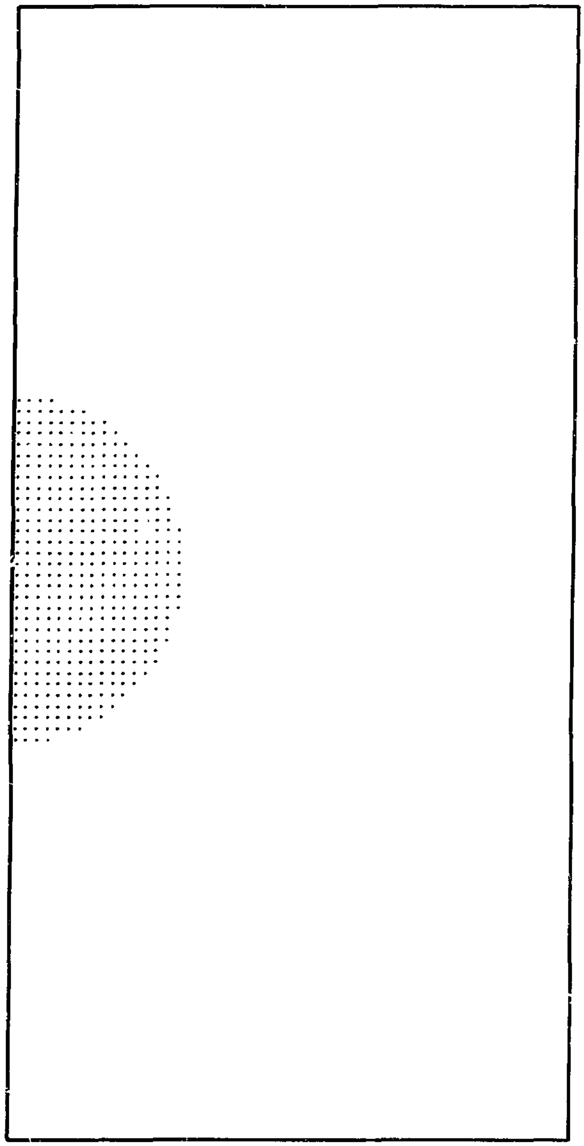
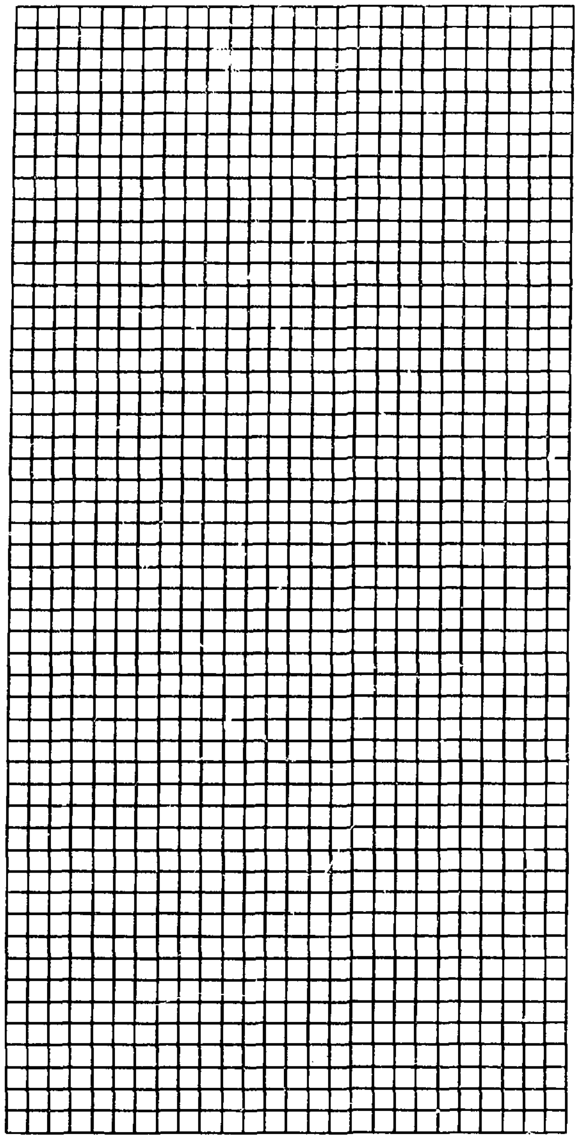


PARTICLES
PDR= 1.00000E+00 PDZ= 1.00000E+00 PXR= 2.60000E+01 PYB= 0. PYT= 5.20000E+01
T3AAA IBA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAAIGB 032272-3) 110872-1 T= 0. CYCLE= 0



ZONES
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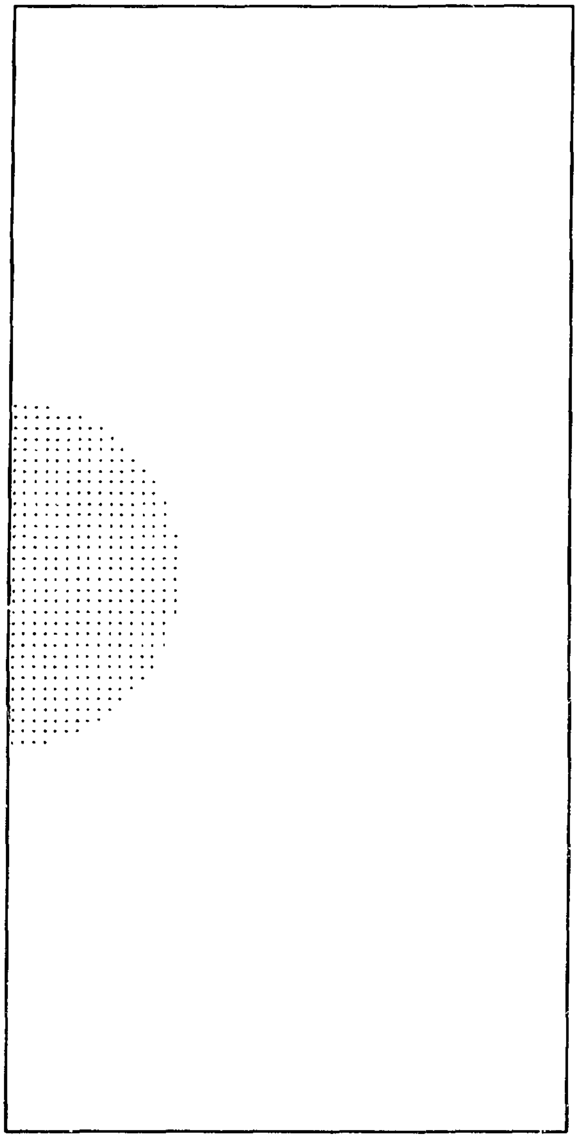
T3AAA 18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 0. CYCLE= 0

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

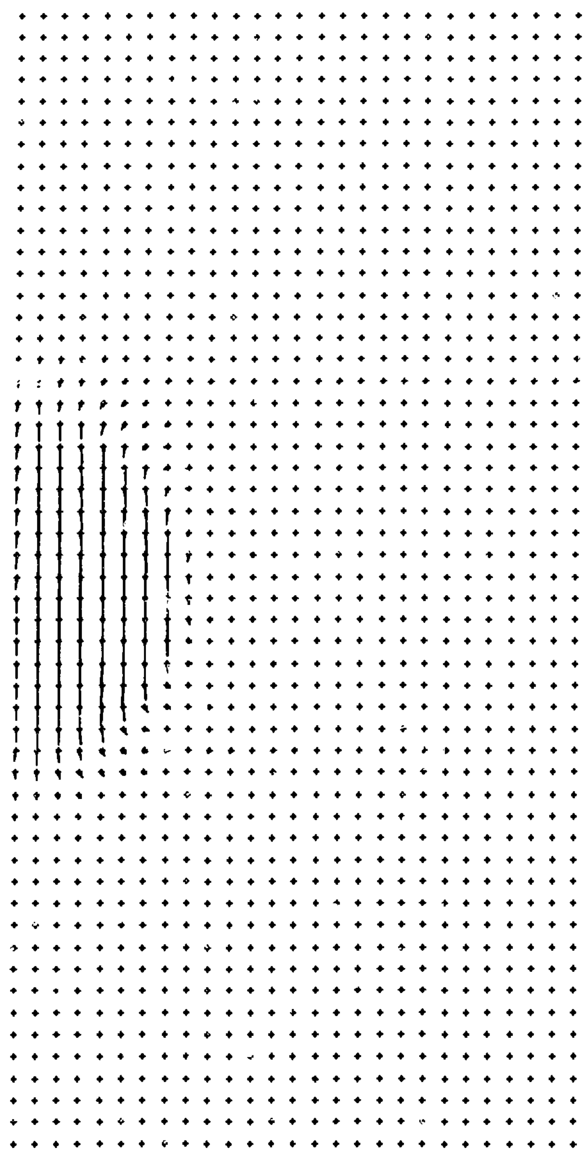
I	J	X	Y	U	V	SIE	RHO	VOL	D	M	P
8,	26	7.0000E+00	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	7.5000E+00	0.	7.0000E+00	0.
9,	26	8.0000E+00	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	8.5000E+00	0.	8.0000E+00	0.
10,	26	9.0000E+00	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	9.5000E+00	0.	9.0000E+00	0.
11,	26	1.0000E+01	2.4000E+01	0.	0.	1.0000E+00	1.0000E+00	1.0500E+01	0.	1.0000E+01	0.
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	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.



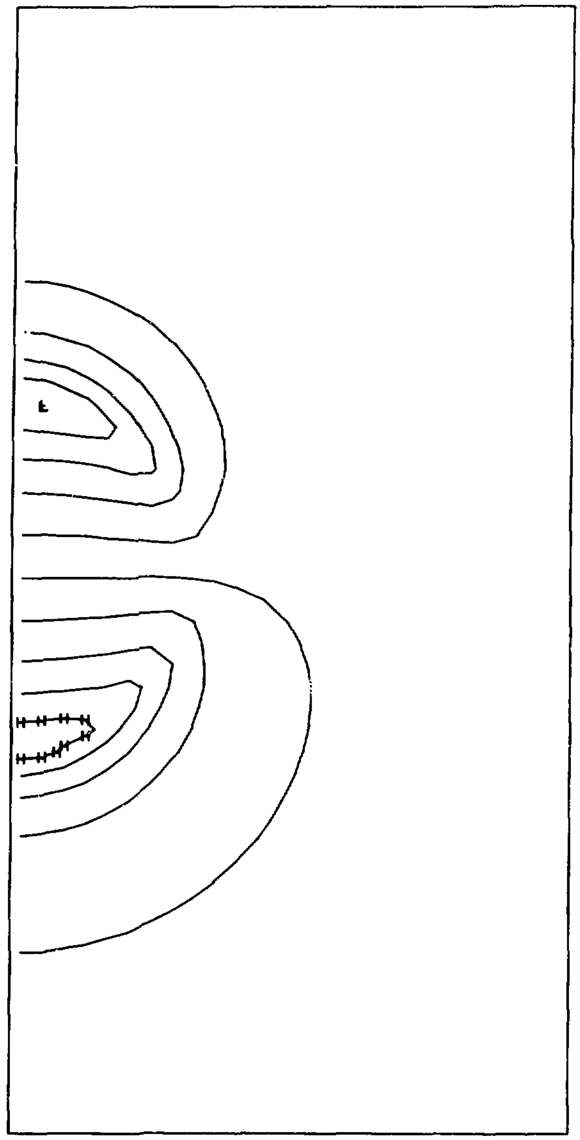
PARTICLES
POR= 1.00000E+00 PDZ= 1.00000E+00 PXR= 2.60000E+01 PYB= 0.   PYT= 5.20000E+01
T3AAA   18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAAIGB 032272-3)   110872-1   T= 1.00000E+00 CYCLE=   7



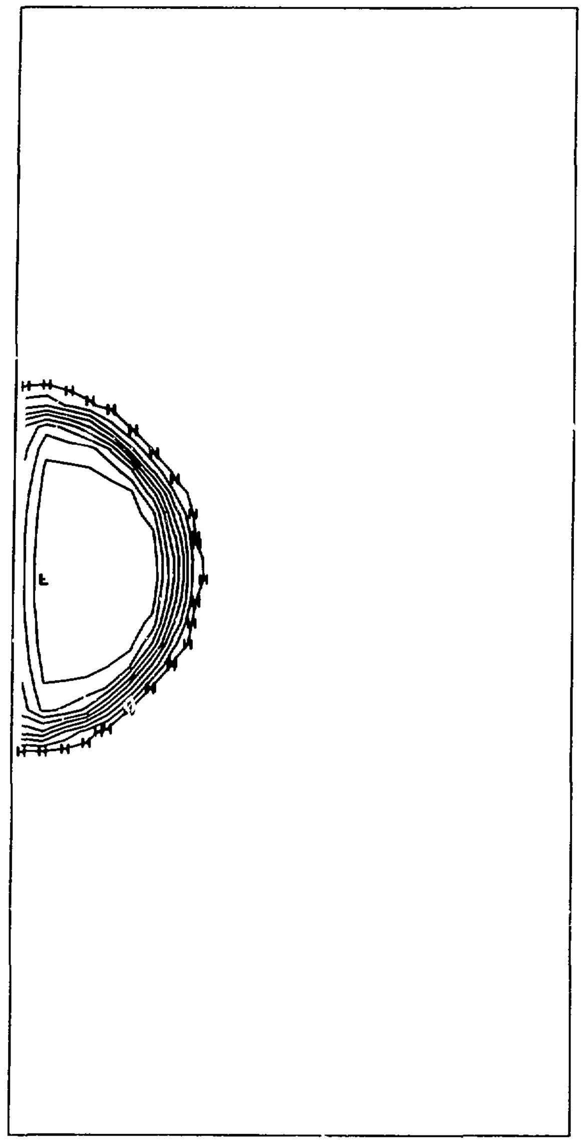
VELOCITY VECTORS

VMAX= 2.96442E-01

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



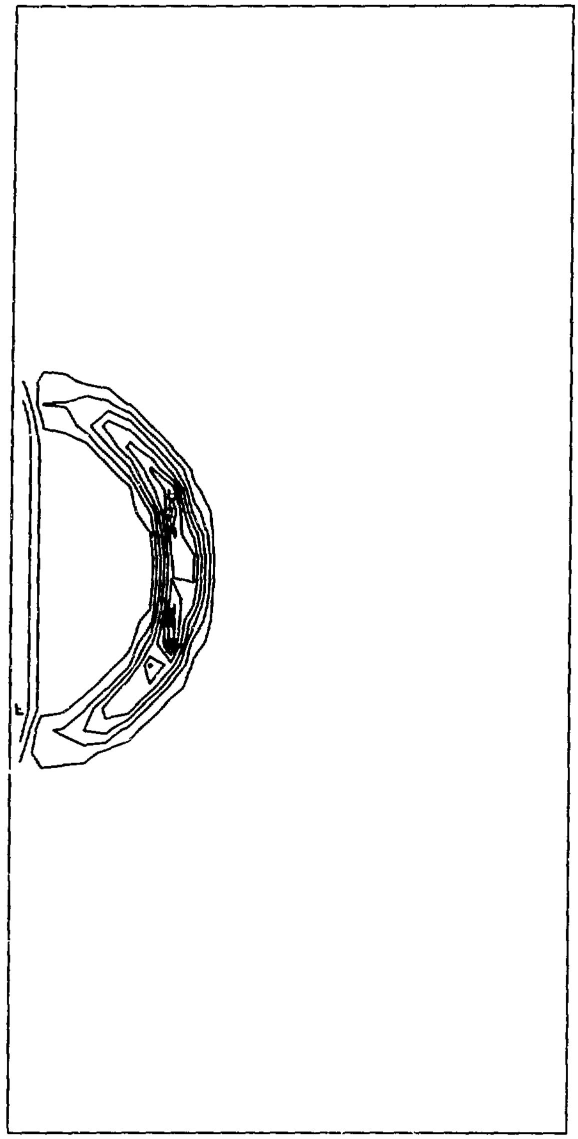
ISOPYCNICS
MIN= 9.90697E-01 MAX= 1.00900E+00 L= 9.90697E-01 H= 1.00807E+00 DQ= 1.93073E-03
T3AAA 1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 110872-1 T= 1.00000E+00 CYCLE= 7



ISOTHERMS

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

T3AAA 18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA:G8 032272-3) 110872-1 T= 1.00000E+00 CYCLE= 7



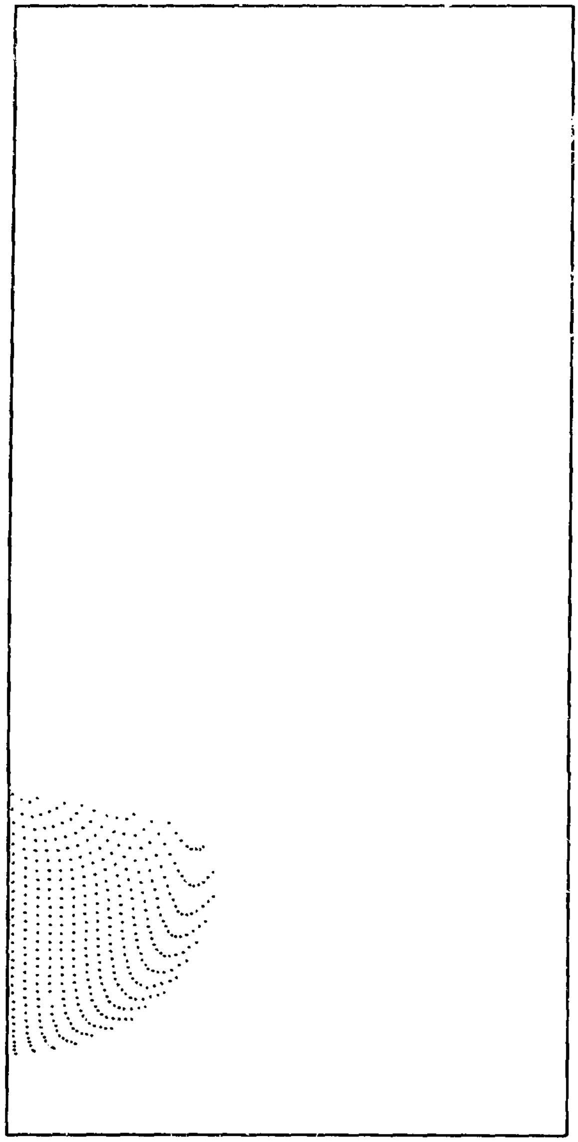
VORTICITY

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

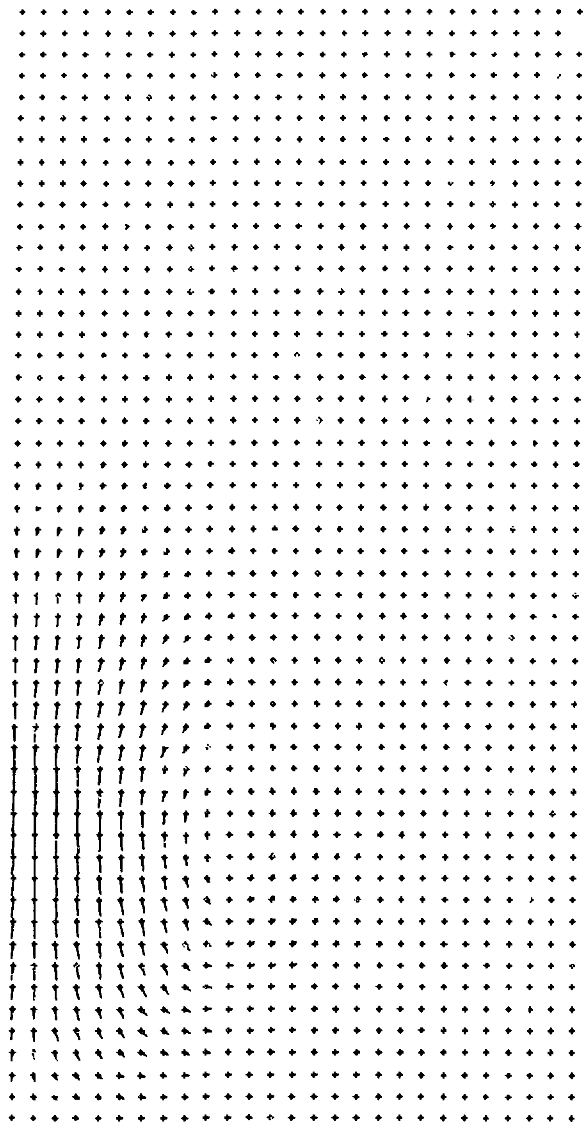
T3AAA 1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 11C872-1 T= 1.00000E+00 CYCLE= 7

T3AAA 18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1G8 032272-3) 110872-1 T= 1.0000E+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
14,	26	1.3000E+01	2.4000E+01	4.0581E-03	3.9648E-03	1.0000E+00	1.0002E+00	1.3500E+01	-3.8710E-04	1.3004E+01	1.7033E-02
15,	26	1.4000E+01	2.4000E+01	2.5859E-03	2.5520E-03	1.0000E+00	1.0001E+00	1.4500E+01	-2.8930E-04	1.4003E+01	1.2253E-02
16,	26	1.5000E+01	2.4000E+01	1.6565E-03	1.6012E-03	1.0000E+00	1.0001E+00	1.5500E+01	-2.0397E-04	1.5002E+01	8.4277E-03
17,	26	1.6000E+01	2.4000E+01	1.0698E-03	1.0108E-03	1.0000E+00	1.0001E+00	1.6500E+01	-1.4646E-04	1.6001E+01	6.3515E-03
18,	26	1.7000E+01	2.4000E+01	6.6491E-04	5.9648E-04	1.0000E+00	1.0000E+00	1.7500E+01	-9.4129E-05	1.7001E+01	4.4433E-03
19,	26	1.8000E+01	2.4000E+01	4.2952E-04	3.6599E-04	1.0000E+00	1.0000E+00	1.8500E+01	-6.4694E-05	1.8001E+01	3.4923E-03
20,	26	1.9000E+01	2.4000E+01	2.7631E-04	2.0612E-04	1.0000E+00	1.0000E+00	1.9500E+01	-5.8896E-05	1.9001E+01	2.2837E-03
21,	26	2.0000E+01	2.4000E+01	1.7590E-04	1.2050E-04	1.0000E+00	1.0000E+00	2.0500E+01	-4.8841E-05	2.0000E+01	1.4581E-03
22,	26	2.1000E+01	2.4000E+01	1.1380E-04	5.7997E-05	1.0000E+00	1.0000E+00	2.1500E+01	-4.9223E-05	2.1000E+01	8.3332E-04
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
25,	26	2.4000E+01	2.4000E+01	1.2598E-10	3.0704E-12	1.0000E+00	1.0000E+00	2.4500E+01	-3.2800E-10	2.4000E+01	4.6107E-09
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
2,	27	1.0000E+00	2.5000E+01	-2.9517E-04	-2.9595E-01	9.7236E-01	1.0004E+00	1.5000E+00	-7.1263E-04	1.0008E+00	3.5199E-02
3,	27	2.0000E+00	2.5000E+01	-5.9180E-04	-2.9586E-01	9.7244E-01	1.0004E+00	2.5000E+00	-7.0650E-04	2.0017E+00	3.5792E-02
4,	27	3.0000E+00	2.5000E+01	-8.3517E-04	-2.9501E-01	9.7257E-01	1.0004E+00	3.5000E+00	-7.1226E-04	3.0026E+00	3.5994E-02
5,	27	4.0000E+00	2.5000E+01	-1.2579E-03	-2.9375E-01	9.7276E-01	1.0004E+00	4.5000E+00	-7.2403E-04	4.0035E+00	3.7266E-02
6,	27	5.0000E+00	2.5000E+01	-1.3142E-03	-2.9187E-01	9.7306E-01	1.0004E+00	5.5000E+00	-7.5051E-04	5.0046E+00	3.7192E-02
7,	27	6.0000E+00	2.5000E+01	-2.7082E-03	-2.9012E-01	9.7308E-01	1.0004E+00	6.5000E+00	-8.7686E-04	6.0058E+00	4.1218E-02
8,	27	7.0000E+00	2.5000E+01	-6.0943E-04	-2.8739E-01	9.8371E-01	1.0004E+00	7.5000E+00	-1.9334E-04	7.0070E+00	3.6000E-02
9,	27	8.0000E+00	2.5000E+01	7.8593E-03	-1.2689E-01	9.9727E-01	1.0003E+00	8.5000E+00	4.9862E-05	8.0073E+00	3.2829E-02
10,	27	9.0000E+00	2.5000E+01	1.2810E-02	2.7868E-02	9.9986E-01	1.0003E+00	9.5000E+00	-3.1845E-04	9.0063E+00	2.5339E-02
11,	27	1.0000E+01	2.5000E+01	9.4904E-03	1.9209E-02	9.9993E-01	1.0002E+00	1.0500E+01	-3.0268E-04	1.0005E+01	1.5377E-02
12,	27	1.1000E+01	2.5000E+01	5.3329E-03	1.1866E-02	9.9997E-01	1.0001E+00	1.1500E+01	-2.0272E-04	1.1003E+01	1.0709E-02
13,	27	1.2000E+01	2.5000E+01	3.3904E-03	7.3901E-03	9.9999E-01	1.0001E+00	1.2500E+01	-1.5791E-04	1.2002E+01	7.2363E-03
14,	27	1.3000E+01	2.5000E+01	2.0998E-03	4.6773E-03	1.0000E+00	1.0001E+00	1.3500E+01	-1.3187E-04	1.3002E+01	5.7312E-03
15,	27	1.4000E+01	2.5000E+01	1.3434E-03	2.9204E-03	1.0000E+00	1.0000E+00	1.4500E+01	-7.9575E-05	1.4001E+01	4.0369E-03
16,	27	1.5000E+01	2.5000E+01	8.5737E-04	1.8475E-03	1.0000E+00	1.0000E+00	1.5500E+01	-7.3828E-05	1.5001E+01	3.5379E-03
17,	27	1.6000E+01	2.5000E+01	5.4414E-04	1.1233E-03	1.0000E+00	1.0000E+00	1.6500E+01	-1.5073E-05	1.6001E+01	2.4859E-03
18,	27	1.7000E+01	2.5000E+01	3.5296E-04	7.0730E-04	1.0000E+00	1.0000E+00	1.7500E+01	-4.7181E-05	1.7001E+01	2.4012E-03
19,	27	1.8000E+01	2.5000E+01	2.0440E-04	4.0366E-04	1.0000E+00	1.0000E+00	1.8500E+01	5.8972E-05	1.8000E+01	7.9734E-04
20,	27	1.9000E+01	2.5000E+01	1.5145E-04	2.1652E-04	1.0000E+00	1.0000E+00	1.9500E+01	3.6586E-05	1.9000E+01	4.9782E-04
21,	27	2.0000E+01	2.5000E+01	1.1140E-04	1.1444E-04	1.0000E+00	1.0000E+00	2.0500E+01	-2.5261E-05	2.0000E+01	6.6580E-04
22,	27	2.1000E+01	2.5000E+01	6.4717E-05	6.3802E-05	1.0000E+00	1.0000E+00	2.1500E+01	-3.5425E-05	2.1000E+01	5.9972E-04
23,	27	2.2000E+01	2.5000E+01	2.6459E-05	1.3518E-05	1.0000E+00	1.0000E+00	2.2500E+01	-1.9696E-05	2.2000E+01	3.3344E-04
24,	27	2.3000E+01	2.5000E+01	3.3286E-10	5.7800E-11	1.0000E+00	1.0000E+00	2.3500E+01	-1.8321E-10	2.3000E+01	1.5753E-09
25,	27	2.4000E+01	2.5000E+01	1.1725E-10	7.5020E-17	1.0000E+00	1.0000E+00	2.4500E+01	-3.2219E-10	2.4000E+01	4.6107E-09
26,	27	2.5000E+01	2.5000E+01	-2.0318E-10	8.2718E-25	1.0000E+00	1.0000E+00	2.5500E+01	1.9920E-10	2.5000E+01	-2.8891E-09
27,	27	2.6000E+01	2.5000E+01	0.	-8.2718E-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
3,	28	2.0000E+00	2.6000E+01	1.3387E-04	-2.9644E-01	9.7252E-01	9.9939E-01	2.5000E+00	1.0944E-03	1.9998E+00	-6.0548E-02
4,	28	3.0000E+00	2.6000E+01	2.1385E-04	-2.9556E-01	9.7266E-01	9.9938E-01	3.5000E+00	1.1228E-03	2.9996E+00	-6.2376E-02
5,	28	4.0000E+00	2.6000E+01	3.4453E-04	-2.9411E-01	9.7284E-01	9.9934E-01	4.5000E+00	1.2313E-03	3.9994E+00	-6.6128E-02
6,	28	5.0000E+00	2.6000E+01	3.8807E-04	-2.9274E-01	9.7315E-01	9.9931E-01	5.5000E+00	1.2896E-03	4.9992E+00	-6.8855E-02
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
8,	28	7.0000E+00	2.6000E+01	-2.8873E-04	-2.9063E-01	9.8397E-01	9.9930E-01	7.5000E+00	2.1035E-03	6.9987E+00	-6.9982E-02
9,	28	8.0000E+00	2.6000E+01	-4.9988E-04	-1.3271E-01	9.9737E-01	9.9943E-01	8.5000E+00	1.6484E-03	7.9988E+00	-5.7472E-02
10,	28	9.0000E+00	2.6000E+01	-7.9370E-04	2.7992E-02	9.9983E-01	9.9957E-01	9.5000E+00	1.2230E-03	8.9991E+00	-4.2553E-02
11,	28	1.0000E+01	2.6000E+01	-9.5067E-04	2.0842E-02	9.9992E-01	9.9976E-01	1.0500E+01	5.3746E-04	9.9994E+00	-2.3870E-02
12,	28	1.1000E+01	2.6000E+01	-2.9771E-04	1.2485E-02	9.9997E-01	9.9983E-01	1.1500E+01	3.7278E-04	1.1000E+01	-1.6534E-02
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
15,	28	1.4000E+01	2.6000E+01	-5.3675E-05	3.0799E-03	1.0000E+00	9.9994E-01	1.4500E+01	1.0783E-04	1.4000E+01	-5.7456E-03



PARTICLES
PDR= 1.00000E+00 PDZ= 1.00000E+00 PXR= 2.60000E+01 PYB= 0. PYT= 5.20000E+01
T3AAA 18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) (10872-1 T= 9.00000E+00 CYCLE= 232



VELOCITY VECTORS

VMAX= 2.93061E+00

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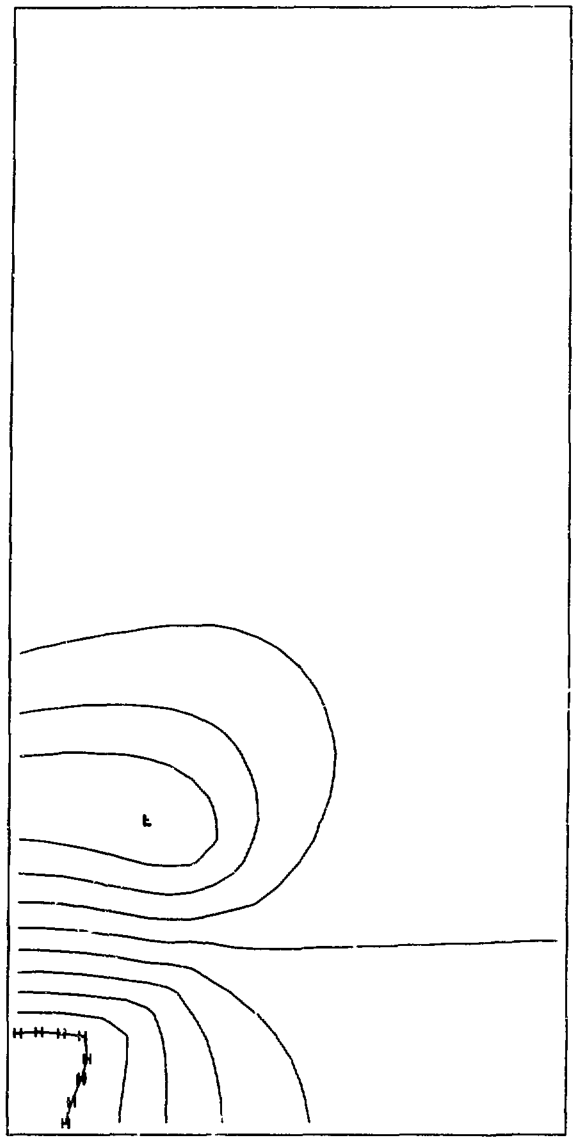

ISOPYCNICS

MIN= 9.72275E-01 MAX= 1.04901E+00 L= 9.72275E-01 H= 1.04223E+00 DQ= 7.77298E-03

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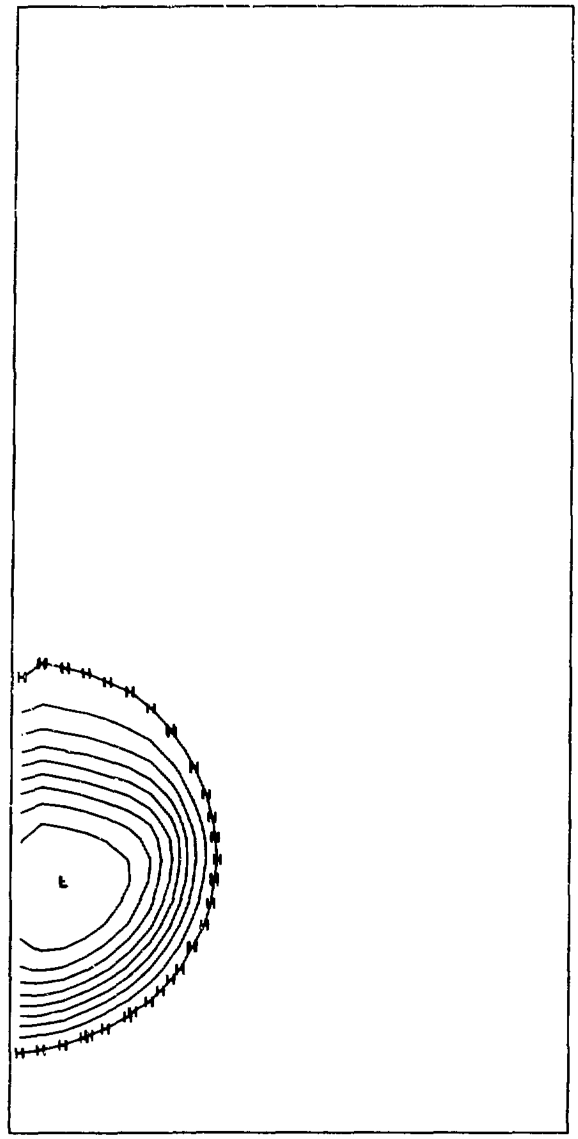

ISOTHERMS

MIN=-7.32911E+00 MAX= 1.22158E+00 L=-7.32911E+00 H= 3.67413E-01 DQ= 8.55170E-01

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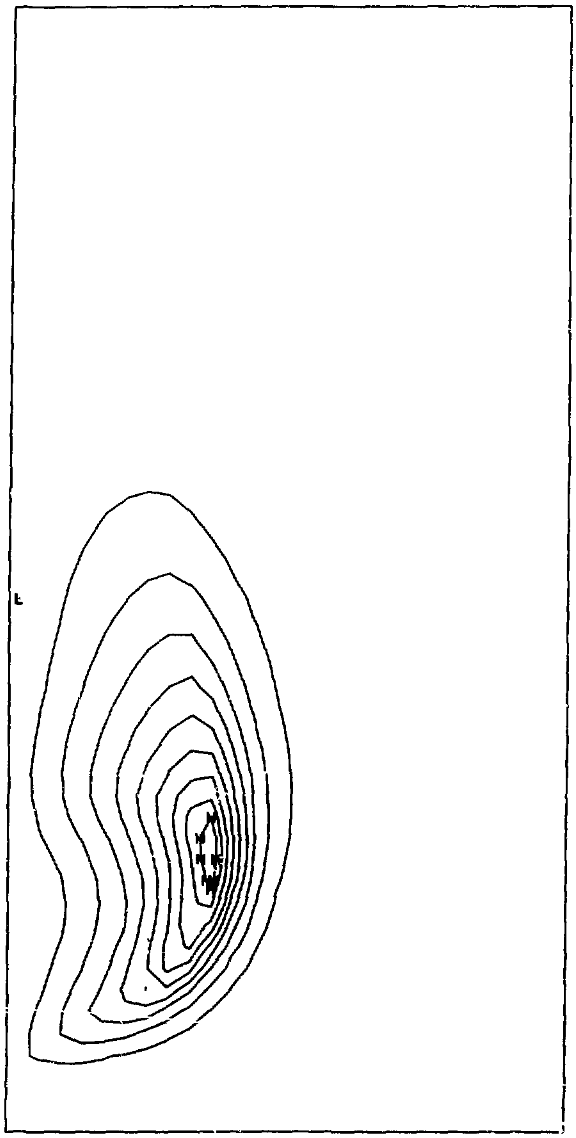


VORTICITY

MIN=-2.39303E-02 MAX= 9.72045E-01 L=-2.39303E-02 H= 8.73348E-01 DQ= 9.96976E-02

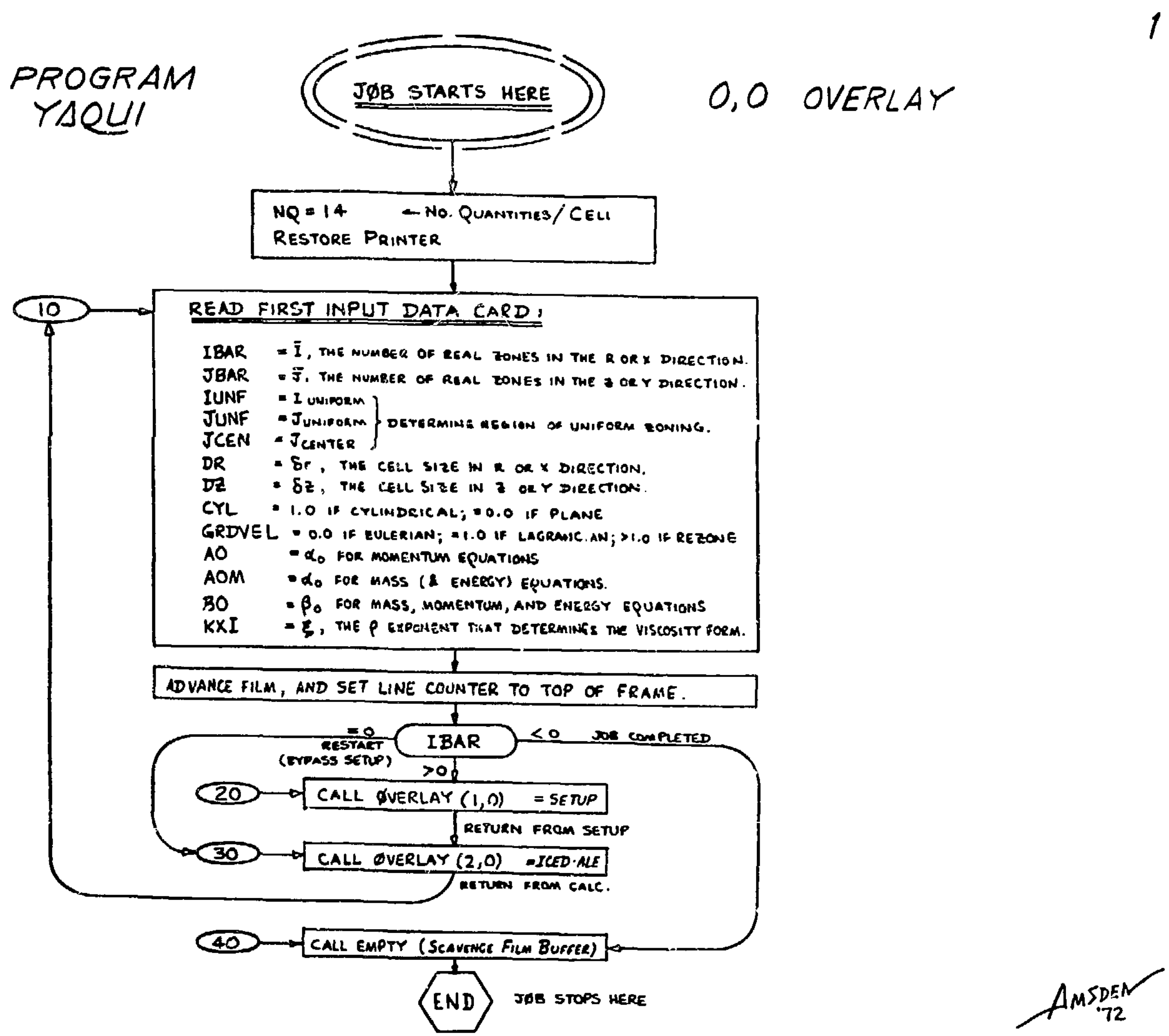
T3AAA 1BA YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 032272-3) 1:0872-1 T= 9.00000E+00 CYCLE= 232

T3AAA 18A YAQUI PARTICLE-FLUID MOMENTUM EXCHANGE TEST. (T3AAA1GB 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	-5.2859E-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	-2.1568E-03	9.9633E+00	-3.2023E-01
12.	26	1.1000E+01	2.4000E+01	-4.4172E-01	4.0408E-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	-1.6031E-03	1.1959E+01	-3.0029E-01
14.	26	1.3000E+01	2.4000E+01	-3.2845E-01	1.7108E-01	1.0057E+00	9.9717E-01	1.3500E+01	-1.3189E-03	1.2959E+01	-2.8300E-01
15.	26	1.4000E+01	2.4000E+01	-2.7853E-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	2.1659E-01	1.0019E+00	9.9774E-01	1.6500E+01	-6.0852E-04	1.5961E+01	-2.2555E-01
18.	26	1.7000E+01	2.4000E+01	-1.5721E-01	2.1866E-01	1.0014E+00	9.9794E-01	1.7500E+01	-4.6446E-04	1.6962E+01	-2.0650E-01
19.	26	1.8000E+01	2.4000E+01	-1.2864E-01	2.1852E-01	1.0010E+00	9.9810E-01	1.8500E+01	-2.9468E-04	1.7964E+01	-1.8964E-01
20.	26	1.9000E+01	2.4000E+01	-1.0426E-01	2.1746E-01	1.0008E+00	9.9826E-01	1.9500E+01	-1.8739E-04	1.8965E+01	-1.7443E-01
21.	26	2.0000E+01	2.4000E+01	-8.3362E-02	2.1595E-01	1.0006E+00	9.9838E-01	2.0500E+01	-8.9868E-05	1.9967E+01	-1.6159E-01
22.	26	2.1000E+01	2.4000E+01	-6.5270E-02	2.1434E-01	1.0005E+00	9.9848E-01	2.1500E+01	-2.2380E-05	2.0968E+01	-1.5157E-01
23.	26	2.2000E+01	2.4000E+01	-4.9414E-02	2.1286E-01	1.0004E+00	9.9857E-01	2.2500E+01	3.5902E-05	2.1969E+01	-1.4326E-01
24.	26	2.3000E+01	2.4000E+01	-3.5348E-02	2.1155E-01	1.0004E+00	9.9862E-01	2.3500E+01	6.2108E-05	2.2969E+01	-1.3776E-01
25.	26	2.4000E+01	2.4000E+01	-2.2633E-02	2.1054E-01	1.0004E+00	9.9866E-01	2.4500E+01	7.6929E-05	2.3969E+01	-1.3387E-01
26.	26	2.5000E+01	2.4000E+01	-1.0954E-02	2.0980E-01	1.0003E+00	9.9869E-01	2.5500E+01	8.7703E-05	2.4968E+01	-1.3237E-01
27.	26	2.6000E+01	2.4000E+01	0.	2.0939E-01	0.	-1.0170E-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
3.	27	2.0000E+00	2.5000E+01	-1.7724E-01	-1.4288E+00	1.0478E+00	9.9979E-01	2.5000E+00	-1.7819E-03	1.9987E+00	-2.5003E-02
4.	27	3.0000E+00	2.5000E+01	-2.6015E-01	-1.3528E+00	1.0401E+00	9.9949E-01	3.5000E+00	-1.8811E-03	2.9970E+00	-6.0391E-02
5.	27	4.0000E+00	2.5000E+01	-3.3598E-01	-1.2374E+00	1.0375E+00	9.9904E-01	4.5000E+00	-2.0103E-03	3.9946E+00	-9.6071E-02
6.	27	5.0000E+00	2.5000E+01	-4.0168E-01	-1.0853E+00	1.0398E+00	9.9869E-01	5.5000E+00	-2.1383E-03	4.9915E+00	-1.3140E-01
7.	27	6.0000E+00	2.5000E+01	-4.5440E-01	-9.0021E-01	1.0452E+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	1.0468E+00	9.9904E-01	7.5000E+00	-2.3078E-03	6.9838E+00	-1.9560E-01
9.	27	8.0000E+00	2.5000E+01	-5.0544E-01	-4.6218E-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	-4.9801E-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	-8.8456E-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	1.0989E+01	-2.5274E-01
13.	27	1.2000E+01	2.5000E+01	-3.6842E-01	9.7781E-02	1.0070E+00	9.9753E-01	1.2500E+01	-1.4725E-03	1.1987E+01	-2.4987E-01
14.	27	1.3000E+01	2.5000E+01	-3.1508E-01	1.4255E-01	1.0059E+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	1.8378E-01	1.0024E+00	9.9777E-01	1.5500E+01	-8.3834E-04	1.4964E+01	-2.2262E-01
17.	27	1.6000E+01	2.5000E+01	-1.8787E-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	-5.3878E-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	-1.0484E-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	-6.6189E-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	-6.9065E-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.	1.9866E-01	0.	-1.0315E-07	0.	0.	1.2732E+01	7.8540E-02
1.	28	0.	2.6000E+01	0.	-1.2898E+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	-8.5058E-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	-1.1824E+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	-3.1839E-01	-1.0883E+00	1.0563E+00	9.9984E-01	4.5000E+00	-1.7357E-03	3.9984E+00	-1.5583E-02
6.	28	5.0000E+00	2.6000E+01	-3.8003E-01	-9.5134E-01	1.0478E+00	9.9948E-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	-1.2046E-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	-4.9220E-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	-8.6894E-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	-3.9087E-01	1.0791E-02	1.0088E+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
1
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
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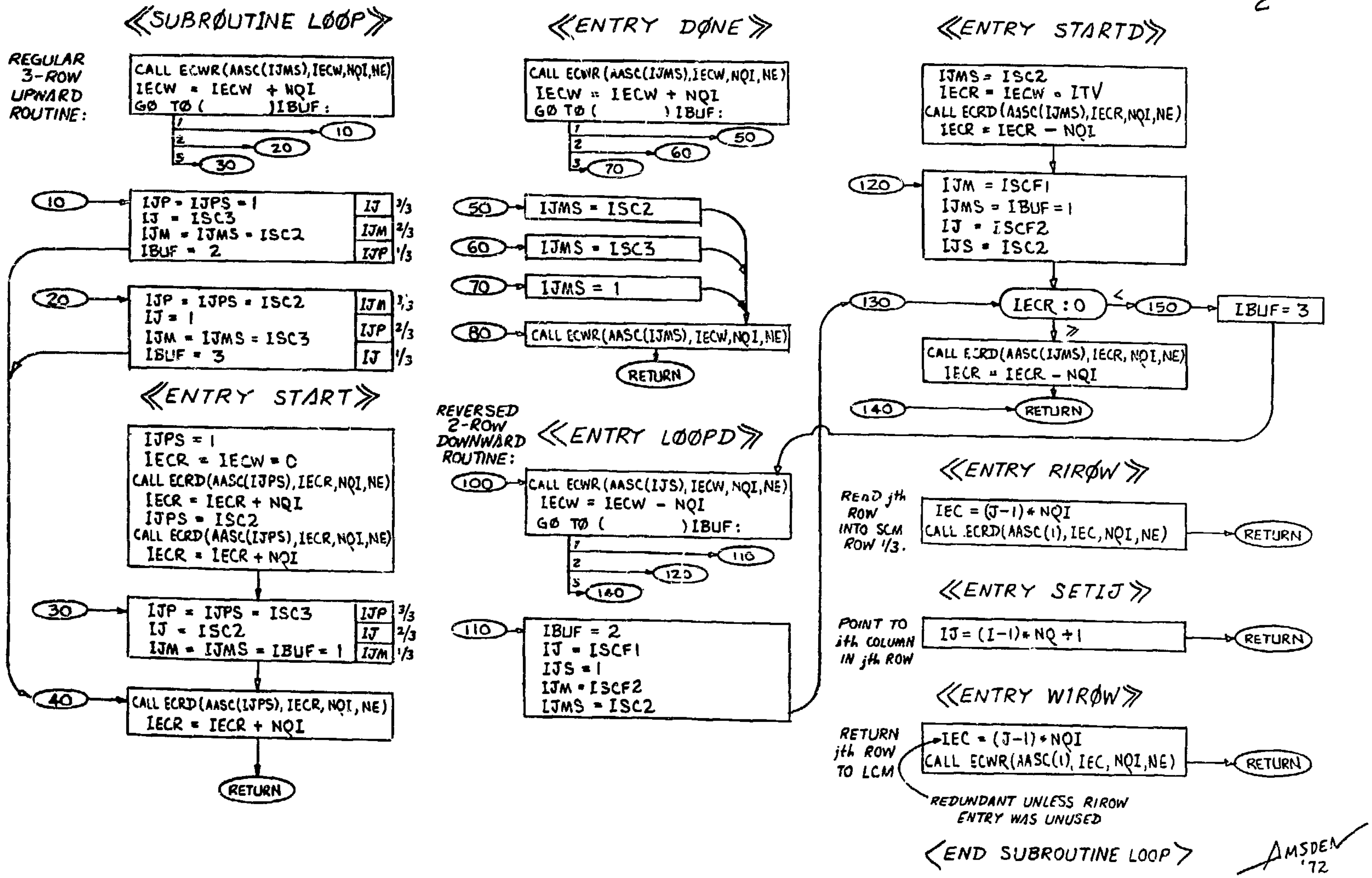
0.0 SUBROUTINES — SCM/LCM 3-ROW BUFFERING:

2



0,0 SUBROUTINES – SETUP PLOTS & PARTICLE GRID: 3

≪SUBROUTINE FILMCØ≫

XL = 0.0
YB = 10^{20}
XR = YT = −YB
} INITIALIZE COMPARANDS FOR DETERMINATION OF GRID SIZE & SWEEP VERTICES:

CALL START
— DØ 129 J = 2, JP2
— DØ 119 I = 1, IP1 } ALL VERTICES
XR = AMAX1 [XR, X(IJ)]
YB = AMIN1 [YB, Y(IJ)]
YT = AMAX1 [YT, Y(IJ)]

(119) → IJ = IJ + NQ
CALL LØØP

(129) → CØNTINUE

VV = 0.9 * XR * RIBAR = VELOCITY VECTOR SCALE
FIYB = 916.0 = YB ON FILM FRAME
XD = XR/(YT−YB) = RATIO WIDTH/HEIGHT
YY = 0.0 INITIALIZE FOR TEST:

1.13556 = 1022/900

XD : 1.13556 — ≤ HIGHER THAN WIDE → YY = 1.0
\> WIDER THAN HIGH

MAXIMIZE PLØT SIZE ØN FILM FRAME:

FIXL = AMAX1 [0.0, (511.−450.*XD)*YY] ENSURE NO IMPROPER "−0."
FIXR = (511.+450.*XD)*YY + 1022.*(1.−YY)
FIYT = 16.*YY + (916.−1022./XD) * (1.−YY)
XCØNV = (FIXR−FIXL)/(XR−XL) } CØNVERSIØN
YCØNV = (FIYT−FIYB)/(YT−YB) } COEFFICIENTS
IXL = FIXL
IXR = FIXR
IYB = FIYB } INTEGER EQUIVALENTS
IYT = FIYT

HIGHER THAN WIDE:
IXL = 511 − 450·XD/YT
IXR = 511 + 450·XD/YT
IYT = 16
WIDER THAN HIGH:
IXL = 0
IXR = 1022
IYT = 916 − 1022·YT/XD

PARTICLE GRID & PARTICLE PLØT SETUP:

NPT : 0 — = NO PARTICLES, BYPASS REMAINDER OF SUBROUTINE → RETURN
≠

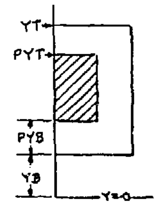
PXL = 0.0
PYB = YB + PYB — COMPUTE DISTANCE FROM Y=0
PXR = PDR * FIBP — $\Delta x * \bar{I}_p$
PYT = PYB + PDZ * FJBP — $YB_p + \Delta y * \bar{J}_p$
PXRP = PXR * ØPEMIO
PYBM = PYB * ØMEMIO } JUST OUTSIDE GRID — FOR TESTS IN PARTMØV
PYTP = PYT * ØPEMIO
RPDR = 1./PDR — $1./\Delta x$
RPDZ = 1./PDZ — $1./\Delta y$
RPDRDZ = RPDR * RPDZ — $1./\Delta x \Delta y$
FIPYB = 916.0 — YB_p ON FILM FRAME
XD = PXR/(PYT−PYB) = RATIO OF WIDTH TO HEIGHT
YY = 0.0 INITIALIZE FOR TEST:

(PDR, PDZ, AND PYB ARE SPECIFIED BY INPUT AND BY SUBR. REZONE)

SETUP FOR PARTICLE PLOT, TO FIT PARTICLE GRID, NOT FLUID GRID.

XD : 1.13556 — ≤ HIGHER THAN WIDE → YY = 1.0
\> WIDER THAN HIGH

FIPXL = AMAX1 [0.0, (511.−450.*XD)*YY]
FIPXR = (511.+450.*XD)*YY + 1022.*(1.−YY)
FIPYT = 16.*YY + (916.−1022./XD) * (1.−YY)
PXCØNV = (FIPXR−FIPXL)/(PXR−PXL) } CONVERSIØN
PYCØNV = (FIPYT−FIPYB)/(PYT−PYB) } CØEFFS.
IPXL = FIPXL
IPXR = FIPXR
IPYB = FIPYB } INTEGER EQUIVALENTS
IPYT = FIPYT



RETURN

<END SUBRØUTINE FILMCØ>

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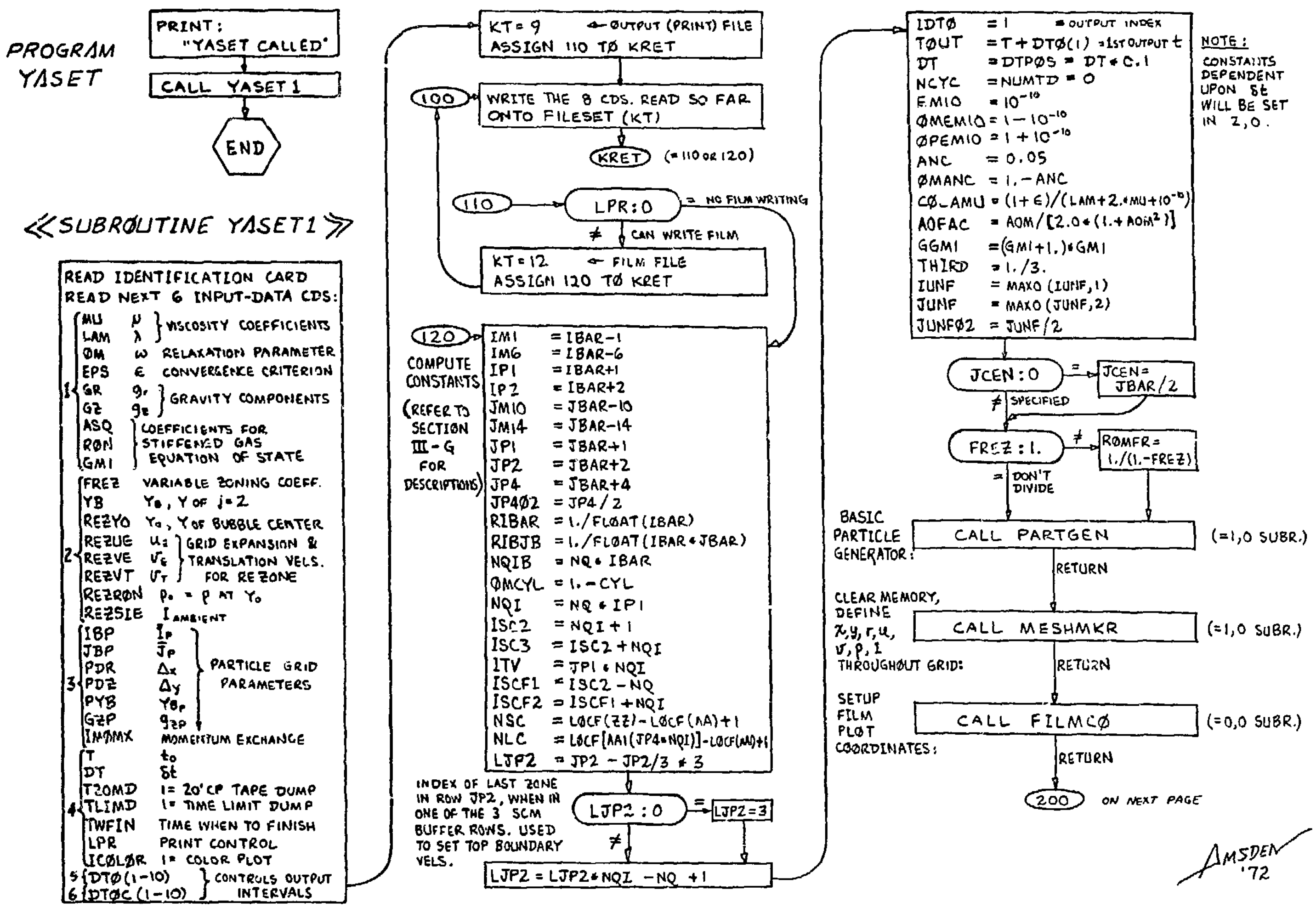
PROGRAM YASET
PRINT: "YASET CALLED"
CALL YASET1
END
≪SUBROUTINE YASET1≫
READ IDENTIFICATION CARD
READ NEXT 6 INPUT-DATA CDS:
1 MU μ, LAM λ VISCOSITY COEFFICIENTS
ØM ω RELAXATION PARAMETER
EPS ε CONVERGENCE CRITERION
GR g_r, GZ g_z GRAVITY COMPONENTS
ASQ, RØN, GMI COEFFICIENTS FOR STIFFENED GAS EQUATION OF STATE
2 FREZ VARIABLE ZONING COEFF.
YB Y_B, Y OF j=2
REZYO Y_0, Y OF BUBBLE CENTER
REZUE u_E, REZVE v_E, REZVT v_T GRID EXPANSION & TRANSLATION VELS. FOR REZONE
REZRØN ρ_0 = ρ AT Y_0
REZSIE I_AMBIENT
3 IBP I_P, JBP J_P, PDR Δx, PDZ Δy, PYB Y_Bp, GZP g_zp PARTICLE GRID PARAMETERS
IMØMX MOMENTUM EXCHANGE
4 T t_0
DT δt
T2OMD 1= 20'CP TAPE DUMP
TLIMD 1= TIME LIMIT DUMP
TWFIN TIME WHEN TO FINISH
LPR PRINT CONTROL
ICØLØR 1= COLOR PLOT
5 DTØ(1-10), 6 DTØC(1-10) CONTROLS OUTPUT INTERVALS
KT=9 ← OUTPUT (PRINT) FILE
ASSIGN 110 TØ KRET
100 WRITE THE 8 CDS. READ SO FAR ONTO FILESET (KT)
KRET (=110 OR 120)
110 LPR:0 = NO FILM WRITING
≠ CAN WRITE FILM
KT=12 ← FILM FILE
ASSIGN 120 TØ KRET
120 COMPUTE CONSTANTS (REFER TO SECTION III-G FOR DESCRIPTIONS)
IM1 = IBAR-1
IM6 = IBAR-6
IP1 = IBAR+1
IP2 = IBAR+2
JM10 = JBAR-10
JM14 = JBAR-14
JP1 = JBAR+1
JP2 = JBAR+2
JP4 = JBAR+4
JP4Ø2 = JP4/2
RIBAR = 1./FLØAT(IBAR)
RIBJB = 1./FLØAT(IBAR*JBAR)
NQIB = NQ*IBAR
ØMCYL = 1.-CYL
NQI = NQ*IP1
ISC2 = NQI+1
ISC3 = ISC2+NQI
ITV = JP1*NQI
ISCF1 = ISC2-NQ
ISCF2 = ISCF1+NQI
NSC = LØCF(ZZ)-LØCF(AA)+1
NLC = LØCF[AA1(JP4*NQI)]-LØCF(AA)+1
LJP2 = JP2 - JP2/3 * 3
INDEX OF LAST ZONE IN ROW JP2, WHEN IN ONE OF THE 3 SCM BUFFER ROWS. USED TO SET TOP BOUNDARY VELS.
LJP2:0 = LJP2=3
≠
LJP2 = LJP2*NQI - NQ + 1
IDTØ = 1 ← OUTPUT INDEX
TØUT = T+DTØ(1) = 1ST OUTPUT t
DT = DTPØS = DT*C.1
NCYC = NUMTD = 0
EM10 = 10^-10
ØMEM10 = 1-10^-10
ØPEM10 = 1+10^-10
ANC = 0.05
ØMANC = 1.-ANC
CØ_AMU = (1+ε)/(LAM+2.*MU+10^-6)
AØFAC = AØM/[2.0*(1.+AØM²)]
GGM1 = (GM1+1.)*GM1
THIRD = 1./3.
IUNF = MAX0(IUNF,1)
JUNF = MAX0(JUNF,2)
JUNFØ2 = JUNF/2
NOTE: CONSTANTS DEPENDENT UPON δt WILL BE SET IN 2,0.
JCEN:0 = JCEN = JBAR/2
≠ SPECIFIED
FREZ:1. ≠ RØMFR = 1./(1.-FREZ)
= DON'T DIVIDE
BASIC PARTICLE GENERATOR: CALL PARTGEN (=1,0 SUBR.)
RETURN
CLEAR MEMORY, DEFINE x,y,r,u,v,ρ,I THROUGHØUT GRID: CALL MESHMKR (=1,0 SUBR.)
RETURN
SETUP FILM PLØT CØØRDINATES: CALL FILMCØ (=0,0 SUBR.)
RETURN
200 ON NEXT PAGE
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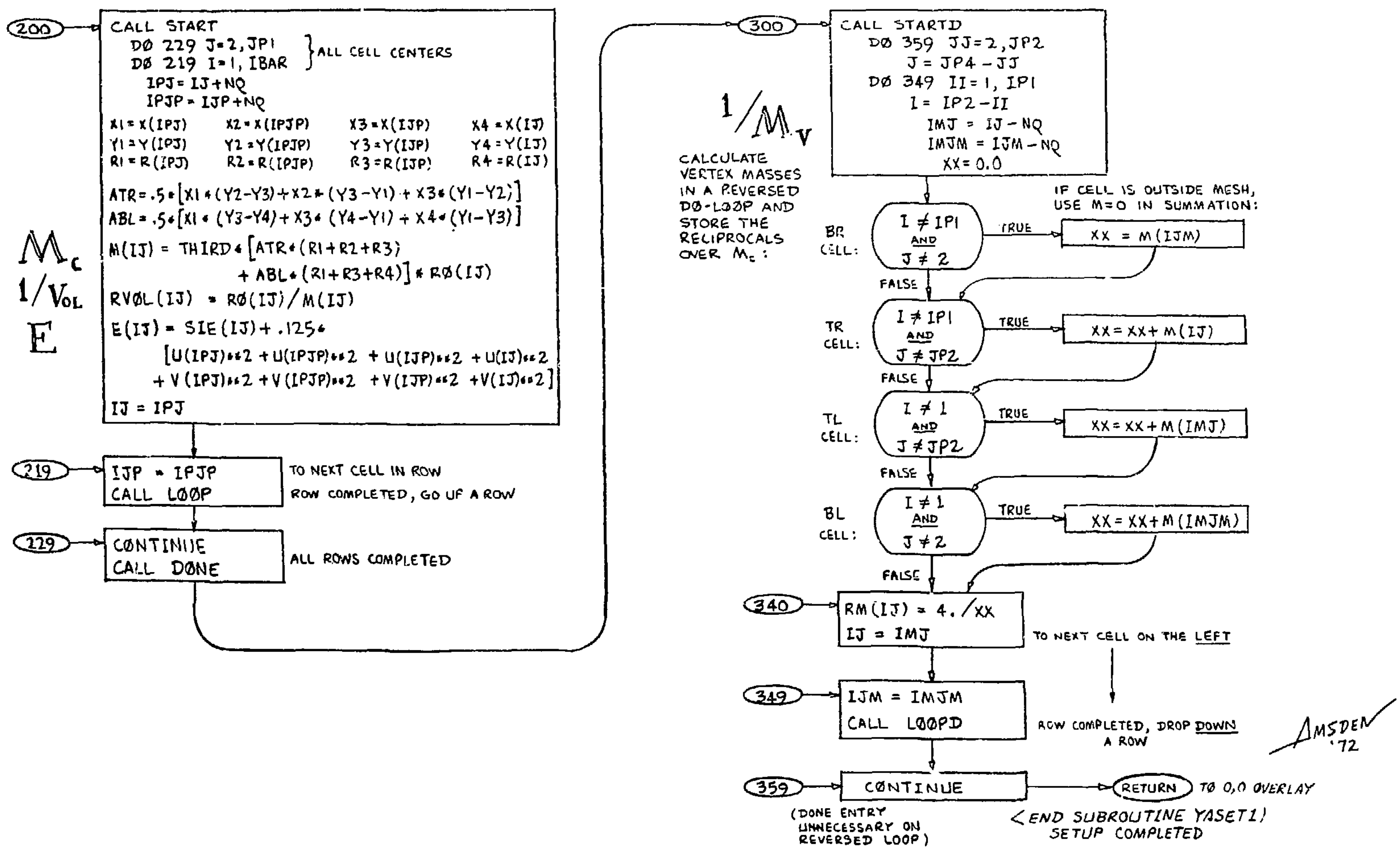
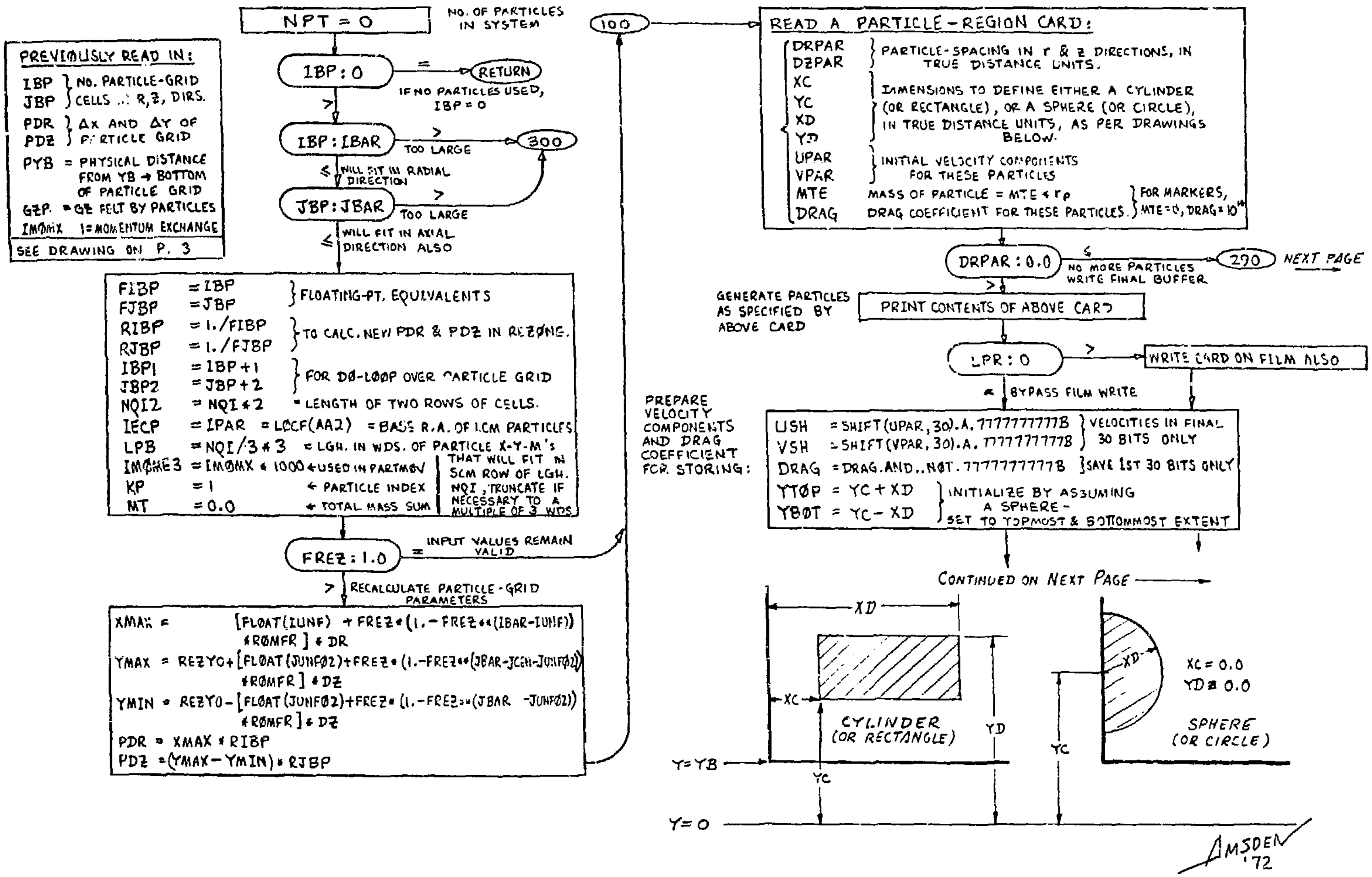
«SUBROUTINE YASET1» CONTINUED:

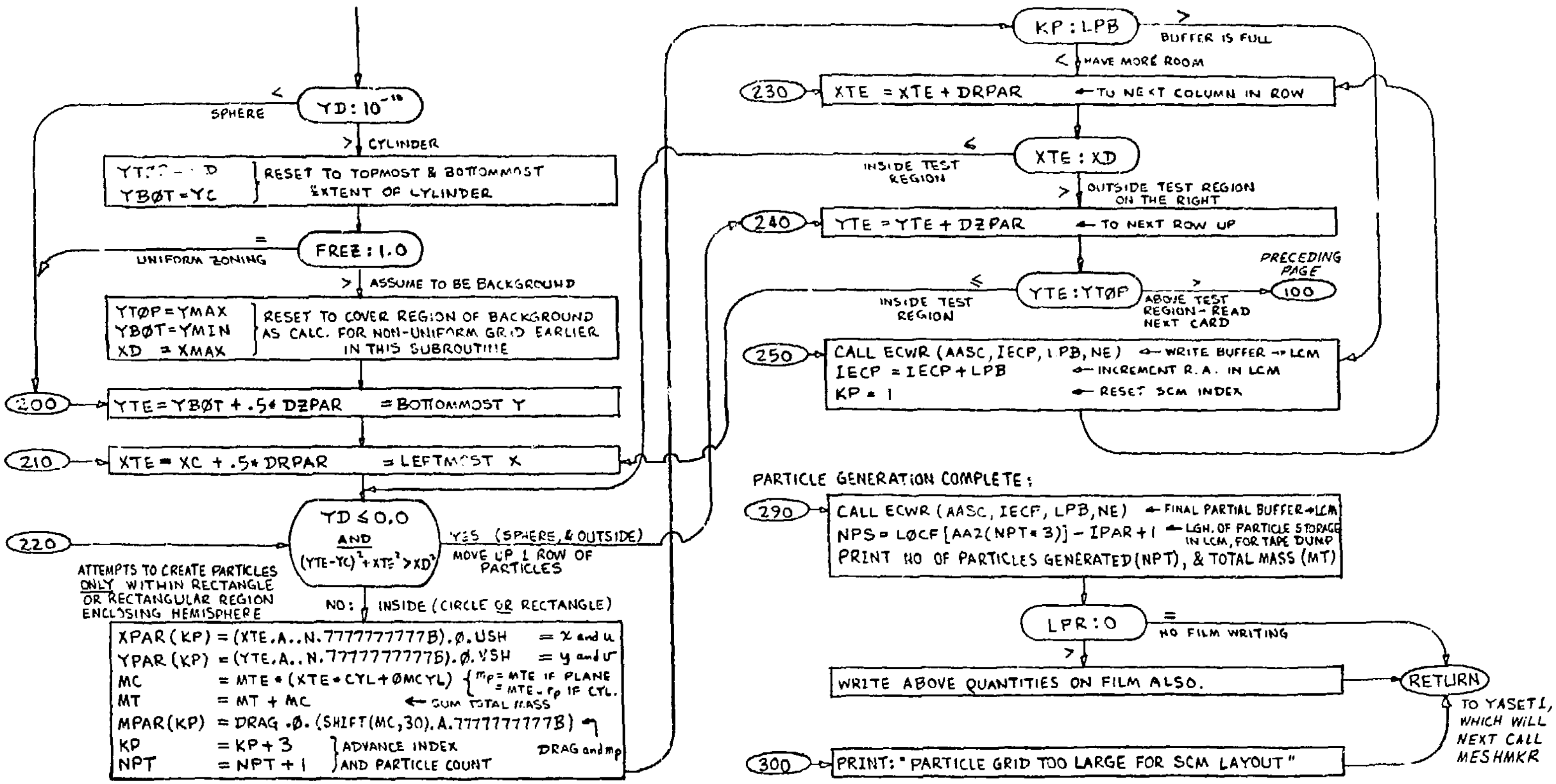


«SUBROUTINE PARTGEN»



1,0 SUBROUTINES -- PARTICLE GENERATOR (CONT'D):

<<SUBROUTINE PARTGEN>> CONTINUED:



<END SUBROUTINE PARTGEN>

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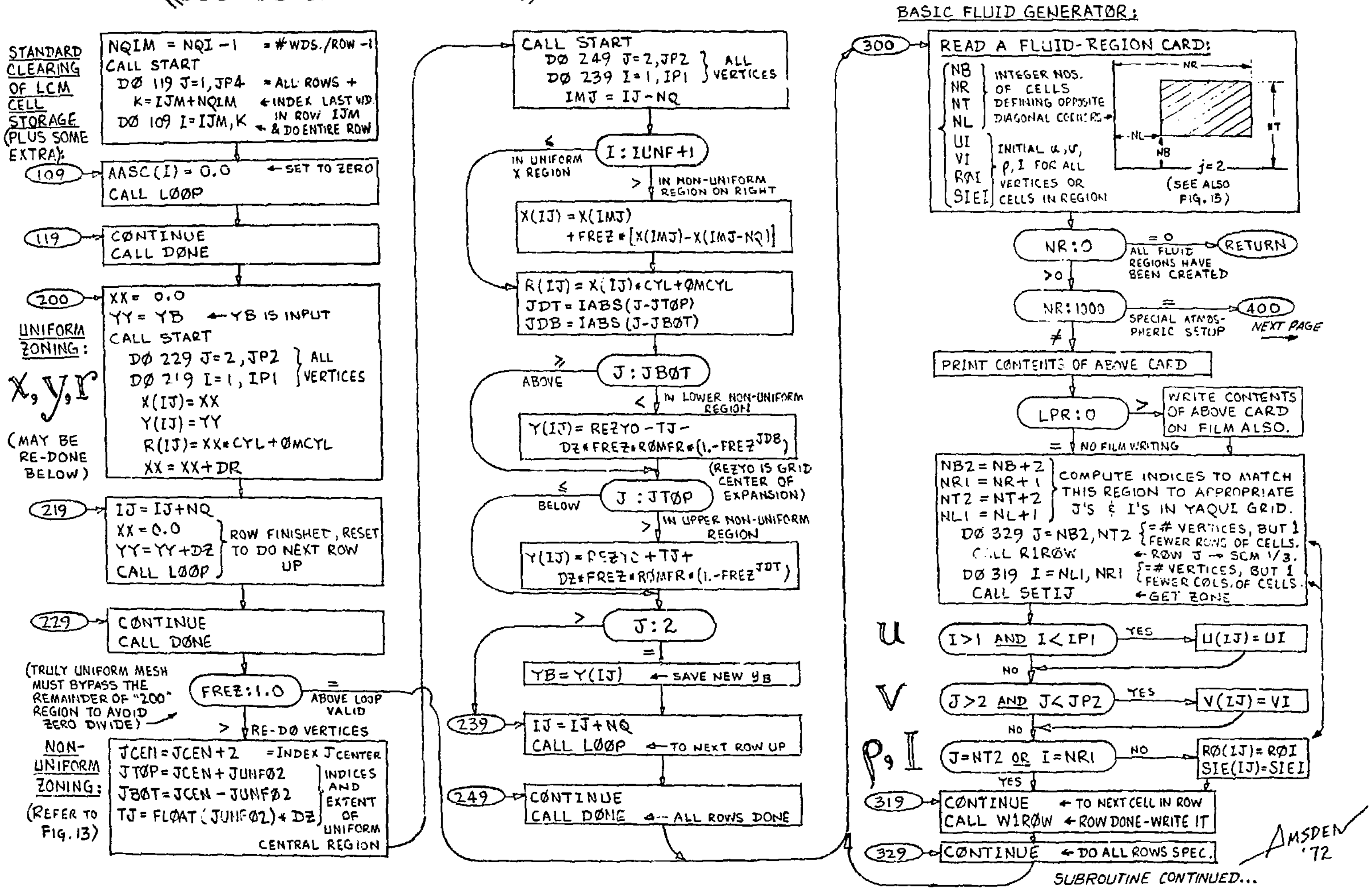
«SUBROUTINE MESHMKR»



SUBROUTINE CONTINUED...

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)         * δz/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
        RØ(IJ) = RØSAV    } & J=2, INCL.
        RØ(IJM) = RØJ1    } EXT. ZONES ON BOTTOM RIGHT
        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.
```

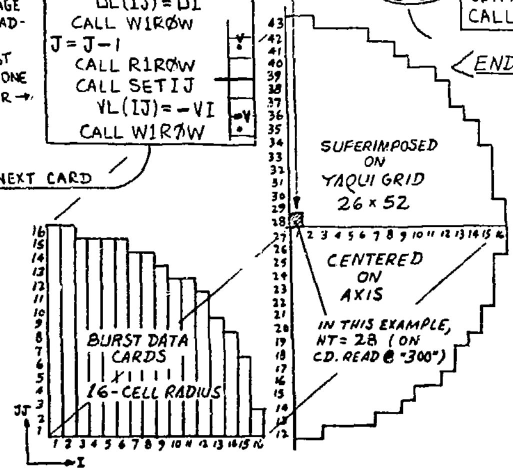
UPPER QUADRANT:

```
     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 →

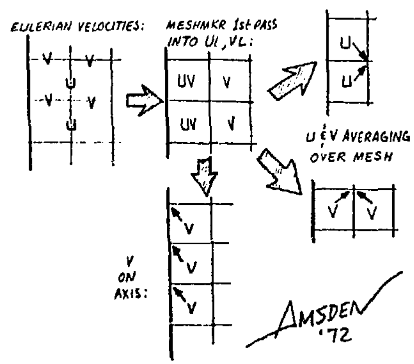
```
     J= J-2*JJ+1
      CALL R1RØW
      CALL SETIJ
       RØ(IJ) = RØI
       SIE(IJ) = SIEI
       UL(IJ) = UI
      CALL W1RØW
     J= J-1
      CALL R1RØW
      CALL SETIJ
       VL(IJ)= -VI
      CALL W1RØW
     READ NEXT CARD -> 500
```



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
     V(IPJP)=.5*[VL(IJ)+VL(IPJ)]      AVERAGING
     IJ = IPJ
539  IJP = IPJP
     CALL LØØP    <- ROW DONE
549  CØNTINUE
     CALL DØNE    <- ALL DONE
     -> RETURN  TO YASET1
```

<END SUBROUTINE MESHMKR>



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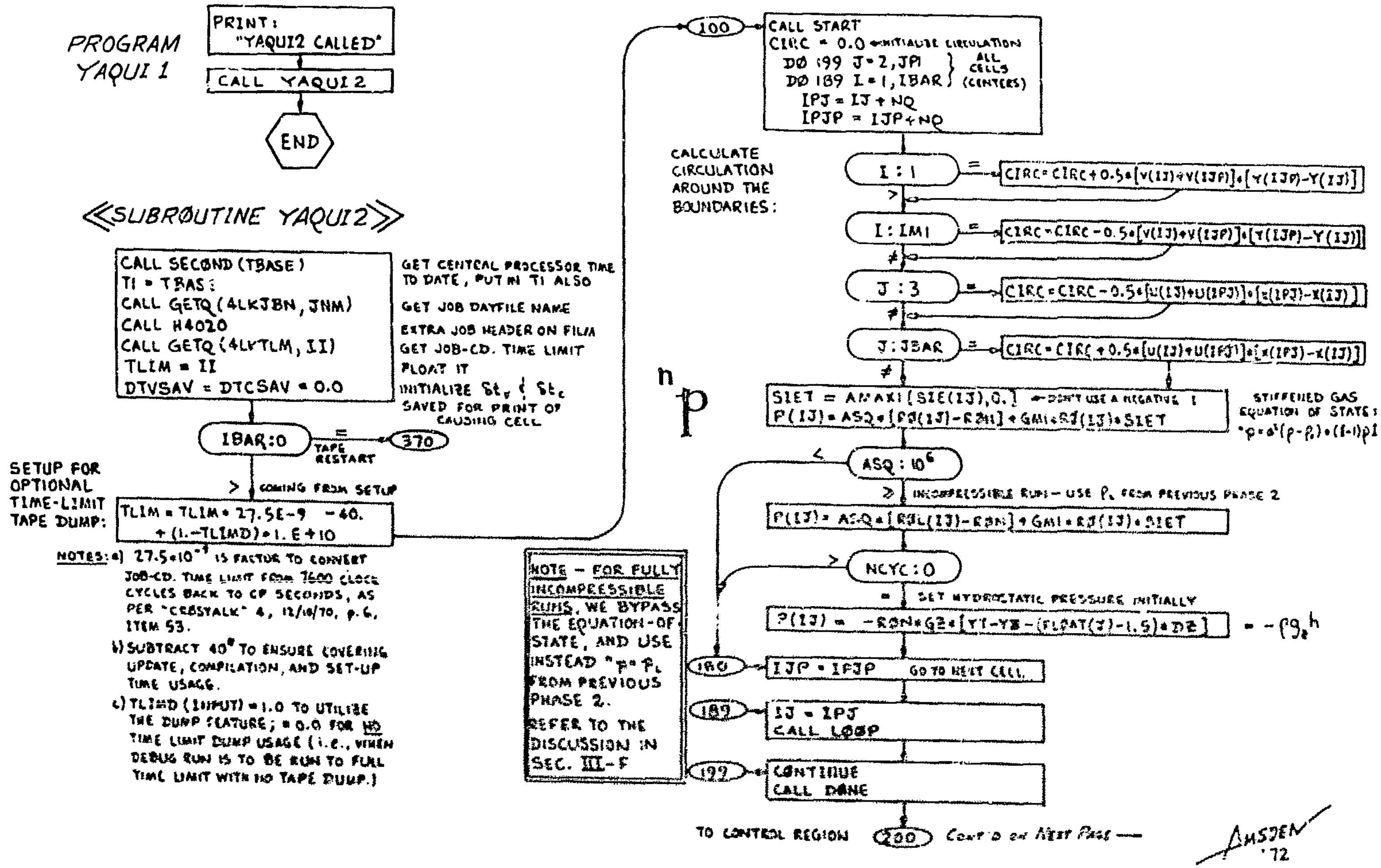
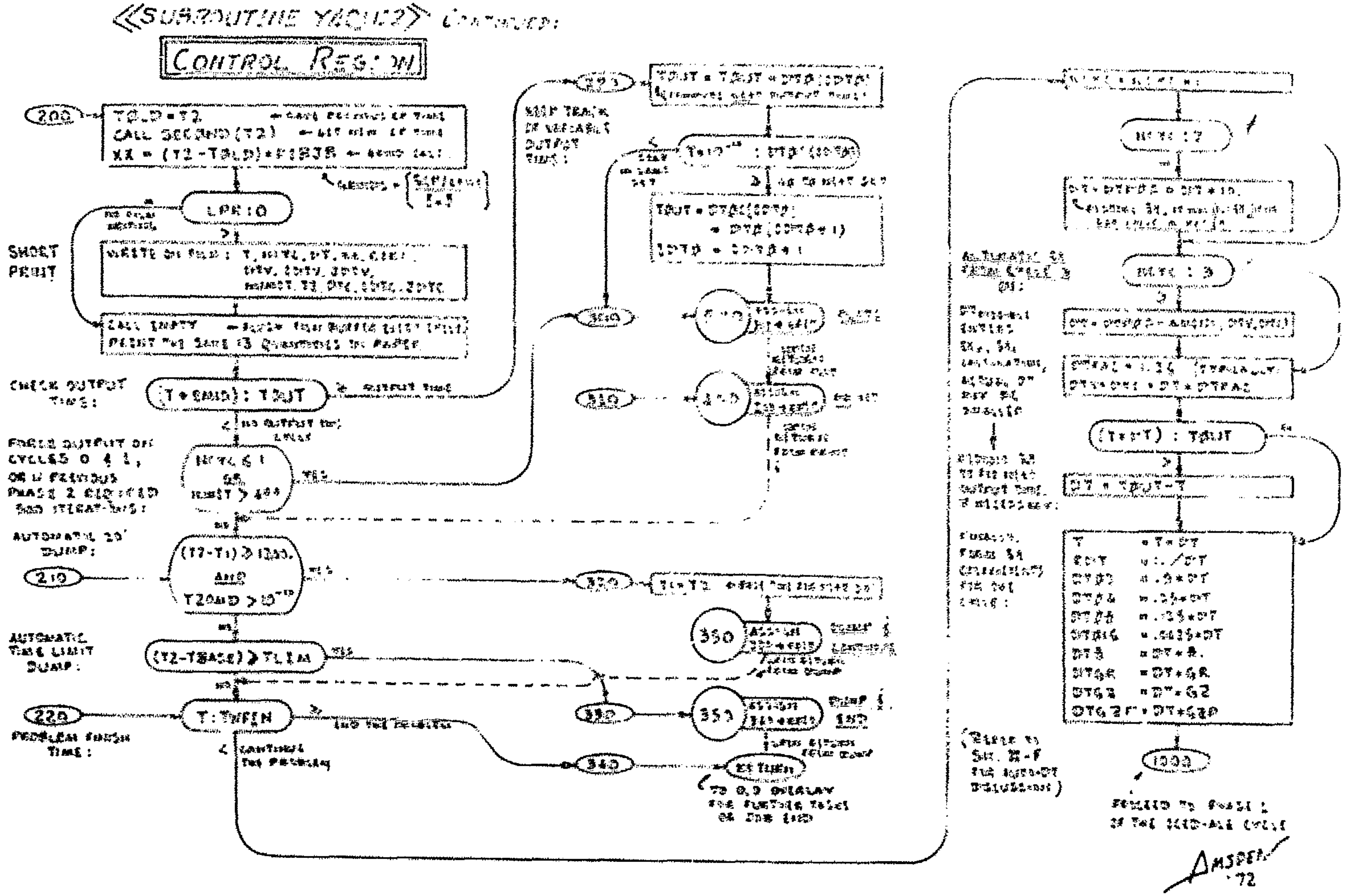
2,0 OVERLAY - 3-PHASE ICED-ALE: 10

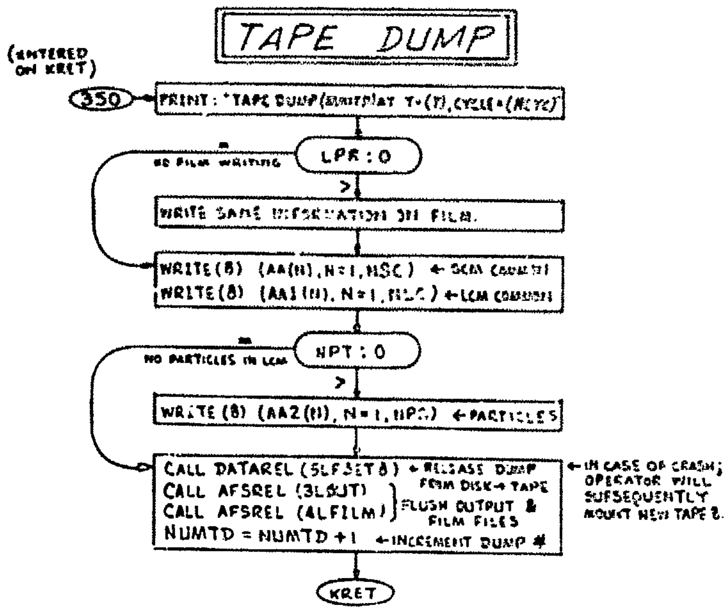


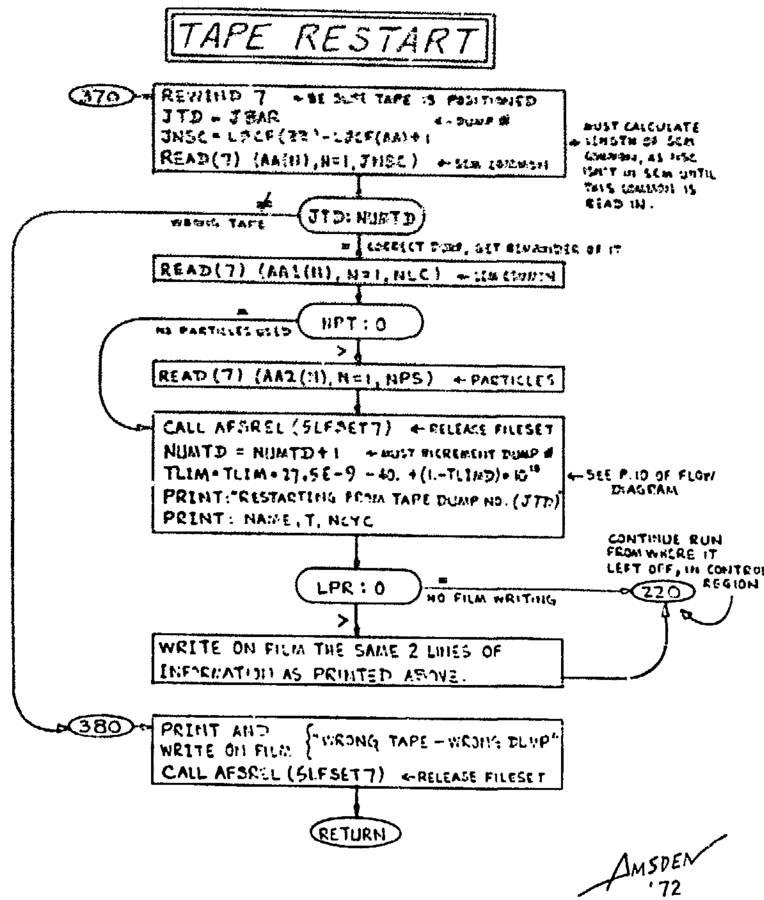
2.0 SUBROUTINES — 3-PHASE ...

11



«SUBROUTINE YAQUI2» CONTINUED:





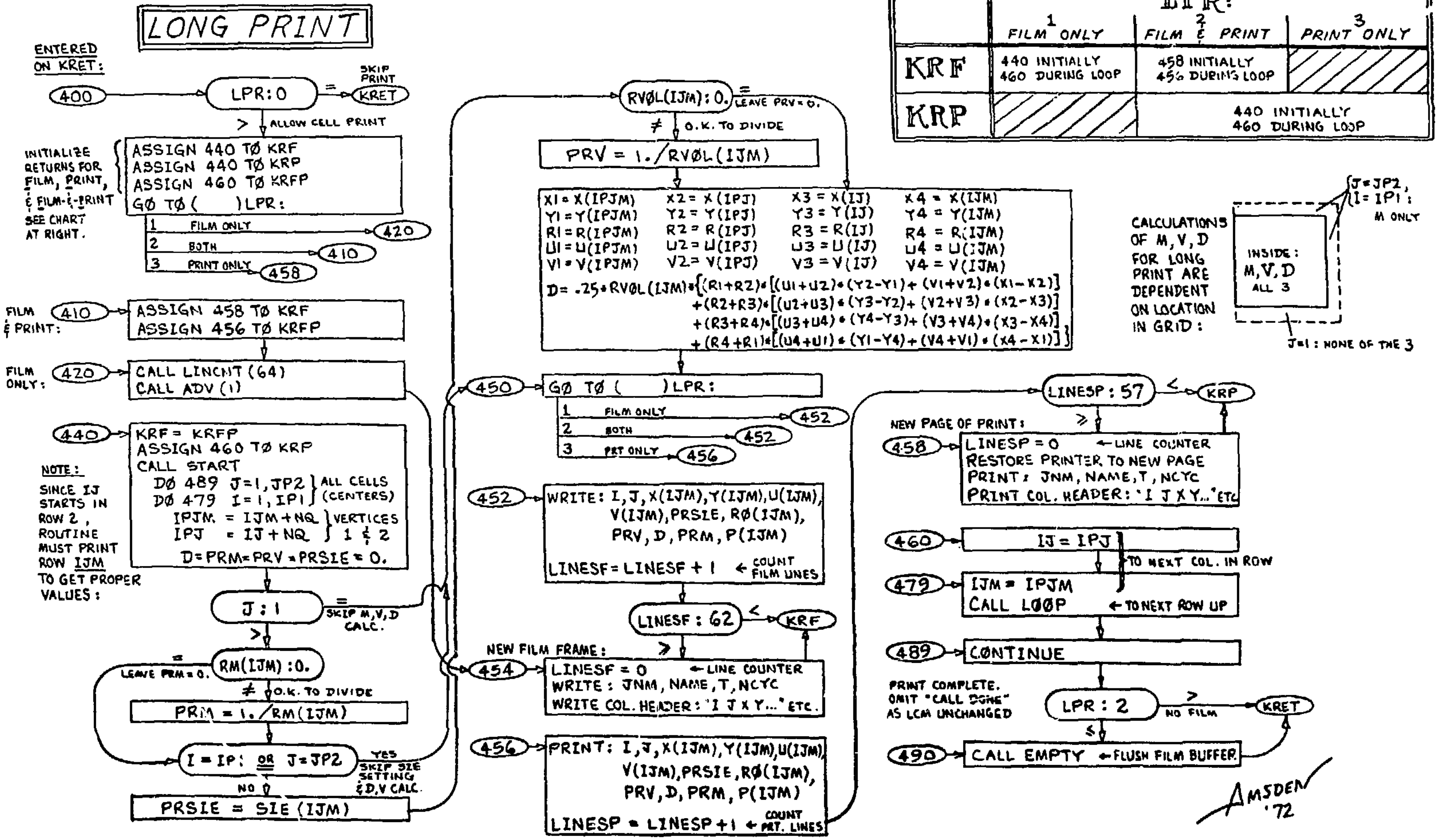
NOTES:

NSC = LENGTH OF SCM COMMON YSC2, = LOCF(22) - LOCF(AA) + 1
NLC = LENGTH OF LCM CELL STORAGE, = LOCF(AA1(JP4+N21)) - LOCF(AA1) + 1
NPS = LENGTH OF LCM PARTICLE STORAGE = LOCF(AA2(NPT+3)) - IPAR + 1 (LWA. - FWA. + 1)

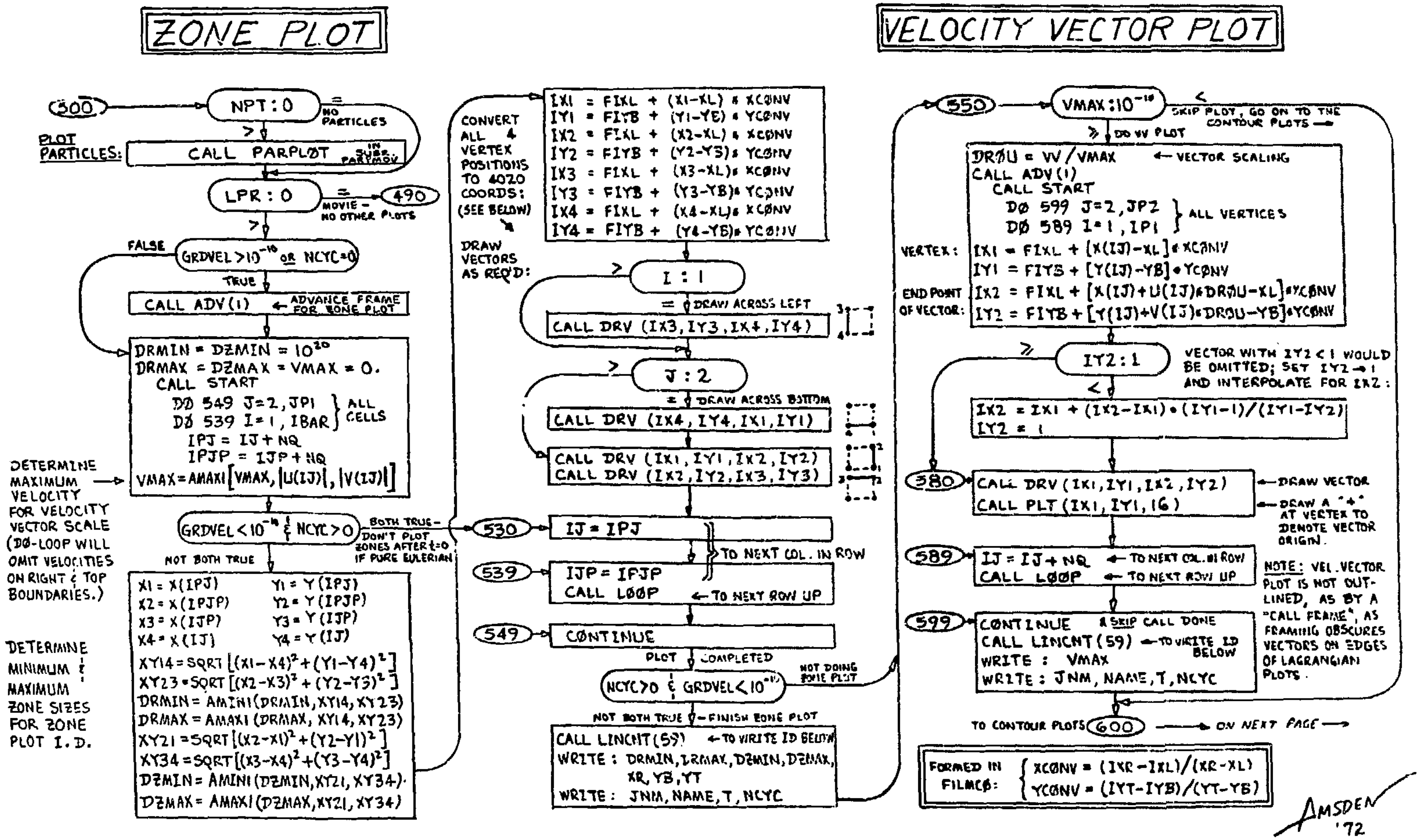
THESE 3 PARAMETERS ARE STORED IN THE SCM COMMON YSC2.
NSC & NLC ARE CALCULATED IN YASET1 IN STATEMENT #120
NPS IS CALCULATED AT THE END OF PARTGEN IN STATEMENT #290.
USE OF JP4 IN NLC ENSURES THAT CAREFULLY-CLEARED LCM WILL BE USED, TO AVOID TROUBLE ON RESTART.
NPT IS THE TOTAL NO. OF PARTICLES IN THE SYSTEM.

≪SUBROUTINE YAQUI2≫ CONTINUED:

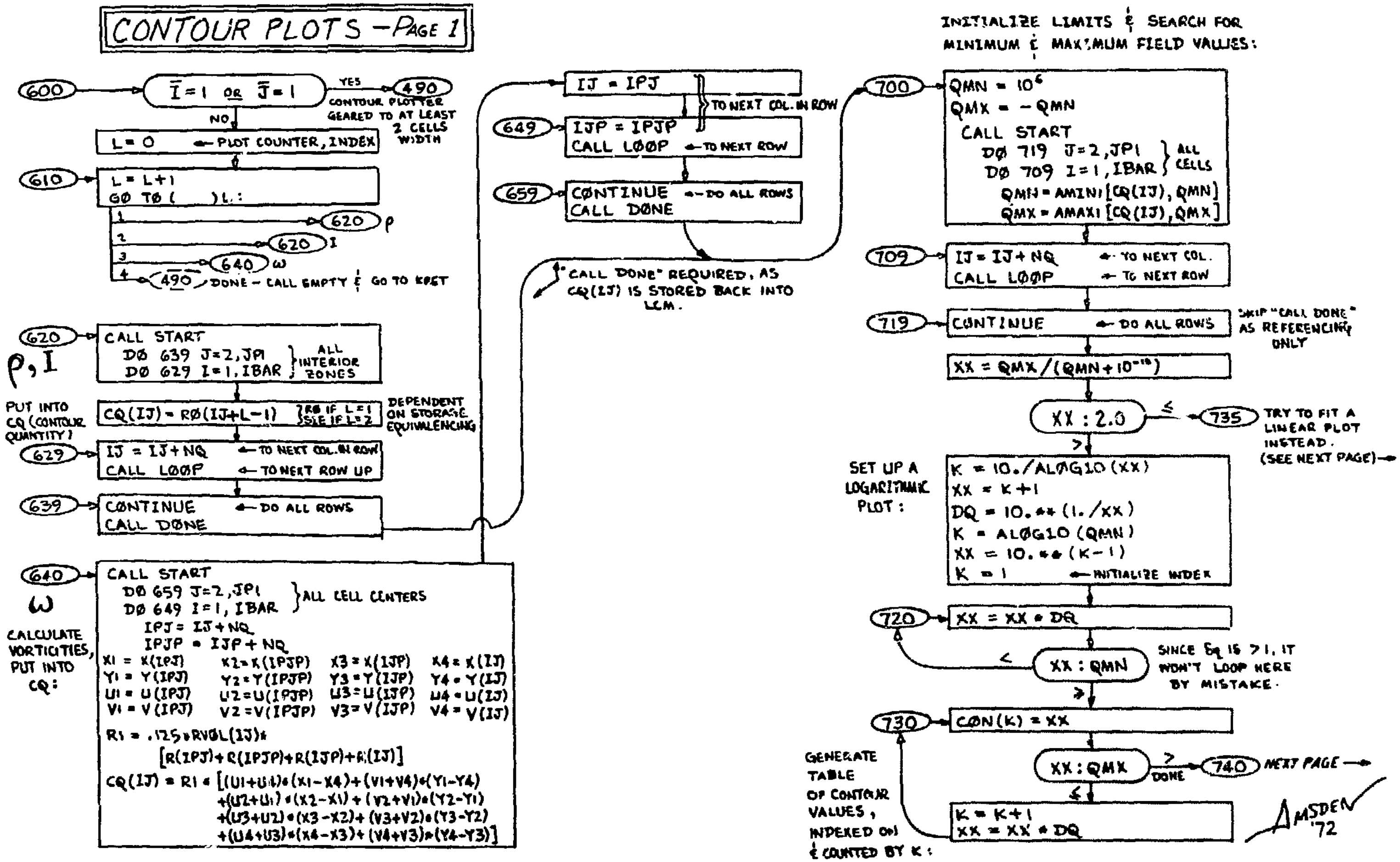
	LPR: 1 FILM ONLY	LPR: 2 FILM & PRINT	LPR: 3 PRINT ONLY
KRF	440 INITIALLY 460 DURING LOOP	458 INITIALLY 456 DURING LOOP	//////
KRP	//////	440 INITIALLY 460 DURING LOOP	



《SUBROUTINE YAQUI2》 CONTINUED:

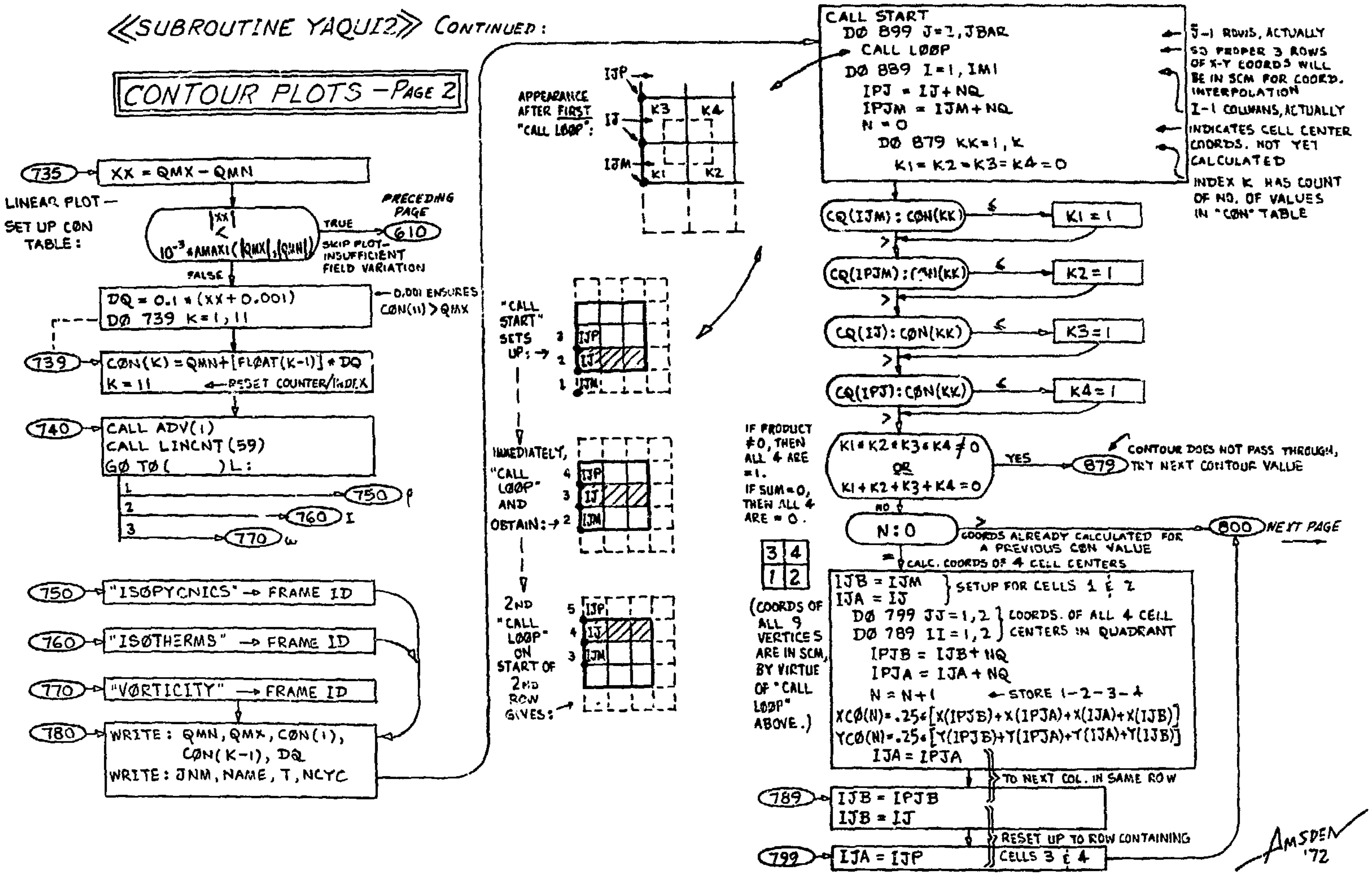


«SUBROUTINE YAQUI» CONTINUED:

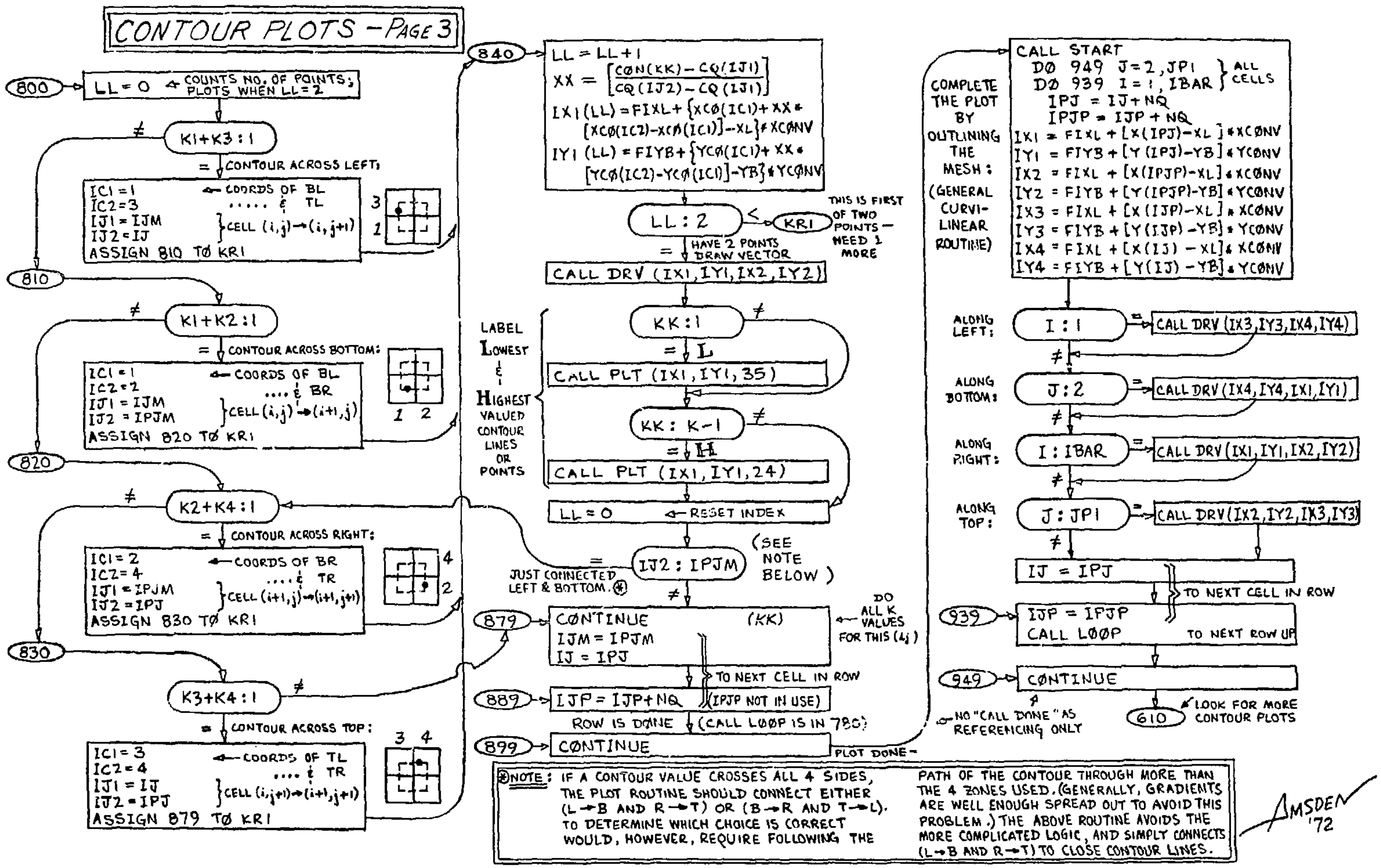


«SUBROUTINE YAQUI2» CONTINUED:

CONTOUR PLOTS — PAGE 2



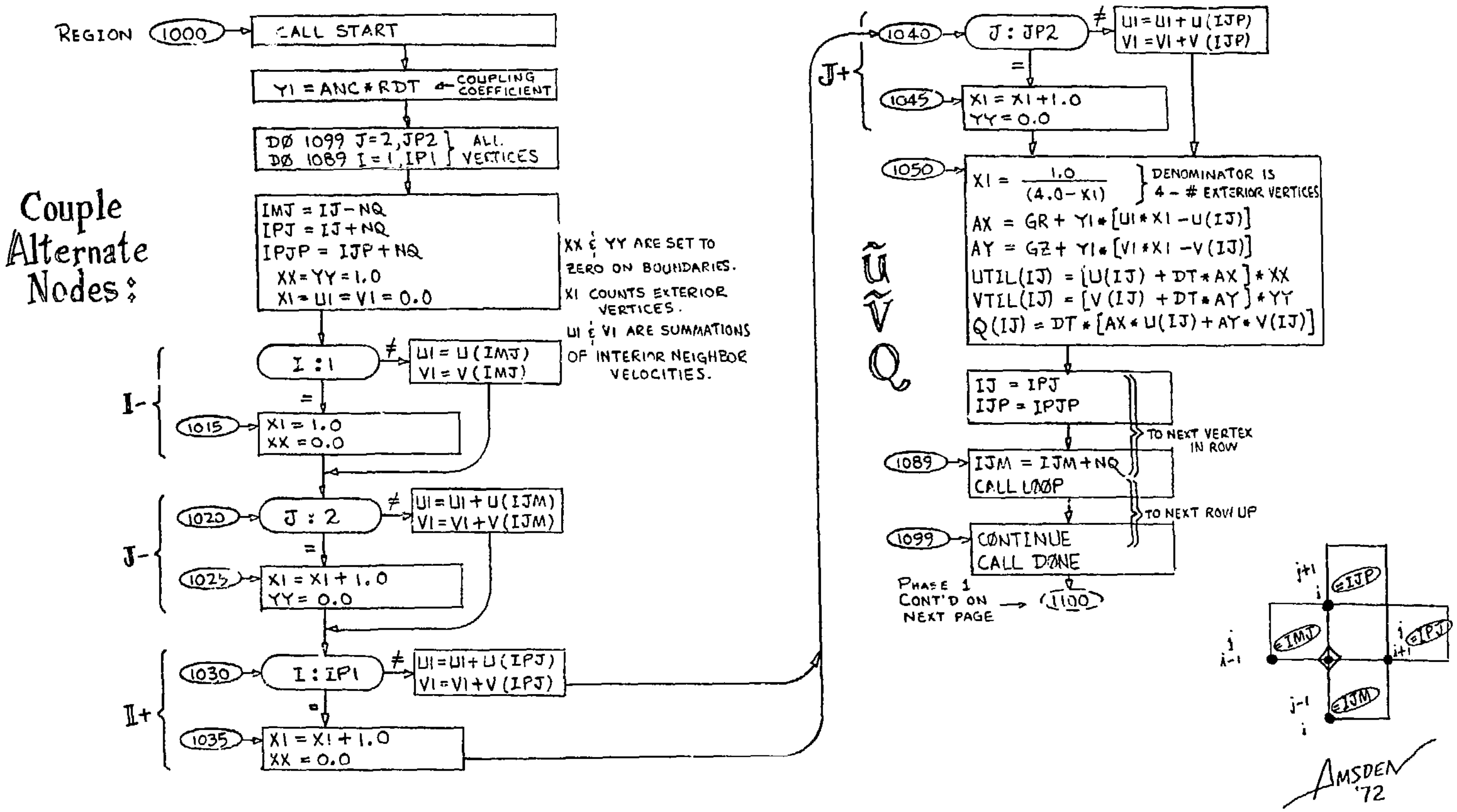
«SUBROUTINE YAQUI2» CONTINUED:



«SUBROUTINE YAQUI2» CONTINUED:

PHASE-1 CALCULATION – PAGE 1

INITIALIZE VERTEX VALUES OF ũ, ṽ, Q:



«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,JPI    } 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
```

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^j)^ξ
AK = RØ(IJ)**KXI  → (1140)
```

COMPUTE EFFECTIVE λ & μ FOR CELL:

$$\left\{ \begin{array}{l} (\lambda_{EFF})_i^j = k\lambda_{INPUT} \\ (\mu_{EFF})_i^j = k\mu_{INPUT} \end{array} \right.$$

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)
```

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

```
KXI < 0
  AND
DT < DTPØS
```

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

YES:
```
AK = RØ(IJ)*CØLAMU*(.5*DTFØS*VELIJ + VELMX)
```

NO: δt_V
```
DQ = [ RØ(IJ)*ØMANC*XX*YY / (2.*AK*(LAM+2.*MU)*(XX+YY)+EMIO) ]
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  PIXX = MUØ2 * RVØL(IJ)*[R12*U12*Y21 + R23*U23*Y32
                  +R34*U34*Y43 + R41*U41*Y14
                  -.5*CYL*(U12+U34)*XY] + LAMD
Π_yy  PIYY = MUØ2 * RVØL(IJ)*[R12*V12*X12 + R23*V23*X23
                  +R34*V34*X34 + R41*V41*X41]+LAMD
Π_xy  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]
Π_θ   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:

ũ
```
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)
```
ṽ
```
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-NQ1B)
         = UTIL(IJ-NQ1B) = 0.0
```
J:2 >

= RESET Ṽ'S ON BOTTOM:
```
      DØ 1210 IJ = ISC2, ISCF2, NQ
1210  VTIL(IJ) = 0.0
```
Ṽ'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 Ṽ'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  CONTINUE
      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. LOØP, 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
```
$\langle \tilde{E} \rangle$
```
ETIL(IJ) = E(IJ) + .25 * [Q(IPJ)+Q(IPJP)+Q(IJP)+Q(IJ)]
RØL(IJ) = RØ(IJ)
```
ρ_L, $1/c^2$
```
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(IPJ)-Y(IJP)]**2
DELSM(IJ) = DT8 * [XX+YY / XX*YY]
IJ = IPJ
```
$2\delta t\left(\frac{1}{\Delta r^2}+\frac{1}{\Delta z^2}\right)$

```
1389  IJP = IPJP
      CALL LØØP
1399  CONTINUE
      CALL DØNE
```
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.

TO Ẽ CALCULATION → (1500) NEXT PAGE →

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«SUBROUTINE YAQUI2» CONTINUED:

PHASE-1 CALCULATION - PAGE 4

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

```
(1500) CALL START
         DØ 1599 J=2,JP1       } ALL CELL
         DØ 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
```

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

```
MR = ML = MT = MB = MC = RØ(IJ)/RVØL(IJ)   } INITIALIZE NEIGHBOR
PR = PLE = PT = PB = PC = P(IJ)            } VALUES = ij VALUES...
```

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

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

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

```
(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) - DTØ4/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 LØØP

(1599) CØNTINUE
       CALL DØNE

(2000) TO PHASE 2, NEXT PAGE →
```

($\tilde{E}$)

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:

$u_L = \tilde{u}$, $v_L = \tilde{v}$, $p_L = {}^n p$ } BUT - THESE ARE IN SAME STORAGE WORDS, THUS NO STORAGE TRANSFER IS REQUIRED. ⇒ UL ≡ UTIL, VL ≡ VTIL, PL ≡ P } REFER TO FIG. 9 — STORAGE ALLOCATION

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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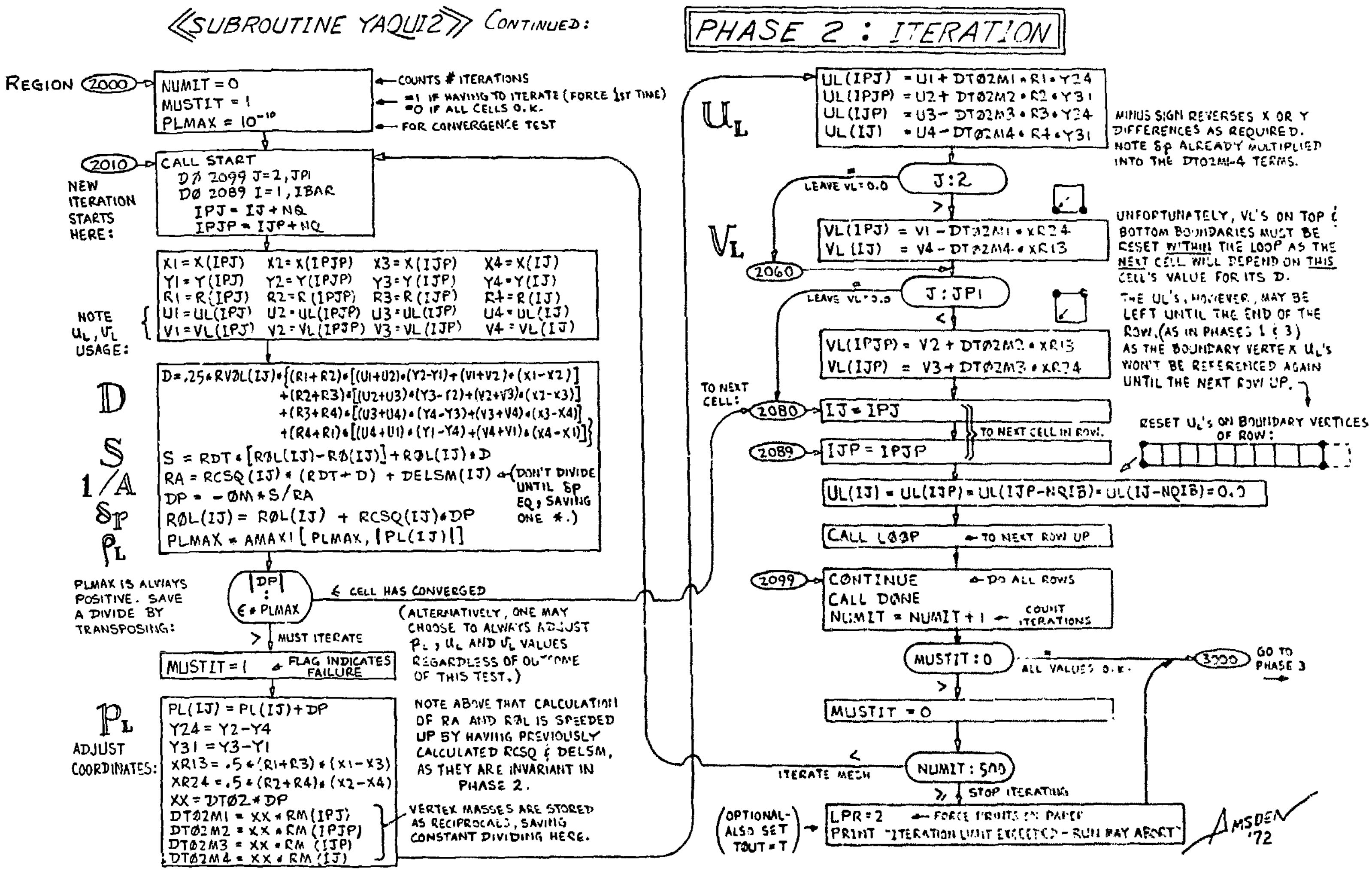
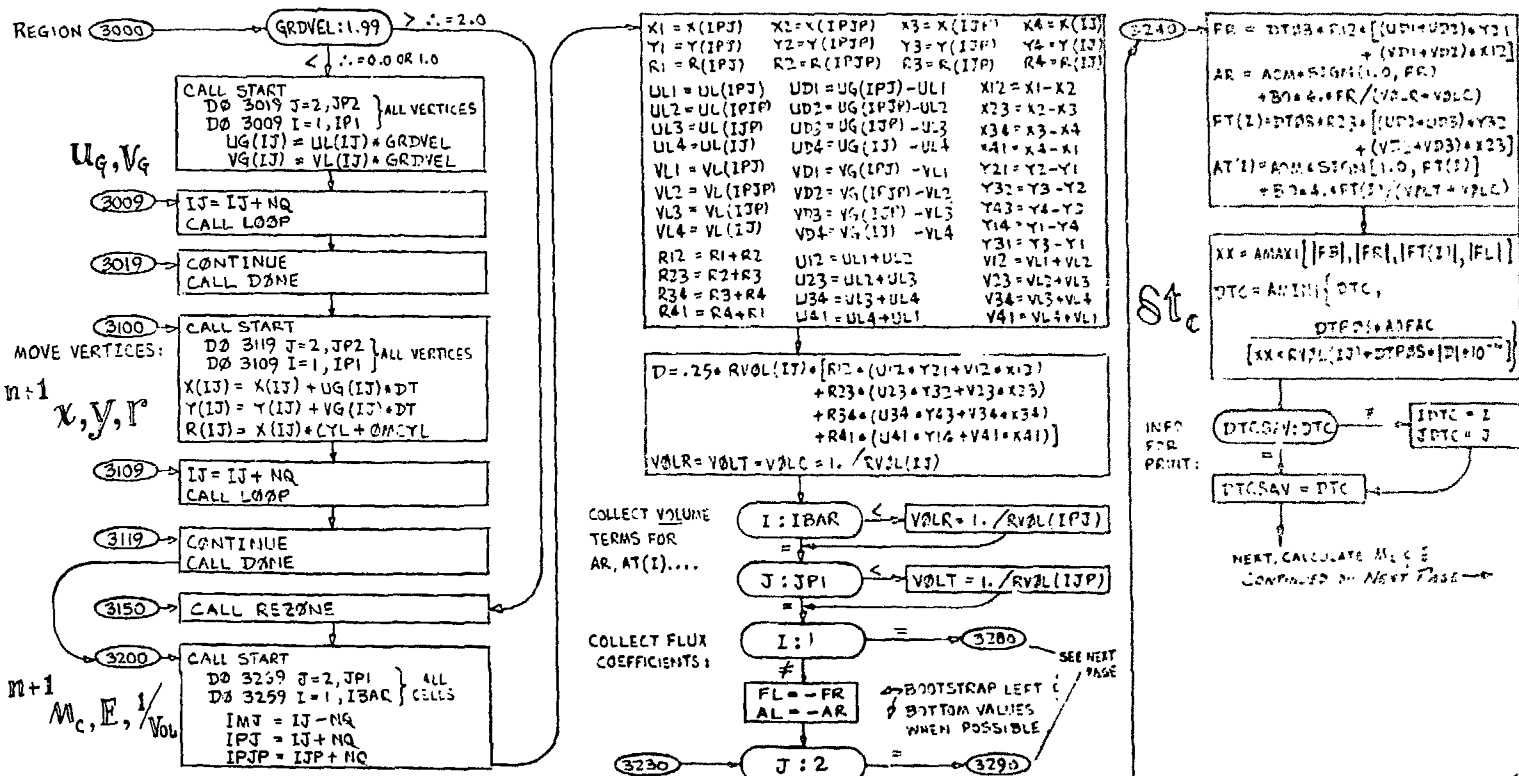

《SUBROUTINE YAQUI2》 CONTINUED:
PHASE 2 : ITERATION
REGION 2000
NUMIT = 0
MUSTIT = 1
PLMAX = 10^-10
COUNTS # ITERATIONS
=1 IF HAVING TO ITERATE (FORCE 1ST TIME)
=0 IF ALL CELLS O.K.
FOR CONVERGENCE TEST
2010
NEW ITERATION STARTS HERE:
CALL START
DØ 2099 J=2,JP1
DØ 2089 I=1,IBAR
IPJ = IJ + NQ
IPJP = IJP + 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 = UL(IPJ) U2 = UL(IPJP) U3 = UL(IJP) U4 = UL(IJ)
V1 = VL(IPJ) V2 = VL(IPJP) V3 = VL(IJP) V4 = VL(IJ)
NOTE UL, VL USAGE:
D
S
1/A
δp
ρL
D = .25*RVØL(IJ)*{(R1+R2)*[(U1+U2)*(Y2-Y1)+(V1+V2)*(X1-X2)]
+(R2+R3)*[(U2+U3)*(Y3-Y2)+(V2+V3)*(X2-X3)]
+(R3+R4)*[(U3+U4)*(Y4-Y3)+(V3+V4)*(X3-X4)]
+(R4+R1)*[(U4+U1)*(Y1-Y4)+(V4+V1)*(X4-X1)]}
S = RDT*[RØL(IJ)-RØ(IJ)]+RØL(IJ)*D
RA = RCSQ(IJ)*(RDT+D) + DELSM(IJ)
DON'T DIVIDE UNTIL δp EQ; SAVING ONE *.
DP = -ØM*S/RA
RØL(IJ) = RØL(IJ) + RCSQ(IJ)*DP
PLMAX = AMAX1[PLMAX, |PL(IJ)|]
PLMAX IS ALWAYS POSITIVE. SAVE A DIVIDE BY TRANSPOSING:
|DP| : ε*PLMAX
≤ CELL HAS CONVERGED
> MUST ITERATE
(ALTERNATIVELY, ONE MAY CHOOSE TO ALWAYS ADJUST ρL, UL AND VL VALUES REGARDLESS OF OUTCOME OF THIS TEST.)
MUSTIT = 1
FLAG INDICATES FAILURE
PL
ADJUST COORDINATES:
PL(IJ) = PL(IJ)+DP
Y24 = Y2-Y4
Y31 = Y3-Y1
XR13 = .5*(R1+R3)*(X1-X3)
XR24 = .5*(R2+R4)*(X2-X4)
XX = DTØ2*DP
DTØ2M1 = XX*RM(IPJ)
DTØ2M2 = XX*RM(IPJP)
DTØ2M3 = XX*RM(IJP)
DTØ2M4 = XX*RM(IJ)
NOTE ABOVE THAT CALCULATION OF RA AND RØL IS SPEEDED UP BY HAVING PREVIOUSLY CALCULATED RCSQ & DELSM, AS THEY ARE INVARIANT IN PHASE 2.
VERTEX MASSES ARE STORED AS RECIPROCALS, SAVING CONSTANT DIVIDING HERE.
UL
UL(IPJ) = U1 + DTØ2M1*R1*Y24
UL(IPJP) = U2 + DTØ2M2*R2*Y31
UL(IJP) = U3 - DTØ2M3*R3*Y24
UL(IJ) = U4 - DTØ2M4*R4*Y31
MINUS SIGN REVERSES X OR Y DIFFERENCES AS REQUIRED. NOTE δp ALREADY MULTIPLIED INTO THE DTØ2M1-4 TERMS.
J:2
= LEAVE VL=0.0
VL
VL(IPJ) = V1 - DTØ2M1*XR24
VL(IJ) = V4 - DTØ2M4*XR13
UNFORTUNATELY, VL'S ON TOP & BOTTOM BOUNDARIES MUST BE RESET WITHIN THE LOOP AS THE NEXT CELL WILL DEPEND ON THIS CELL'S VALUE FOR ITS D.
2060
J:JP1
= LEAVE VL=0.0
THE UL'S, HOWEVER, MAY BE LEFT UNTIL THE END OF THE ROW, (AS IN PHASES 1 & 3) AS THE BOUNDARY VERTEX UL'S WON'T BE REFERENCED AGAIN UNTIL THE NEXT ROW UP.
VL(IPJP) = V2 + DTØ2M2*XR13
VL(IJP) = V3 + DTØ2M3*XR24
TO NEXT CELL:
2080
IJ = IPJ
TO NEXT CELL IN ROW.
2089
IJP = IPJP
RESET UL'S ON BOUNDARY VERTICES OF ROW:
UL(IJ) = UL(IJP) = UL(IJP-NQIB) = UL(IJ-NQIB) = 0.0
CALL LØØP
TO NEXT ROW UP
2099
CONTINUE
DO ALL ROWS
CALL DØNE
NUMIT = NUMIT + 1
COUNT ITERATIONS
MUSTIT : 0
= ALL VALUES O.K.
3000
GO TO PHASE 3
MUSTIT = 0
NUMIT : 500
< ITERATE MESH
> STOP ITERATING
(OPTIONAL - ALSO SET TOUT = T)
LPR = 2
FORCE PRINTS ON PAPER
PRINT "ITERATION LIMIT EXCEEDED - RUN MAY ABORT"
AMSDEN '72

«SUBROUTINE YAQUI2» CONTINUED: PHASE-3 CALCULATION - PAGE 1

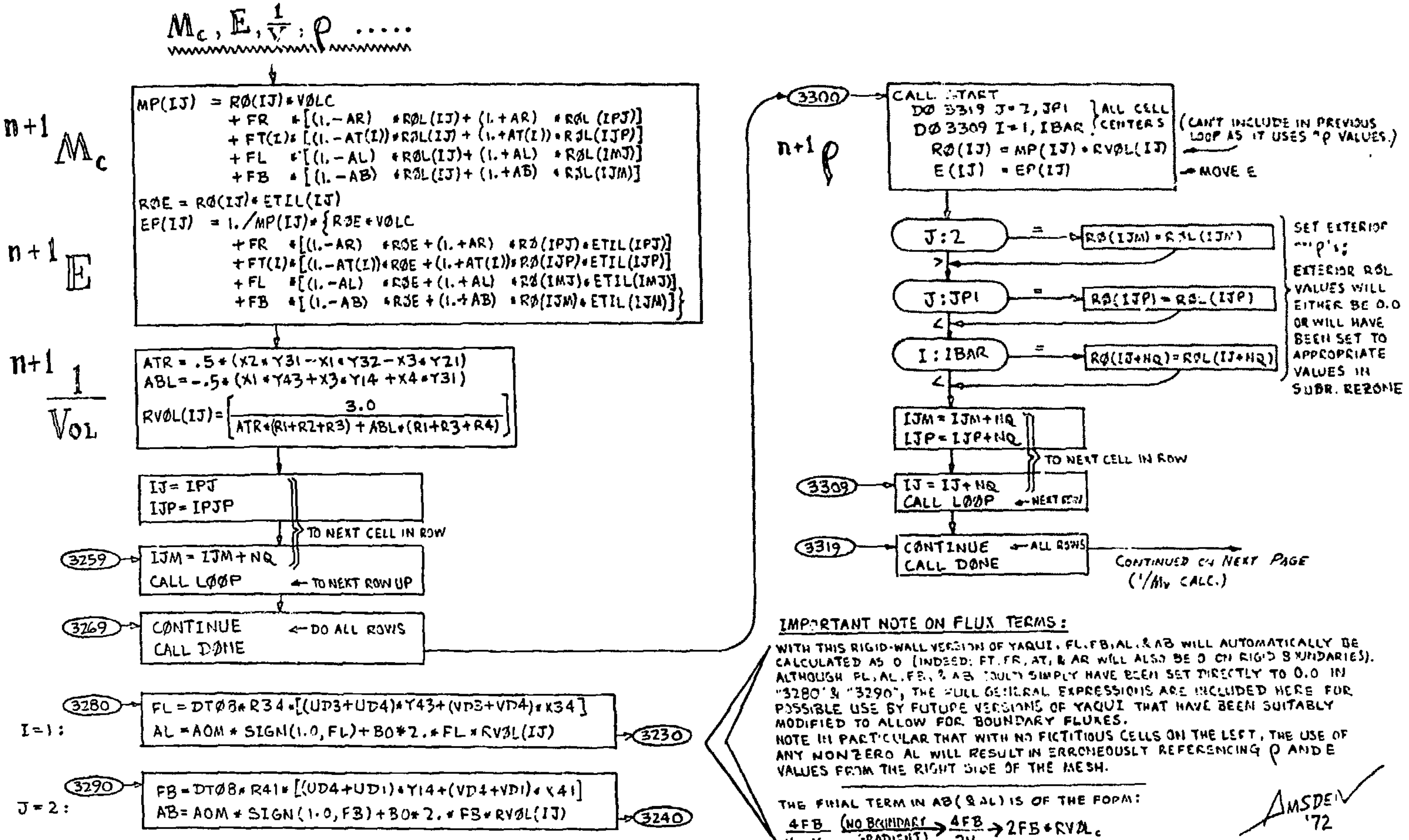
CALCULATE "n+1" VALUES OF $x, y, r, M_c, E, \frac{1}{V}, \rho$



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.

August '72

«SUBROUTINE YAQUI2» CONTINUED: PHASE-3 CALCULATION – PAGE 2



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:

$$\frac{4FB}{V_B+V_C} \xrightarrow{\text{(NO BOUNDARY GRADIENT)}} \frac{4FB}{2V_C} \rightarrow 2FB*RVØL_C$$

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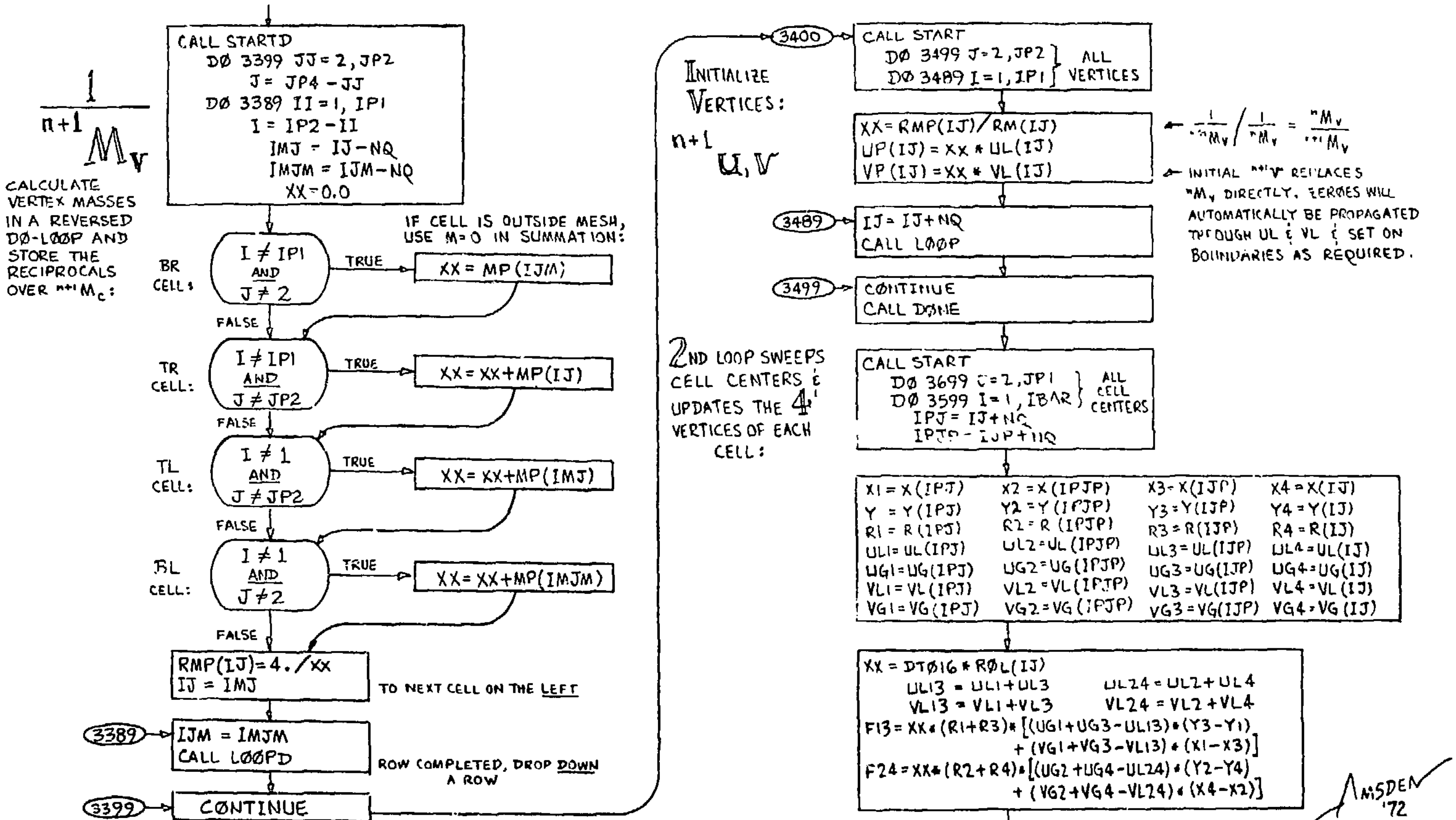
≪SUBROUTINE YAQUI2≫ CONTINUED:

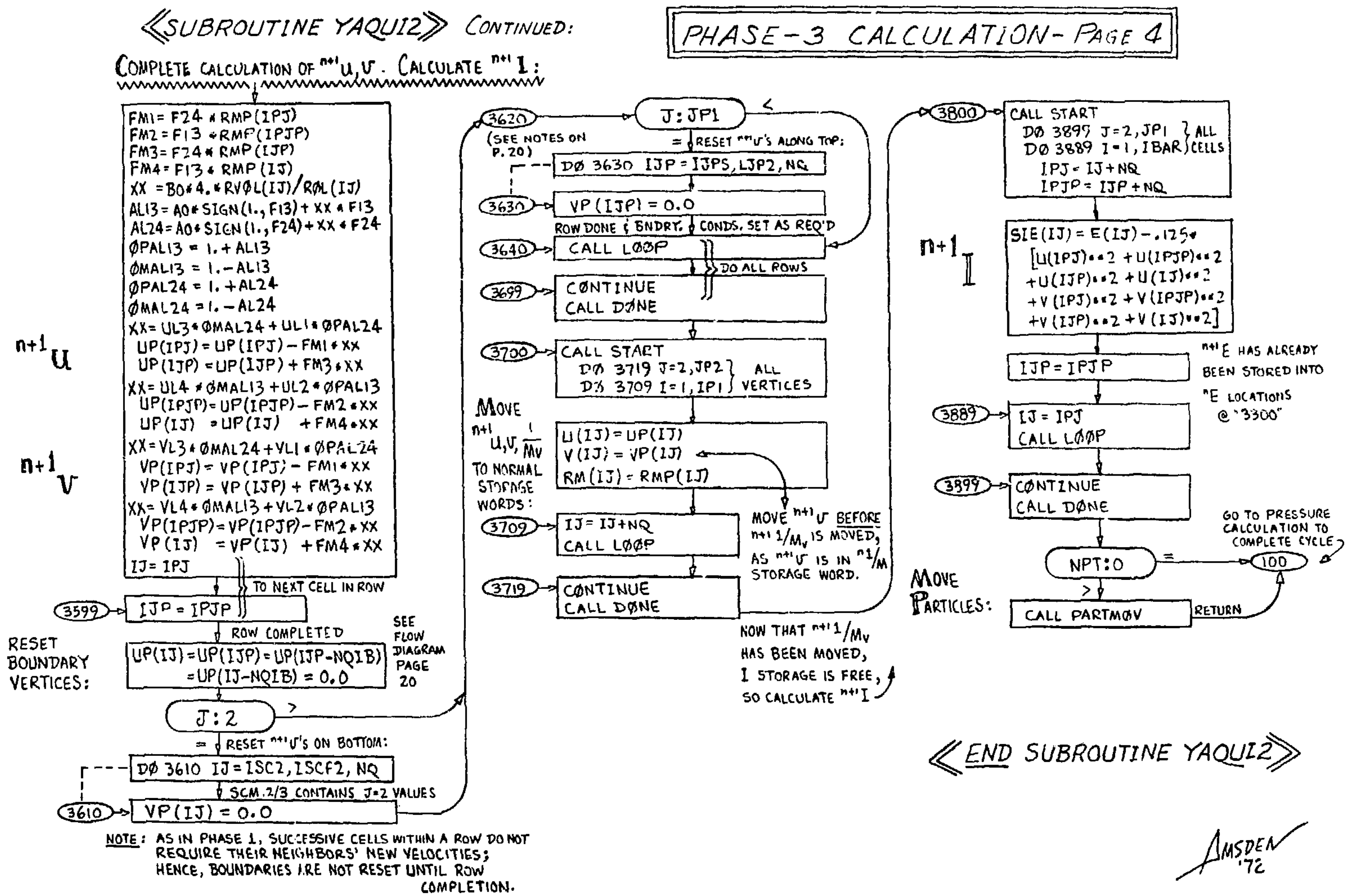
PHASE-3 CALCULATION - PAGE 3

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

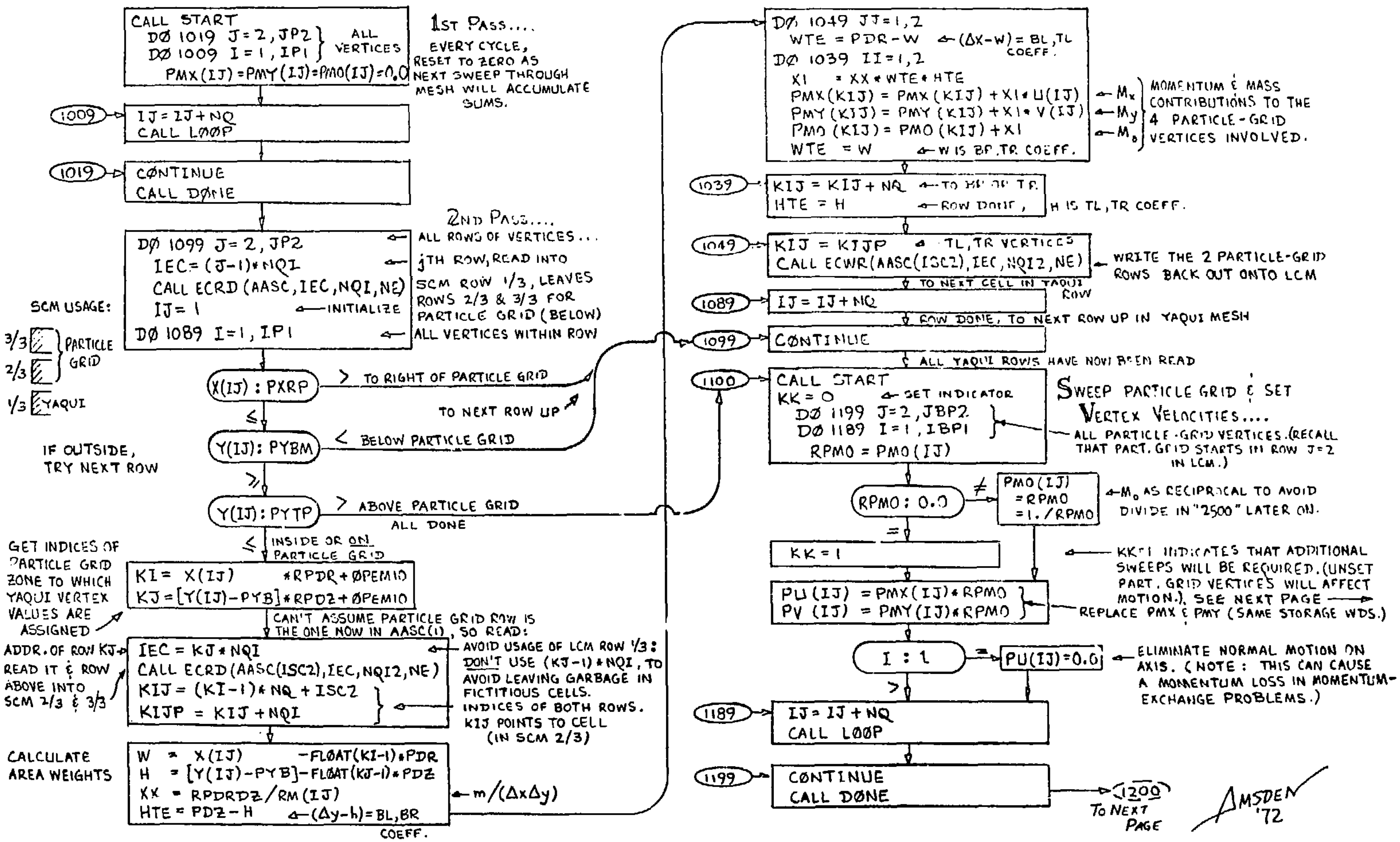


CONTINUED ON NEXT PAGE →

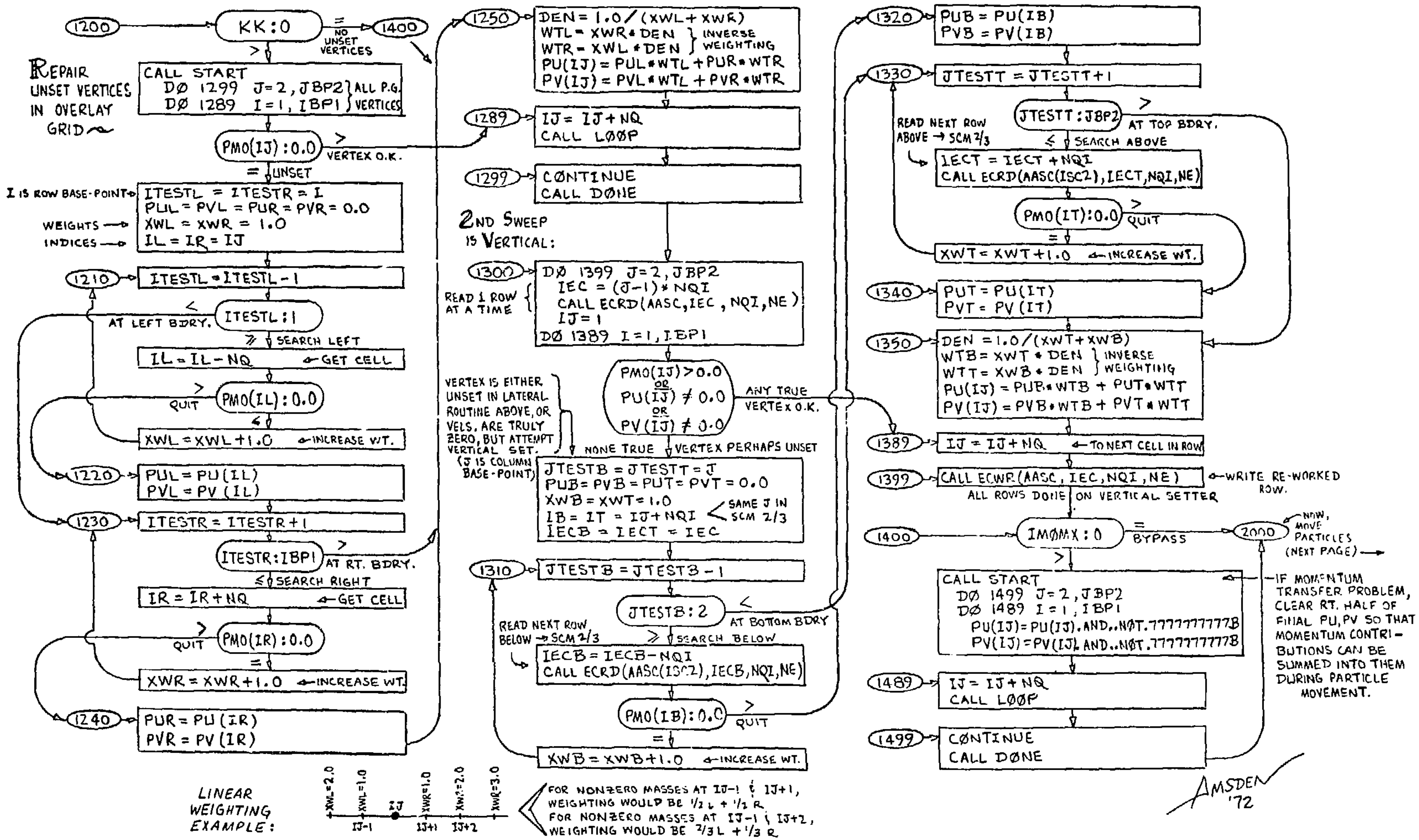
AMSDEN '72


«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
n+1 u
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
n+1 v
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
TO NEXT CELL IN ROW
3599 IJP = IPJP
ROW COMPLETED
RESET BOUNDARY VERTICES:
UP(IJ)=UP(IJP)=UP(IJP-NQIB) =UP(IJ-NQIB) = 0.0
SEE FLOW DIAGRAM PAGE 20
J:2
>
= RESET n+1 v's ON BOTTOM:
DØ 3610 IJ=ISC2,ISCF2,NQ
SCM 2/3 CONTAINS J=2 VALUES
3610 VP(IJ) = 0.0
NOTE: AS IN PHASE 1, SUCCESSIVE CELLS WITHIN A ROW DO NOT REQUIRE THEIR NEIGHBORS' NEW VELOCITIES; HENCE, BOUNDARIES ARE NOT RESET UNTIL ROW COMPLETION.
3620 (SEE NOTES ON P.20)
J:JP1
<
= RESET n+1 v's ALONG TOP:
DØ 3630 IJP = IJPS,IJP2,NQ
3630 VP(IJP) = 0.0
ROW DONE & BNDRY. CONDS. SET AS REQ'D
3640 CALL LØØP
DO ALL ROWS
3699 CØNTINUE
CALL DØNE
3700 CALL START
DØ 3719 J=2,JP2 } ALL
DØ 3709 I=1,IP1 } VERTICES
MOVE n+1 u,v, 1/Mv TO NORMAL STORAGE WORDS:
U(IJ) = UP(IJ)
V(IJ) = VP(IJ)
RM(IJ) = RMP(IJ)
MOVE n+1 v BEFORE n+1 1/Mv IS MOVED, AS n+1 v IS IN n 1/M STORAGE WORD.
3709 IJ= IJ+NQ
CALL LØØP
3719 CØNTINUE
CALL DØNE
NOW THAT n+1 1/Mv HAS BEEN MOVED, I STORAGE IS FREE, SO CALCULATE n+1 I
3800 CALL START
DØ 3899 J=2,JP1 } ALL
DØ 3889 I=1,IBAR } CELLS
IPJ= IJ+NQ
IPJP= IJP+NQ
n+1 I
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
n+1 E HAS ALREADY BEEN STORED INTO n E LOCATIONS @ "3300"
3889 IJ = IPJ
CALL LØØP
3899 CØNTINUE
CALL DØNE
GO TO PRESSURE CALCULATION TO COMPLETE CYCLE
NPT:0
=
100
>
MOVE PARTICLES:
CALL PARTMØV
RETURN
«END SUBROUTINE YAQUI2»
AMSDEN '72

«SUBROUTINE PARTMØV»



«SUBROUTINE PARTMØV» - PAGE 2



«SUBROUTINE PARTMØV» - PAGE 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.

READ PARTICLES INTO SCM 1/3:
(2010)
CALL ECRD (AASC, IECP, LPB, NE)
KP = 1 ← PARTICLE INDEX IN SCM 1/3

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

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.

READ 2 ROWS INTO SCM 2/3 & 3/3 →
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)

THE 4 VERTICES OF PART.-GRID CELL:
(2030)
IJ = (I−1) * NQ + ISC2
IPJ = IJ + NQ
} THESE 2 ARE IN SCM 2/3
IJP = IJ + NQI
IPJP = IPJ + NQI
} THESE 2 ARE IN SCM 3/3.

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

GET INTERPOLATED VELOCITIES (UK, VK) FOR MOVING PARTICLE:
X1 = PDRMW * PDZMH
X2 = W * PDZMH
X3 = PDRMW * H
X4 = W * H
} AREA WEIGHTS

(cell sketch: corners 1, 2, 3, 4; w, h)

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

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

UPAR = SHIFT(XTE, 30)
VPAR = SHIFT(YTE, 30)
} VELOCITIES TO LEFT 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

MOVE PARTICLES IN RELATION TO OVERLAY GRID

UPAR = [UPAR + DTDRAG * (UK + URAND) + DTGR] * RDTDRG
VPAR = [VPAR + DTDRAG * (VK + VRAND) + DTGZP] * RDTDRG
} CALCULATE NEW PARTICLE VELOCITY
XTE = XTE + DT * UPAR
YTE = YTE + DT * VPAR
} MOVE PARTICLE
USH = SHIFT (UPAR, 30).AND.7777777777B
VSH = SHIFT (VPAR, 30).AND.7777777777B
} U & V TO RT. SIDE OF X & Y, RESP.
XPAR(KP) = (XTE.AND..NØT.7777777777B).ØR.USH
YPAR(KP) = (YTE.AND..NØT.7777777777B).ØR.VSH
} COMBINE & 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 ← $M_0 \delta t \eta / (\Delta x \Delta y)$
KIJ = IJ
KK = 0
} INITIALIZE FOR DO-LOOP....
DØ 2149 JJ = 1, 2
DØ 2139 II = 1, 2
} OVER QUADRANT OF 4 PARTICLE-GRID VERTICES
KK = KK + 1
XI = XI(KK) * H ← XI CONTAINS "wh" FACTORS AS SET IN "2030"
PUL = PU(KIJ)
PVL = PV(KIJ)
} GET PARTICLE GRID PU, PV
XX = [SHIFT (PUL, 30)] + XI * (UK − UPAR + URAND)
YY = [SHIFT (PVL, 30)] + XI * (VK − VPAR + VRAND)
} CONTRIBUTE TO MOMENTUM SUMS
PU(KIJ) = (PUL.AND..NØT.7777777777B) .ØR.(SHIFT(XX, 30).AND.7777777777B)
PV(KIJ) = (PVL.AND..NØT.7777777777B) .ØR.(SHIFT(YY, 30).AND.7777777777B)
} RECOMBINE WITH PU & PV & STORE THEM.

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

(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 →

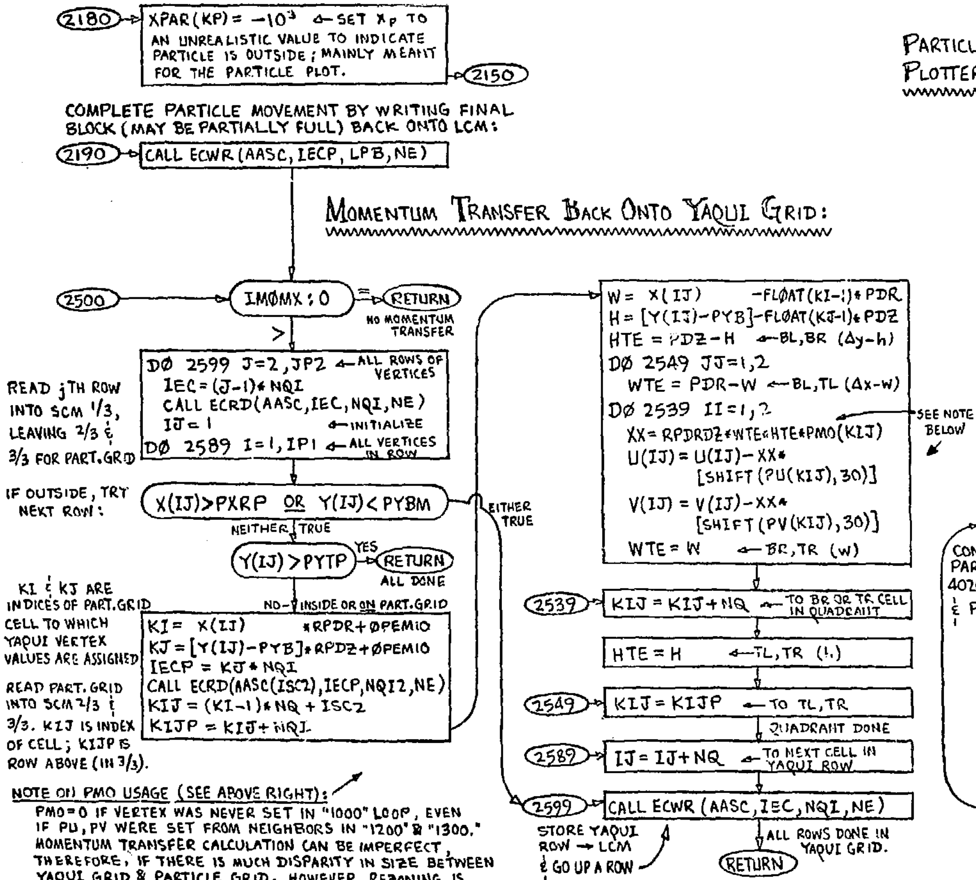
< ↓ MORE TO BE MOVED
KP = KP + 3 ← INCREMENT BUFFER INDEX

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)

AMSDEN '72

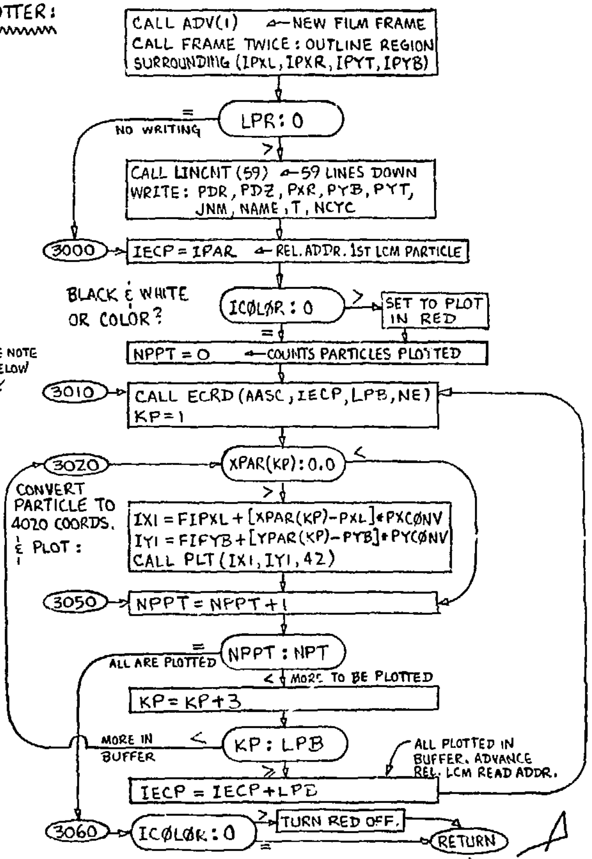
<<SUBROUTINE PARTMØV>> - PAGE 4



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.

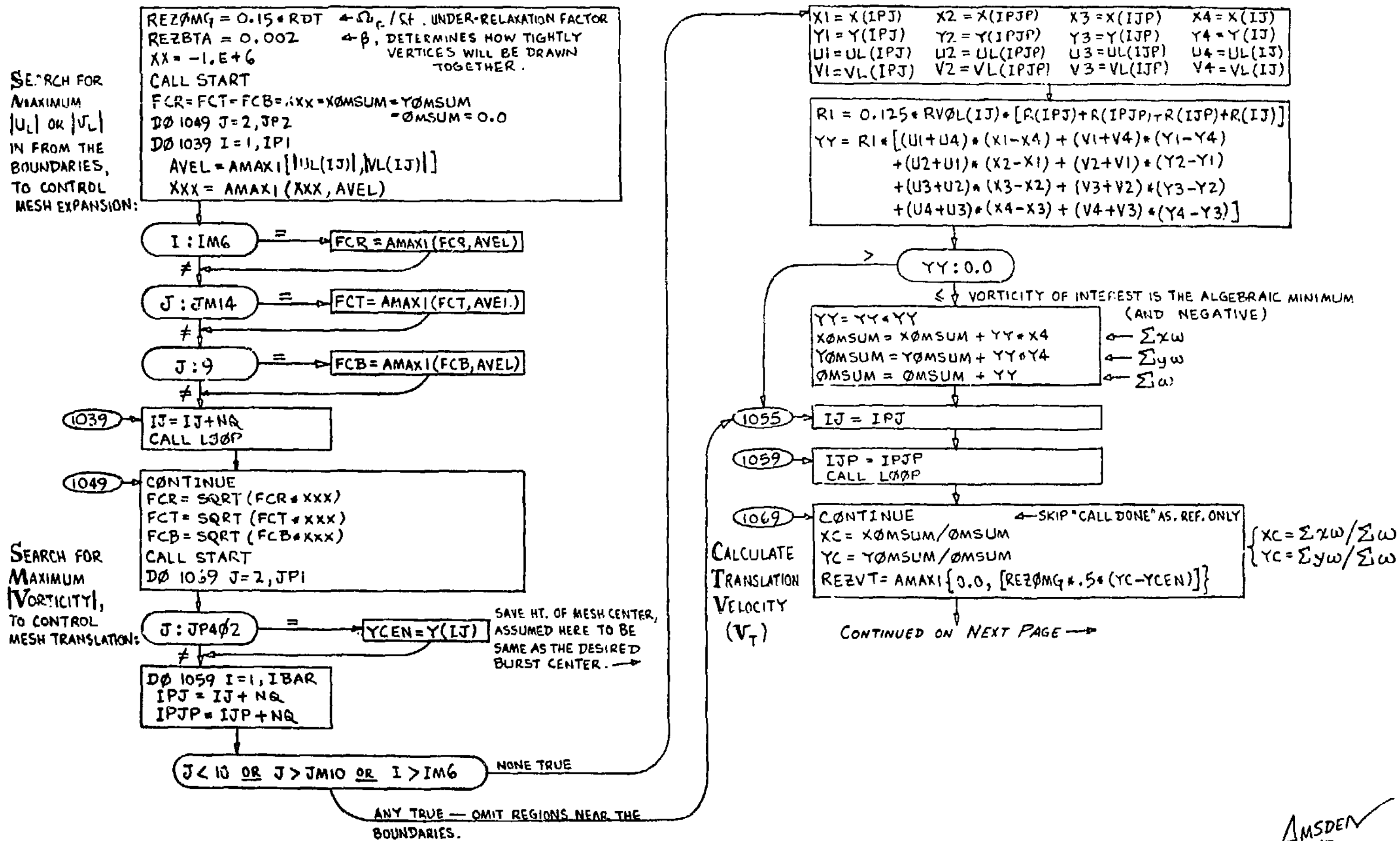
<<ENTRY PARPLOT>>

PARTICLE PLOTTER:



<<END SUBROUTINE PARTMOV>>

⟪SUBROUTINE REZONE⟫



CONTINUED ON NEXT PAGE →

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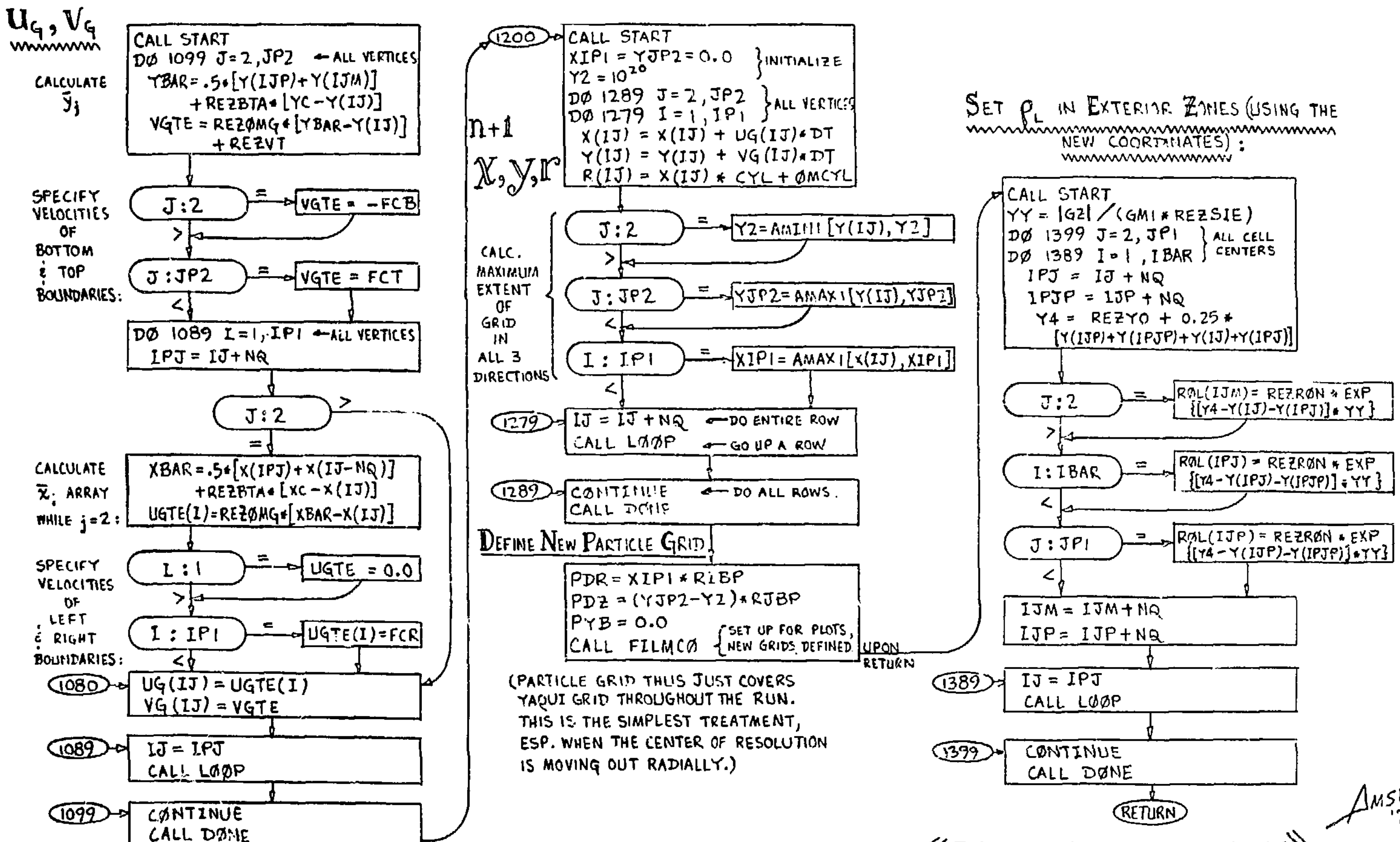
<<SUBROUTINE REZONE>> - PAGE 2



<<END SUBROUTINE REZONE>>

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APPENDIX B

FORTRAN IV INDEX LISTING OF THE YAQUI PROGRAM

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

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INDEX   01/12/73   PROGRAM YAQUI(INP,OUT,FILM,FSET9=OUT,FSET12=FILM,FSET7,FSET8)                      PAGE     2
                         PROGRAM YAQUI(INP,OUT,FILM,FSET9=OUT,FSET12=FILM,FSET7,FSET8)                YAQUI    00003
                         LCM /YLC1/   AA1(131000)   /YLC2/ AA2(131000)                                YAQUI    00004
                         COMMON /YSC1/ AASC(4242)                                                     COMMON2  00002
                         COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,A0M,B0,COLAMU,CYL,                      COMMON2  00003
                    1          DR,DT,DT ,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,NQ1,NQIB,NQ12,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,RJBF,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
                         NQ = 14                                                                      YAQUI    00007
                         PRINT 100                                                                    YAQUI    00008
                10       READ 110, IBAR,JBAR,IUNF,JUNF,JCEN,DR,DZ,CYL,GRDVEL,A0,A0M,B0,KXI            YAQUI    00009
                         CALL ADV (3)                                                                 YAQUI    00010
                         CALL LINCNT (64)                                                             YAQUI    00011
                         IF (IBAR) 40,30,20                                                           YAQUI    00012
                20       CALL OVERLAY (7LYAQUFIL,1,0,0)                                               YAQUI    00013
                30       CALL OVERLAY (7LYAQUFIL,2,0,0)                                               YAQUI    00014
                         GO TO 10                                                                     YAQUI    00015
                40       CALL EMPTY                                                                   YAQUI    00016
                C                                                                                     YAQUI    00017
                100      FORMAT (1H1)                                                                 YAQUI    00018
                110      FORMAT (5I4,/F8.3,I4)                                                        YAQUI    00019
                         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
 A0FAC    -R    4CO   FIPYB    -R   4CO   IM6      -I   4CO   LCM      -    2F    P        -R   5EQ   REZVT    -R   4CO   VG       -R   5FQ
 COLAMU   -R    4CO   FIPYT    -R   4CO   INP      -I   1AG   LINCNT   -    11SU  PDR      -R   4CO   REZY0    -R   4CO   VL       -R   5FQ
 CQ       -R    5EQ   FIXL     -R   4CO   IPAR     -I   4CO   LJP2     -I   4CO   POZ      -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   5FQ
 OT       -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   PM0      -R   5EQ   RM       -R   5EQ   XCONV    -R   4CO
 DTC2     -R    4CO   FREZ     -R   4CO   IP1      -I   4CO   ML       -R   6RL   PRINT    -    8F    RMP      -R   5EQ   XL       -R   4CO
 OTGZ     -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
 DT016    -R    4CO   GGM1     -R   4CO   ISC3     -I   4CO   MU04     -R   6RL   PXR      -R   4CO   RPDR     -R   4CO   YB       -R   4CO
 DT02     -R    4CO   GM1      -R   4CO   ITV      -I   4CO   NAME     ()I   4CO   PXRP     -R   4CO   RPDRDZ   -R   4CO   YCONV    -R   4CO
 DT04     -R    4CO   GR       -R   4CO   IXL      -I   4CO   NCYC     -I   4CO   PYB      -R   4CO   RPDZ     -R   4CO   YLC1     -    2CN
 DT08     -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
 EM10     -R    4CO   IDTO     -I   4CO   JM10     -I   4CO   NSC      -I   4CO   RCSQ     -R   5EQ   TWFIN    -R   4CO
 EP       -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
A0       -R   4CO   9RD
A0M      -R   4CO   9RD
B0       -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
KXT      -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
NQ       -I   4CO   7=
OUT      -R   1AG   1AG
OVERLAY  -    13SU  14SU
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INDEX  01/12/73                SUBROUTINE LOOP                                    PAGE   5
               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       DTO16,DTO2,DTO4,DTO8,DTPOS,DTV,DTB,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,NQI8,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,TZOMD,        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 = I                                                     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
```

```
          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 R1ROW                                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 W1ROW                                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   DTOR    -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   3CC   PYTP    -R   3CO   THIRD   -R  3CO
  A0     -R    3CO   DTB     -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   IDTD   -I   3CO   JMI4   -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   WIROW   -  74SU
  DONE   -    31SU   FIPXR   -R   3CO   IM1    -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   RIRJB   -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   POZ     -R   3CO   RON     -R   3CO   YSC2    -  3CN
  DTGZP  -R    3CO   FJBP    -R   3CO   IP1    -I   3CO   LOOP   -    1SU   PXCONV  -R   3CO   RPDR    -R   3CO   YT      -R  3CO
  DTO    ()R   3CO   FREZ    -R   3CO   IP2    -I   3CO   LOOPD  -   42SU   PXL     -R   3CO   RPDRDZ  -R   3CO   ZZ      -R  3CO
  DTOC   ()R   3CO   GGM1    -R   3CO   IUNF   -I   3CO   LPB    -I   3CO   PXR     -R   3CO   RPDZ    -R   3CO
  DTO16  -R    3CO   GM1     -R   3CO   IXL    -I   3CO   LPR    -I   3CO   PXRP    -R   3CO   RIROW   -  67SU
  DTO2   -R    3CO   GR      -R   3CO   IXR    -I   3CO   MU     -I   3CO   PYB     -R   3CO   SETIJ   -  71SU
  DTO4   -R    3CO   GROVEL  -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
ENTRY   -      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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      SUBROUTINE FILMCO                                                  YAQUI    00098
      COMMON /YSC1/ AASC(4242)                                           COMMON2  00002
      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,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,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,NQIR,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
      XL = 0.0                                                           YAQUI    00102
      YB = 1.E+20                                                        YAQUI    00103
      XR = YT = -YB                                                      YAQUI    00104
      CALL START                                                         YAQUI    00105
      DO 129 J=2,JP2                                                     YAQUI    00106
      DO 119 I=1,IP1                                                     YAQUI    00107
      XR = AMAX1(XR,X(IJ))                                               YAQUI    00108
      YB = AMIN1(YB,Y(IJ))                                               YAQUI    00109
      YT = AMAX1(YT,Y(IJ))                                               YAQUI    00110
  119 IJ = IJ + NQ                                                       YAQUI    00111
      CALL LOOP                                                          YAQUI    00112
  129 CONTINUE                                                           YAQUI    00113
      VV = 0.9*XR*RIBAR                                                  YAQUI    00114
      FIYB = 916.0                                                       YAQUI    00115
      XD  = XR/(YT-YB)                                                   YAQUI    00116
      YY    = 0.0                                                        YAQUI    00117
      IF (XD.LE.1.13556) YY=1.                                           YAQUI    00118
      FIXL = AMAX1(0.,(511.-450.*XD)*YY)                                 YAQUI    00119
      FIXR = (511.+450.*XD)*YY + 1022.*(1.-YY)                           YAQUI    00120
      FIYT = 16.*YY  + (916.-1022./XD)*(1.-YY)                           YAQUI    00121
      XCONV = (FIXR-FIXL)/(XR-XL)                                        YAQUI    00122
      YCONV = (FIYT-FIYB)/(YT-YB)                                        YAQUI    00123
      IXL = FIXL                                                         YAQUI    00124
      IXR = FIXR                                                         YAQUI    00125
      IYB = FIYB                                                         YAQUI    00126
      IYT = FIYT                                                         YAQUI    00127
      IF (NPT.EQ.0) RETURN                                               YAQUI    00128
      PXL = 0.0                                                          YAQUI    00129
      PYB = YB + PYB                                                     YAQUI    00130
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      PXR = PDR*FIBP                                                    YAQUI  00131
      PYT = PYB + PDZ*FJBP                                              YAQUI  00132
      PXRP = PXR*OPEM10                                                 YAQUI  00133
      PYBM = PYB*OMEM10                                                 YAQUI  00134
      PYTP = PYT*OPEM10                                                 YAQUI  00135
      RPDR = 1./PDR                                                     YAQUI  00136
      RPDZ = 1./PDZ                                                     YAQUI  00137
      RPDRDZ = RPDR*RPDZ                                                YAQUI  00138
      FIPYB = 916.0                                                     YAQUI  00139
      XD = PXR/(PYT-PYB)                                                YAQUI  00140
      YY = 0.0                                                          YAQUI  00141
      IF (XD.LE.1.13556) YY=1.                                          YAQUI  00142
      FIPXL = AMAX1(0.,(511.-450.*XD)*YY)                               YAQUI  00143
      FIPXR = (511.+450.*XD)*YY + 1022.*(1.-YY)                         YAQUI  00144
      FIPYT = 16.*YY + (916.-1022./XD) *(1.-YY)                         YAQUI  00145
      PXCONV = (FIPXR-FIPXL)/(PXR-PXL)                                  YAQUI  00146
      PYCONV = (FIPYT-FIPYB)/(PYT-PYB)                                  YAQUI  00147
      IPXL = FIPXL                                                      YAQUI  00148
      IPXR = FIPXR                                                      YAQUI  00149
      IPYB = FIPYB                                                      YAQUI  00150
      IPYT = FIPYT                                                      YAQUI  00151
      RETURN                                                            YAQUI  00152
      END                                                               YAQUI  00153
```

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 INDEX  01/12/73                                  SUBROUTINE FILMCO                                                  PAGE  11
SINGLY REFERENCED VARIABLES
 AA       ()R   3CO   DTO      ()R   3CO   GRDVEL  -R   3CO   ISCF2   -I   3CO   LJP2    -I   3CO   NQI2    -I   3CO   ROMFR   -R   3CO
 AMINI    -    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
 ASQ      -R    3CO   DT02     -R    3CO   IBAR    -I   3CO   ITV     -I   3CO   LPR     -I   3CO   NUMTD   -I   3CO   T       -R   3CO
 AO       -R    3CO   DT04     -R    3CO   IBP     -I   3CO   IUNF    -I   3CO   MB      -R   5RL   OM      -R   3CO   THIRD   -R   3CO
 AOFAC    -R    3CO   DT08     -R    3CO   IBPI    -I   3CO   JBAR    -I   3CO   MC      -R   5RL   OMANC   -R   3CO   TLIMD   -R   3CO
 AOM      -R    3CO   DTPOS    -R    3CO   ICOLOR  -I   3CO   JBP     -I   3CO   ML      -R   5RL   OMCYL   -R   3CO   TOUT    -R   3CO
 BO       -R    3CO   DTV      -R    3CO   IDTO    -I   3CO   JBP2    -I   3CO   MR      -R   5RL   RDT     -R   3CO   TXFIN   -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 -     12D0    16*
   129 -     11D0    18*
AASC     ()R    2CO    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ    4EQ
AMAXI    -     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    12D0
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    12D0
IXL      -I     3CO    29=
IXR      -I     3CO    30=
IYB      -I     3CO    31=
IYT      -I     3CO    32=
J        -I     3CO    11D0
JP2      -I     3CO    11D0
LAM      -R     3CO    5RL
M        ()R    4EQ    5RL    6DI
MP       ()R    4EQ    5RL    6DI
MPAR     ()R    4EQ    5RL    6DI
```

```
MU       -R    3CO   5RL
NPT      -I    3CO   33
NQ       -I    3CO   16
OMEMIO   -R    3CO   39
OPEMIO   -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=
XO       -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*
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
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  1          SUBROUTINE YASET1                                                 YASET    00008
  2          LCM /YLC1/   AA1(131000)   /YLC2/ AA2(131000)                     YASET    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,DTGZ,DTGZP,DTO(10),DTOC(10),           COMMON2  00004
            2      DTO16,DTO2,DTO4,DTO8,DTPOS,DTV,DTB,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,NQIR,NQI2,NSC,      COMMON2  00012
            1      NUMIT,NUMTO,OM,OMANG,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,RIBJR,RIBP,RJBP,ROMFR,        COMMON2  00015
            4      RDN,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,PMO),(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,MUO2,MUO4           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),PMO(1)                            DIMEN    00006
  8          READ 500, NAME                                                    YASET    00013
  9          READ 510, MU,LAM,OM,EPS,GR,GZ,ASQ,RON,GM1                         YASET    00014
 10          READ 515, FREZ,YB,REZYO,REZUE,REZVE,REZVT,REZRON,REZSIE           YASET    00015
 11          READ 520, IBP,JBP,PDR,PDZ,PYB,GZP,IMOMX                           YASET    00016
 12          READ 530, T,DT,T20MD,TLIMO,TWFIN,LPR,ICOLOR                       YASET    00017
 13          READ 540, (DTO(N),N=1,10)                                         YASET    00018
 14          READ 540, (DTOC(N),N=1,10)                                        YASET    00019
 15          KT = 9                                                            YASET    00020
 16          ASSIGN 110 TO KRET                                                YASET    00021
 17   100    WRITE(KT,500) NAME                                                YASET    00022
 18          WRITE(KT,550) IBAR,JBAR,IUNF,JUNF,JCEN,DR,DZ,CYL,GRDVEL,          YASET    00023
            1              A0,A0M,R0,KXI                                       YASET    00024
 19          WRITE(KT,560) MU,LAM,OM,EPS,GR,GZ,ASQ,RON,GM1                     YASET    00025
 20          WRITE(KT,565) FREZ,YB,REZYO,REZUE,REZVE,REZVT,REZRON,REZSIE       YASET    00026
 21          WRITE(KT,570) IBP,JBP,PDR,PDZ,PYB,GZP,IMOMX                       YASET    00027
 22          WRITE(KT,580) T,DT,T20MD,TLIMD,TWFIN,LPR,ICOLOR                   YASET    00028
 23          WRITE(KT,590) (DTO(N),N=1,10)                                     YASET    00029
 24          WRITE(KT,600) (DTOC(N),N=1,10)                                    YASET    00030
 25          GO TO KRET                                                        YASET    00031
 26   110    IF (LPR.EQ.0) GOTO 120                                            YASET    00032
 27          KT = 12                                                           YASET    00033
 28          ASSIGN 120 TO KRET                                                YASET    00034
 29          GO TO 100                                                         YASET    00035
 30   120    IM1  = IBAR - 1                                                   YASET    00036
 31          IM6 = IBAR-6                                                      YASET    00037
 32          IP1  = IBAR + 1                                                   YASET    00038
 33          IP2  = IBAR + 2                                                   YASET    00039
 34          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
      JP4O2 = 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
      NQ1    = 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
      JUNFO2 = 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(2I4,4F6.3,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*    DT04     -R    4CO   FIYB     -R    4CO   IYB      -I    4CO   MT       -R    6RL   PYBM     -R    4CO   START0   -  103SU
      300 -   103*    DT0A     -R    4CO   FIYT     -R    4CO   IYT      -I    4CO   MTE      -R    6RL   PYCONV   -R    4CO   VV       -R    4CO
      340 -   115*    DTV      -R    4CO   FJAP     -R    4CO   JAP2     -I    4CO   MU02     -R    6RL   PYT      -R    4CO   XCONV    -R    4CO
  AA2     ()R    2LC  DT8      -R    4CO   IBP1     -I    4CO   LAMD     -R    6RL   MU04     -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   LODPD    -  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   RPOR     -R    4CO   YSC1     -     3CN
  DTGZP   -R    4CO   FIPYT    -R    4CO   IPYT     -I    4CO   MESHMKR  -   74SU    PXL      -R    4CO   RPDRDZ   -R    4CO   YSC2     -     4CN
  DT016   -R    4CO   FIXL     -R    4CO   IXL      -I    4CO   ML       -R    6RL   PXR      -R    4CO   RPDZ     -R    4CO   YT       -R    4CO
  DT02    -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
A0        -R    4CO    18WR
A0FAC     -R    4CO    65=
A0M       -R    4CO    18WR    65      65
B0        -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
DT0      ()R    4CO    13RD    23WR    56
DT0C     ()R    4CO    14RD    24WR
DTPOS     -R    4CO    57=
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DZ       -R     4CO    18WR
E        ()R    5EQ    7DI    97=
EMIO     -R     4CO    59=    60     61     64
EP       ()R    5EQ    7DI
EPS      -R     4CO    9RD    19WR
ETIL     ()R    5EQ    7DI
FLOAT    -      40SU   41SU
FREZ     -R     4CO    10RD   20WR   72     72
GGMI     -R     4CO    66=
GMI      -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     78DO
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
JMIO     -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    -      6ASU    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=
NO      -I     4CO     42      44      48      54      79      80      108     109
NOI     -I     4CO     44=     45      46      47      49      51      54
NOIR    -I     4CO     42=
NSC     -I     4CO     50=
NUMTD   -I     4CO     58=
OM      -R     4CO      9RD    19WP
OMANC   -R     4CO     63=
OMCYL   -R     4CO     43=
OMEMIO  -R     4CO     60=
OPEMIO  -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
RIDAR   -R     4CO     40=
RIRJR   -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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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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      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        DT016,DT02,DT04,DT08,DTPOS,DTV,DTR,DZ,EM10,EPS,FIBP,  COMMON2 00005
               3        FIPXL,FIPXR,FIPYB,FIPYT,FIXL,FIXR,FIYB,FIYT,FJBP,     COMMON2 00006
               4        FRFZ,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,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          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 ECWF (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   IYR      -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
 ADFAC     -R   4CO   EPS      -R   4CO   IJM      -I   4CO   J        -I   4CO   NQ       -I   4CO   READ     -   29F    XCONV    -R   4CO
 ADM       -R   4CO   EQUIVAL  -    5F    IJP      -I   4CO   JM10     -I   4CO   NGIB     -I   4CO   REAL     -    6F    XL       -R   4CO
 B0        -R   4CO   FIPXL    -R   4CO   IJP5     -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   YB       -R   4CO
 DIMENSI   -    7F    FIPYB    -R   4CO   IM6      -I   4CO   JP2      -I   4CO   NUMTO    -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
 DTO      ()R   4CO   GM1      -R   4CO   ISCF1    -I   4CO   LJP2     -I   4CO   PXL      -R   4CO   RPDRDZ   -R   4CO
 DTOC     ()R   4CO   GR       -R   4CO   ISCF2    -I   4CO   MB       -R   6RL   PXR      -R   4CO   RPDZ     -R   4CO
 DT016     -R   4CO   GRDVEL   -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     5EG     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
```

```
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
JUNFO2   -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    7DI
MC       -R    6RL    50=    51     52
MP       ()R   5EQ     6RL    7DI
MPAR     ()R   5EQ     6RL    7DI   52=
MY       -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
NQI      -I    4CO    17     19
NQI2     -I    4CO    17=
OMCYL    -R    4CO    50
P        ()R   5EQ     7DI
PDR      -R    4CO    27=
PDZ      -R    4CO    28=
PL       ()R   5EQ     7DI
PMX      ()R   5EQ     7DI
PMY      ()R   5EQ     7DI
PMO      ()R   5EQ     7DI
PRINT    -     31F    67F    70F
PU       ()R   5EQ     7DI
PV       ()R   5EQ     7DI
Q        ()R   5EQ     7DI
R        ()R   5EQ     7DI
RCSQ     ()R   5EQ     7DI
RETURN   -     9F     69F    71F
REZYO    -R    4CO    25     26
RIBP     -R    4CO    13=    27
RJBP     -R    4CO    14=    28
RM       ()R   5EQ     7DI
RMP      ()R   5EQ     7DI
RO       ()R   5EQ     7DI
ROL      ()R   5EQ     7DI
ROMFR    -R    4CO    24     25     26
RVOL     ()R   5EQ     7DI
SHIFT    -     33SU   34SU   52SU
SIE      ()R   5EQ     7DI
U        ()R   5EQ     7DI
UG       ()R   5EQ     7DI
UL       ()R   5EQ     7DI
UP       ()R   5EQ     7DI
```

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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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   1          SUBROUTINE MESHMKR                                                  YASET    00231
   2          COMMON /YSC1/ AASC(4242)                                            COMMON2  00002
   3          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,DTB,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,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
   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          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                           YASET  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 = REZROH*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
```

```
      E(IJ) = REZSIE
  469 IJ = IJ + NQ
      CALL LOOP
  479 CONTINUE
      FNUM = FNUM*FREZ
      FDEN = FDEN*FREZ
      ROJP2 = ROSAV*(XX-FNUM)/(XX*FDEN)
      DO 489 I=1,IP1
      RO(IJ) = ROJP2
      E(IJ) = REZSIE
  489 IJ = IJ + NQ
      CALL DONE
  500 READ 1020, I,JJ,ROI,SIEI,VI,UI
      IF (I.EQ.0) GO TO 520
      J = JJ + NT-1
      CALL RIROW
      CALL SETIJ
      RO(IJ) = ROI
      SIE(IJ) = SIEI
      UL(IJ) = UI
      VL(IJ) = VI
      CALL WIROW
      J = J-2*JJ+1
      CALL RIROW
      CALL SETIJ
      RO(IJ) = ROI
      SIE(IJ) = SIEI
      UL(IJ) = UI
      CALL WIROW
      J = J-1
      CALL RIROW
      CALL SETIJ
      VL(IJ) = -VI
      CALL WIROW
      GO TO 500
  520 CALL START
      DO 549 J=2,JBAR
      DO 539 I=1,IM1
      IPJ = IJ+NQ
      IPJP = IJP+NQ
      IF(I.EQ.1) V(IJP) = VL(IJ)
      U(IPJP) = .5*(UL(IJ)+UL(IJP))
      V(IPJP) = .5*(VL(IJ)+VL(IPJ))
      IJ = IPJ
  539 IJP = IPJP
      CALL LOOP
  549 CONTINUE
      CALL DONE
      RETURN
C
 1000 FORMAT(3I4,4F8.3)
 1010 FORMAT(* NB=*I3* NM=*I3* NT=*I3* NL=*I3* UI=*1PE12.5* VI=*
     1 E12.5* ROI=*E12.5* SIEI=*E12.5)
 1020 FORMAT(2I5,4(4X,E11.5))
      END
```

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 INDEX  01/12/77                           SUBROUTINE MESHMKR                                                     PAGE  32
SINGLY REFERENCED VARIABLES
  200  -    16*    DTO4    -R   3CO   GR      -R   3CO   ISC3    -I   3CO   MT      -R   5RL   PXCONV  -R   3CO   RPDZ    -R   3CO
 AA    ()R   3CO   DTOB    -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   MUO2    -R   5RL   PXR     -R   3CO   THIRD   -R   3CO
 ANC   -R    3CO   DTV     -R   3CO   I9AR    -I   3CO   IXR     -I   3CO   MUD4    -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
 AO    -R    3CO   EM10    -R   3CO   IBP1    -I   3CO   IYT     -I   3CO   NCYC    -I   3CO   PYBM    -R   3CO   TWFIN   -R   3CO
 AOFAC -R    3CO   EPS     -R   3CO   ICOLOR  -I   3CO   JAP     -I   3CO   NLC     -I   3CO   PYCONV  -R   3CO   T2OMD   -R   3CO
 AOM   -R    3CO   EQUIVAL -    4F    IDTO    -I   3CO   JAP2    -I   3CO   NPS     -I   3CO   PYT     -R   3CO   VV      -R   3CO
 BO    -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   NOIB    -I   3CO   RDT     -R   3CO   XCONV   -R   3CO
 DIMENSI -   6F    FIPXL   -R   3CO   IMOMX   -I   3CO   JP402   -I   3CO   NOI2    -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   MA      -R   5RL   OMEM10  -R   3CO   RIAP    -R   3CO.  ZZ      -R   3CO
 DTO   ()R   3CO   FIYT    -R   3CO   IP2     -I   3CO   MC      -R   5RL   OPEM10  -R   3CO   RJBP    -R   3CO
 DTOC  ()R   3CO   FJBP    -R   3CO   ISCF1   -I   3CO   MESHMKR -    1SU   PDR     -R   3CO   RDN     -R   3CO
 DTO16 -R    3CO   FLOAT   -   35SU   ISCF2   -I   3CO   ML      -R   5RL   PDZ     -R   3CO   RPOR    -R   3CO
 DTO2  -R    3CO   GGMI    -R   3CO   ISC2    -I   3CO   MR      -R   5RL   PRINT   -   54F   RPORDZ  -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 -     54FR   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
DELSM   ()R   4EQ    6DI
DONE    -    15SU   30SU   50SU   105SU  141SU
DR      -R    3CO    24
DZ      -R    3CO    27     35     44     45
E       ()R   4EQ    5DI    84*    84*    94*    103*
EP      ()R   4EQ    6DI
ETIL    ()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    3CO   31     40     44     44     45     45     79     98     99
GMI    -R    3CO   73
GZ     -R    3CO   74     77
I      -I    3CO   11DO   12     20DO   38DO   40     62DO   64     64     65     81DO   92DO   101DO  106RD  107    131DO  134
IABS   -    42SU   43SU
IJ     -I    3CO   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    3CO   10     11DO   83     84     86=    86     90
IJP    -I    3CO   76     78     89     133    1?4    135    138=
IMJ    -I   39=    40     40     40
IM1    -I    3CO   131DO
IPJ    -I  132=    136    137
IPJP   -I  133=    135    136    138
IP1    -I    3CO   20DO   38DO   64     81DO   92DO   101DO
IUNF   -I    3CO   40
J      -I    3CO    9DO   19DO   37DO   42     43     44     45     46     60DO   55     65     66     88DO   108=   116=   116
           123=    123    130DO
JBAR   -I    3CO   130DO
JBOT   -I   34=    43     44
JCEN   -I    3CO   32=    32     33     34
JDB    -I   43=    44
JDT    -I   42=    45
JJ     -I  106RD   108    116
JP1    -I    3CO   88DO
JP2    -I    3CO   19DO   37DO   65
JP4    -I    3CO    9DO
JTOP   -I   33=    42     45
JUNFO2 -I    3CO   33     34     35
K      -I   10=    11DO
LAM    -R    3CO    5RL
LOOP   -    13SU   28SU   48SU   87SU   96SU   139SU
LPR    -I    3CO   55
M      ()R   4EQ    5RL    6DI
MP     ()R   4EQ    5RL    6DI
MPAR   ()R   4EQ    5RL    6DI
MU     -R    3CO    5RL
NB     -I   51RD   54PR   55WR   56
NB2    -I   56=    60DO
NL     -I   51RD   54PR   55WR   59
NL1    -I   59=    62DO
NQ     -I    3CO   25     3°     40     47     85     86     95     104    132    133
NQT    -I    3CO    7
NQTM   -I    7=    10
NR     -I   51RD   52     53     54PR   55WR   57
NR1    -I   57=    62DO   66
NT     -I   51RD   54PR   55WR   58     108
NT2    -I   58=    60DO   66
OMCYL  -R    3CO   23     41
P      ()R   4EQ    6DI
PL     ()R   4EQ    6DI
PMX    ()R   4EQ    6DI
PMY    ()R   4EQ    6DI
PMG    ()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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```
RCSO     ()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
RIROW    -     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
WIROW    -     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       -I    17=    22     27=    27     74=    78     89     90
```

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INDEX  01/12/73                OVERLAY(YAQUFIL,2,0)                                   PAGE  35
          1           OVERLAY(YAQUFIL,2,0)                                          YAQUI1  00002
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INDEX  01/12/73                PROGRAM YAQUI1                                         PAGE  36
          1           PROGRAM YAQUI1                                                YAQUI1  00003
          2           PRINT 10                                                      YAQUI1  00004
          3           CALL YAQUI2                                                   YAQUI1  00005
          4     10    FORMAT(*  YAQUI2 CALLED*)                                     YAQUI1  00006
          5           END                                                           YAQUI1  00007
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 INDEX  01/12/73                PROGRAM YAQUI1                                        PAGE  37
SINGLY REFERENCED VARIABLES
 PRINT   -    2F    YAQUI1  -    1SU   YAQUI2  -    3SU
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
MULTIPLY-REFERENCED VARIABLES
   10 -      2PR     4*
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
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  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,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,PYT2,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,V2),(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,MFLR,MR,MT,MTE,MU,MU02,MU04         EQVREAL  00008
  7              DIMENSION X(1),XPAR(1),R(1),YPAR(1),Y(1),MPAR(1),U(1),UG(1),    DIMEN    00002
               1          DELSM(1),V(1),VG(1),RO(1),SIE(1),MP(1),RMP(1),RCSQ(1), DIMEN    00003
               2          E(1),ETIL(1),RVOL(1),M(1),RM(1),V2(1),P(1),PL(1),EP(1),DIMEN    00004
               3          UP(1),UTIL(1),UL(1),CQ(1),PMX(1),PU(1),VTIL(1),VL(1),  DIMEN    00005
               4          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)*RIBJR                                              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. T20MD.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
      DTB = DT*B.                                                       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 (4LF1LM)                                              YAQUI1  00098
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INDEX  01/12/73              SUBROUTINE YAQUI2                                      PAGE  40
              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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148           U3 = U(IJ)                                                 YAQUI1  00157
149           V3 = V(IJ)                                                 YAQUI1  00158
150           X4 = X(IJM)                                                YAQUI1  00159
151           Y4 = Y(IJM)                                                YAQUI1  00160
152           R4 = R(IJM)                                                YAQUI1  00161
153           U4 = U(IJM)                                                YAQUI1  00162
154           V4 = V(IJM)                                                YAQUI1  00163
155           D = .25*RVOL(IJM)*((R1+R2)*((U1+U2)*(Y2-Y1)+(V1+V2)*(X1-X2))  YAQUI1  00164
             1                   +(R2+R3)*((U2+U3)*(Y3-Y2)+(V2+V3)*(X2-X3))  YAQUI1  00165
             2                   +(R3+R4)*((U3+U4)*(Y4-Y3)+(V3+V4)*(X3-X4))  YAQUI1  00166
             3                   +(R4+R1)*((U4+U1)*(Y1-Y4)+(V4+V1)*(X4-X1)))  YAQUI1  00167
156     450   GO TO (452,452,456) LPR                                    YAQUI1  00168
157     452   WRITE(12,4070) I,J,X(IJM),Y(IJM),U(IJM),V(IJM),PRSIE,RO(IJM),PRV,  YAQUI1  00169
             1               D,PRM,P(IJM)                                YAQUI1  00170
158           LINESF = LINESF + 1                                        YAQUI1  00171
159           IF (LINESF.LT.62) GO TO KRF                                YAQUI1  00172
160     454   LINESF = 0                                                 YAQUI1  00173
161           WRITE(12,4080) JNM,NAME,T,NCYC                             YAQUI1  00174
162           WRITE(12,4060)                                             YAQUI1  00175
163           GO TO KRF                                                  YAQUI1  00176
164     456   PRINT 4070,     I,J,X(IJM),Y(IJM),U(IJM),V(IJM),PRSIE,RO(IJM),PRV,  YAQUI1  00177
             1               D,PRM,P(IJM)                                YAQUI1  00178
165           LINESP = LINESP + 1                                        YAQUI1  00179
166           IF (LINESP.LT.57) GO TO KRP                                YAQUI1  00180
167     458   LINESP = 0                                                 YAQUI1  00181
168           PRINT 4050                                                 YAQUI1  00182
169           PRINT 4080, JNM,NAME,T,NCYC                                YAQUI1  00183
170           PRINT 4060                                                 YAQUI1  00184
171           GO TO KRP                                                  YAQUI1  00185
172     460   IJ = IPJ                                                   YAQUI1  00186
173     479   IJM = IPJM                                                 YAQUI1  00187
174           CALL LOOP                                                  YAQUI1  00188
175     489   CONTINUE                                                   YAQUI1  00189
176           IF (LPR.GT.2) GO TO KRET                                   YAQUI1  00190
177     490   CALL EMPTY                                                 YAQUI1  00191
178           GO TO KRET                                                 YAQUI1  00192
179     500   IF (NPT.GT.0) CALL PARPLOT                                 YAQUI1  00193
180           IF (LPR.EQ.0) GO TO 490                                    YAQUI1  00194
181           IF (GRDVEL.GT.EM10 .OR. NCYC.EQ.0) CALL ADV(1)             YAQUI1  00195
182           DRMIN = DZMIN = 1.E+20                                     YAQUI1  00196
183           DRMAX = DZMAX = VMAX = 0.                                  YAQUI1  00197
184           CALL START                                                 YAQUI1  00198
185           DO 549 J=2,JP1                                             YAQUI1  00199
186           DO 539 I=1,IBAR                                            YAQUI1  00200
187           IPJ = IJ + NQ                                              YAQUI1  00201
188           IPJP = IJP + NQ                                            YAQUI1  00202
189           VMAX = AMAX1 (VMAX,ABS(U(IJ)),ABS(V(IJ)))                  YAQUI1  00203
190           IF (NCYC.GT.0 .AND. GRDVEL.LT.EM10) GO TO 530              YAQUI1  00204
191           X1 = X(IPJ)                                                YAQUI1  00205
192           X2 = X(IPJP)                                               YAQUI1  00206
193           X3 = X(IJP)                                                YAQUI1  00207
194           X4 = X(IJ)                                                 YAQUI1  00208
195           Y1 = Y(IPJ)                                                YAQUI1  00209
196           Y2 = Y(IPJP)                                               YAQUI1  00210
197           Y3 = Y(IJP)                                                YAQUI1  00211
198           Y4 = Y(IJ)                                                 YAQUI1  00212
199           XY14  = SQRT((X1-X4)**2 + (Y1-Y4)**2)                      YAQUI1  00213
200           XY23  = SQRT((X2 X3)**2 + (Y2-Y3)**2)                      YAQUI1  00214
```

```
          DRMIN = AMIN1(DRMIN,XY14,XY23)
          DRMAX = AMAX1(DRMAX,XY14,XY23)
          XY21  = SQRT((X2-X1)**2 + (Y2-Y1)**2)
          XY34  = SQRT((X3-X4)**2 + (Y3-Y4)**2)
          DZMIN = AMIN1(DZMIN,XY21,XY34)
          DZMAX = AMAX1(DZMAX,XY21,XY34)
          IX1 = FIXL + (X1-XL)*XCONV
          IY1 = FIYB + (Y1-YB)*YCONV
          IX2 = FIXL + (X2-XL)*XCONV
          IY2 = FIYB + (Y2-YB)*YCONV
          IX3 = FIXL + (X3-XL)*XCONV
          IY3 = FIYB + (Y3-YB)*YCONV
          IX4 = FIXL + (X4-XL)*XCONV
          IY4 = FIYB + (Y4-YB)*YCONV
          IF (I.EQ.1) CALL DRV (IX3,IY3,IX4,IY4)
          IF (J.EQ.2) CALL DRV (IX4,IY4,IX1,IY1)
          CALL DRV (IX1,IY1,IX2,IY2)
          CALL DRV (IX2,IY2,IX3,IY3)
    530   IJ = IPJ
    539   IJP = IPJP
          CALL LOOP
    549   CONTINUE
          IF (NCYC.GT.0 .AND. GRDVEL.LT.EM10) GO TO 550
          CALL LINCNT(59)
          WRITE(12,4140) DRMIN,DRMAX,DZMIN,DZMAX,XR,YB,YT
          WRITE(12,4080) JNM,NAME,T,NCYC
    550   IF (VMAX.LT.EM10) GO TO 600
          DROU = VV/VMAX
          CALL ADV(1)
          CALL START
          DO 599 J=2,JP2
          DO 589 I=1,IP1
          IX1 = FIXL + (X(IJ)-XL)*XCONV
          IY1 = FIYB + (Y(IJ)-YB)*YCONV
          IX2 = FIXL + (X(IJ)+U(IJ)*DROU-XL)*XCONV
          IY2 = FIYB + (Y(IJ)+V(IJ)*DROU-YB)*YCONV
          IF (IY2.GE.1) GO TO 580
          IX2 = IX1 + (IX2-IX1)*(IY1-1)/(IY1-IY2)
          IY2 = 1
    580   CALL DRV (IX1,IY1,IX2,IY2)
          CALL PLT (IX1,IY1,16)
    589   IJ = IJ + NQ
          CALL LOOP
    599   CONTINUE
          CALL LINCNT(59)
          WRITE(12,4150) VMAX
          WRITE(12,4080) JNM,NAME,T,NCYC
    600   IF (IBAR.EQ.1 .OR. JBAR.EQ.1) GO TO 490
          L = 0
    610   L = L+1
          GO TO (620,620,640,490)L
    620   CALL START
          DO 639 J=2,JP1
          DO 629 I=1,IBAR
          CQ(IJ) = RO(IJ+L-1)
    629   IJ = IJ + NQ
          CALL LOOP
    639   CONTINUE
```

```
            CALL DONE                                                        YAQUI1  00273
            GO TO 700                                                        YAQUI1  00274
      640   CALL START                                                       YAQUI1  00275
            DO 659 J=2,JP1                                                   YAQUI1  00276
            DO 649 I=1,IBAR                                                  YAQUI1  00277
            IPJ = IJ + NQ                                                    YAQUI1  00278
            IPJP = IJP + NQ                                                  YAQUI1  00279
            X1 = X(IPJ)                                                      YAQUI1  00280
            Y1 = Y(IPJ)                                                      YAQUI1  00281
            U1 = U(IPJ)                                                      YAQUI1  00282
            V1 = V(IPJ)                                                      YAQUI1  00283
            X2 = X(IPJP)                                                     YAQUI1  00284
            Y2 = Y(IPJP)                                                     YAQUI1  00285
            U2 = U(IPJP)                                                     YAQUI1  00286
            V2 = V(IPJP)                                                     YAQUI1  00287
            X3 = X(IJP)                                                      YAQUI1  00288
            Y3 = Y(IJP)                                                      YAQUI1  00289
            U3 = U(IJP)                                                      YAQUI1  00290
            V3 = V(IJP)                                                      YAQUI1  00291
            X4 = X(IJ)                                                       YAQUI1  00292
            Y4 = Y(IJ)                                                       YAQUI1  00293
            U4 = U(IJ)                                                       YAQUI1  00294
            V4 = V(IJ)                                                       YAQUI1  00295
            R1 = .125*RVOL(IJ)*(R(IPJ)+R(IPJP)+R(IJP)+R(IJ))                 YAQUI1  00296
            CQ(IJ) = R1*((U1+U4)*(X1-X4)+(V1+V4)*(Y1-Y4)                     YAQUI1  00297
           2            +(U2+U1)*(X2-X1)+(V2+V1)*(Y2-Y1)                     YAQUI1  00298
           3            +(U3+U2)*(X3-X2)+(V3+V2)*(Y3-Y2)                     YAQUI1  00299
           4            +(U4+U3)*(X4-X3)+(V4+V3)*(Y4-Y3))                    YAQUI1  00300
            IJ = IPJ                                                         YAQUI1  00301
      649   IJP = IPJP                                                       YAQUI1  00302
            CALL LOOP                                                        YAQUI1  00303
      659   CONTINUE                                                         YAQUI1  00304
            CALL DONE                                                        YAQUI1  00305
      700   QMN = 1.E+6                                                      YAQUI1  00306
            QMX = -QMN                                                       YAQUI1  00307
            CALL START                                                       YAQUI1  00308
            DO 719 J=2,JP1                                                   YAQUI1  00309
            DO 709 I=1,IBAR                                                  YAQUI1  00310
            QMN = AMIN1 (CQ(IJ),QMN)                                         YAQUI1  00311
            QMX = AMAX1 (CQ(IJ),QMX)                                         YAQUI1  00312
      709   IJ = IJ + NQ                                                     YAQUI1  00313
            CALL LOOP                                                        YAQUI1  00314
      719   CONTINUE                                                         YAQUI1  00315
            XX = QMX/(QMN+EM10)                                              YAQUI1  00316
            IF (XX.LE.2.0) GO TO 735                                         YAQUI1  00317
            K = 10./ALOG10(XX)                                               YAQUI1  00318
            XX = K+1                                                         YAQUI1  00319
            DQ = 10.**(1./XX)                                                YAQUI1  00320
            K = ALOG10(QMN)                                                  YAQUI1  00321
            XX = 10.**(K-1)                                                  YAQUI1  00322
            K = 1                                                            YAQUI1  00323
      720   XX = XX*DQ                                                       YAQUI1  00324
            IF (XX.LT.QMN) GO TO 720                                         YAQUI1  00325
      730   CON(K) = XX                                                      YAQUI1  00326
            IF (XX.GT.QMX) GO TO 740                                         YAQUI1  00327
            K = K+1                                                          YAQUI1  00328
            XX = XX*DQ                                                       YAQUI1  00329
            GO TO 730                                                        YAQUI1  00330
```

```
 735  XX = QMX-QMN
      IF (ABS(XX).LT.1.E-3*AMAX1(ABS(QMX),ABS(QMN))) GO TO 610
      DQ = .1*(XX+.001)
      DO 739 K=1,11
 739  CON(K) = QMN+(FLOAT(K-1))*DQ
      K = 11
 740  CALL ADV(1)
      CALL LINCNT (59)
      GO TO (750,760,770)L
 750  WRITE(12,4090)
      GO TO 780
 760  WRITE(12,4100)
      GO TO 780
 770  WRITE(12,4110)
 780  WRITE(12,4120) QMN,QMX,CON(1),CON(K-1),DQ
      WRITE(12,4080) JNM,NAME,T,NCYC
      CALL START
      DO 899 J=2,JBAR
      CALL LOOP
      DO 889 I=1,IM1
      IPJ = IJ + NQ
      IPJM = IJM + NQ
      N = 0
      DO 879 KK=1,K
      K1 = K2 = K3 = K4 = 0
      IF (CQ(IJM) .LE.CON(KK)) K1=1
      IF (CQ(IPJM).LE.CON(KK)) K2=1
      IF (CQ(IJ)  .LE.CON(KK)) K3=1
      IF (CQ(IPJ) .LE.CON(KK)) K4=1
      IF (K1*K2*K3*K4 .NE. 0 .OR. K1+K2+K3+K4 .EQ. 0) GO TO 879
      IF (N.GT.0) GO TO 800
      IJB = IJM
      IJA = IJ
      DO 799 JJ=1,2
      DO 789 II=1,2
      IPJB = IJB+NQ
      IPJA = IJA+NQ
      N = N+1
      XCO(N) = .25*(X(IPJB)+X(IPJA)+X(IJA)+X(IJB))
      YCO(N) = .25*(Y(IPJB)+Y(IPJA)+Y(IJA)+Y(IJB))
      IJA = IPJA
 789  IJB = IPJB
      IJB = IJ
 799  IJA = IJP
 800  LL = 0
      IF (K1+K3.NE.1) GO TO 810
      IC1 = 1
      IC2 = 3
      IJ1 = IJM
      IJ2 = IJ
      ASSIGN 810 TO KR1
      GO TO 840
 810  IF (K1+K2.NE.1) GO TO 820
      IC1 = 1
      IC2 = 2
      IJ1 = IJM
      IJ2 = IPJM
      ASSIGN 820 TO KR1
```

```
      GO TO 840
820   IF (K2+K4.NE.1) GO TO 830
      IC1 = 2
      IC2 = 4
      IJ1 = IPJM
      IJ2 = IPJ
      ASSIGN 830 TO KR1
      GO TO 840
830   IF (K3+K4.NE.1) GO TO 879
      IC1 = 3
      IC2 = 4
      IJ1 = IJ
      IJ2 = IPJ
      ASSIGN 879 TO KR1
840   LL = LL+1
      XX = (CON(KK)-CO(IJ1))/(CO(IJ2)-CO(IJ1))
      IX1(LL) = FIXL + (XCO(IC1)+XX*(XCO(IC2)-XCO(IC1))-XL)*XCONV
      IY1(LL) = FIYB + (YCO(IC1)+XX*(YCO(IC2)-YCO(IC1))-YB)*YCONV
      IF (LL.LT.2) GO TO KR1
      CALL DRV (IX1,IY1,IX2,IY2)
      IF (KK.EQ.1)   CALL PLT (IX1,IY1,35)
      IF (KK.EQ.K-1) CALL PLT (IX1,IY1,24)
      LL = 0
      IF (IJ2.EQ.IPJM) GO TO 820
879   CONTINUE
      IJM = IPJM
      IJ = IPJ
889   IJP = IJP+NQ
899   CONTINUE
      CALL START
      DO 949 J=2,JP1
      DO 939 I=1,IBAR
      IPJ = IJ + NQ
      IPJP = IJP + NQ
      IX1 = FIXL + (X(IPJ) -XL)*XCONV
      IY1 = FIYB + (Y(IPJ) -YB)*YCONV
      IX2 = FIXL + (X(IPJP)-XL)*XCONV
      IY2 = FIYB + (Y(IPJP)-YB)*YCONV
      IX3 = FIXL + (X(IJP) -XL)*XCONV
      IY3 = FIYB + (Y(IJP) -YB)*YCONV
      IX4 = FIXL + (X(IJ)  -XL)*XCONV
      IY4 = FIYB + (Y(IJ)  -YB)*YCONV
      IF (I.EQ.1)    CALL DRV (IX3,IY3,IX4,IY4)
      IF (J.EQ.2)    CALL DRV (IX4,IY4,IX1,IY1)
      IF (I.EQ.IBAR) CALL DRV (IX1,IY1,IX2,IY2)
      IF (J.EQ.JP1)  CALL DRV (IX2,IY2,IX3,IY3)
      IJ = IPJ
939   IJP = IPJP
      CALL LOOP
949   CONTINUE
      GO TO 610
1000  CALL START
      Y1 = ANC*RDT
      DO 1099 J=2,JP2
      DO 1089 I=1,IP1
      IMJ = IJ-NQ
      IPJ = IJ+NQ
      IPJP = IJP+NQ
```

```
              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
```

```
      X4 = X(IJ)
      Y4 = Y(IJ)
      R4 = R(IJ)
      U4 = U(IJ)
      V4 = V(IJ)
      X12 = X1-X2
      X23 = X2-X3
      X34 = X3-X4
      X41 = X4-X1
      X24 = X2-X4
      X31 = X3-X1
      Y21 = Y2-Y1
      Y32 = Y3-Y2
      Y43 = Y4-Y3
      Y14 = Y1-Y4
      Y24 = Y2-Y4
      Y31 = Y3-Y1
      R12 = R1+R2
      R23 = R2+R3
      R34 = R3+R4
      R41 = R4+R1
      HR13 = .5*(R1+R3)
      HR24 = .5*(R2+R4)
      U12 = U1+U2
      U23 = U2+U3
      U34 = U3+U4
      U41 = U4+U1
      U24 = U2+U4
      U13 = U1+U3
      V12 = V1+V2
      V23 = V2+V3
      V34 = V3+V4
      V41 = V4+V1
      V24 = V2+V4
      V13 = V1+V3
      DTO2M1 = DTO2*RM(IPJ)
      DTO2M2 = DTO2*RM(IPJP)
      DTO2M3 = DTO2*RM(IJP)
      DTO2M4 = DTO2*RM(IJ)
      XY = X24*Y31-X31*Y24
      D = .25*RVOL(IJ)*(R12*(U12*Y21+V12*X12)+R23*(U23*Y32+V23*X23)
     1                +R34*(U34*Y43+V34*X34)+R41*(U41*Y14+V41*X41))
      XX = .5*(X2-X4+X1-X3)
      YY = .5*(Y2-Y4+Y3-Y1)
      IF (KXI.LT.0) GO TO 1130
      AK = RO(IJ)**KXI
      GO TO 1140
 1130 VELIJ = U4**2 + V4**2
      VELMX = 0.7 * AMAX1(ABS(U4*XX),ABS(V4*YY))
      AK = RO(IJ)*COLAMU*(DTO2*VELIJ + VELMX)
 1140 LAMD = AMIN1(D,0.) *AK*LAM
      MU02 = .5*AK*MU
      MU04 = .5*MU02
      XX = XX*XX
      YY = YY*YY
      IF (KXI.LT.0 .AND. DT.LT.DTPOS)
     1               AK = RO(IJ)*COLAMU*(.5*DTPOS*VELIJ + VELMX)
      DQ = RO(IJ)*OMANC*XX*YY/(2.* AK*(LAM+2.*MU) *(XX+YY)+EM10)
```

```
      DTV = AMIN1(DTV,.5*DQ)
      IF (DTVSAV.NE.DTV) IDTV = I
      IF (DTVSAV.NE.DTV) JDTV = J
      DTVSAV = DTV
      PIXX = MU02*RVOL(IJ)*(R12*U12*Y21+R23*U23*Y32
     1       +R34*U34*Y43+R41*U41*Y14 -.5*CYL*(U12+U34)*XY) + LAMD
      PIYY = MU02*RVOL(IJ)*(R12*V12*X12+R23*V23*X23
     1       +R34*V34*X34+R41*V41*X41) + LAMD
      PIXY = MU04*RVOL(IJ)*(R12*(U12*X12+V12*Y21)+R23*(U23*X23+V23*Y32)
     1                      +R34*(U34*X34+V34*Y43)+R41*(U41*X41+V41*Y14)
     2                      -.5*CYL*(V12+V34)*XY)
      PITH = .25*XY*CYL*(MU04*RVOL(IJ)*((U12+U34)*XY) + LAMD)
      XX = HR24*(PIXY*X24-PIXX*Y24)
      YY = Y24*P(IJ)
      UTIL(IPJ)  = UTIL(IPJ) +DTO2M1*(XX+R1*YY-PITH)
      UTIL(IJP)  = UTIL(IJP) -DTO2M3*(XX+R3*YY+PITH)
      XX = HR13*(PIXY*X31-PIXX*Y31)
      YY = Y31*P(IJ)
      UTIL(IPJP) = UTIL(IPJP)+DTO2M2*(XX+R2*YY-PITH)
      UTIL(IJ)   = UTIL(IJ)  -DTO2M4*(XX+R4*YY+PITH)
      PYYMP = PIYY-P(IJ)
      XX = HR24*(PYYMP*X24-PIXY*Y24)
      VTIL(IPJ)  = VTIL(IPJ) +DTO2M1*XX
      VTIL(IJP)  = VTIL(IJP) -DTO2M3*XX
      XX = HR13*(PYYMP*X31-PIXY*Y31)
      VTIL(IPJP) = VTIL(IPJP)+DTO2M2*XX
      VTIL(IJ)   = VTIL(IJ)  -DTO2M4*XX
      XX = .5*HR24*(U24*(X24*PIXY-Y24*PIXX)+V24*(Y24*PIXY-X24*PIYY))
      Q(IPJ)  = Q(IPJ) +DTO2M1*XX
      Q(IJP)  = Q(IJP) -DTO2M3*XX
      XX = .5*HR13*(U13*(X31*PIXY-Y31*PIXX)+V13*(Y31*PIXY-X31*PIYY))
      Q(IPJP) = Q(IPJP)+DTO2M2*XX
      Q(IJ)   = Q(IJ)  -DTO2M4*XX
      IJ = IPJ
 1199 IJP = IPJP
      UTIL(IJ) = UTIL(IJP) = UTIL(IJP-NQIB) = UTIL(IJ-NQIB) = 0.
      IF (J.NE.2)   GO TO 1220
      DO 1210 IJ=ISC2,ISCF2,NQ
 1210 VTIL(IJ) = 0.
 1220 IF (J.NE.JP1) GO TO 1240
      DO 1230 IJP=IJPS,LJP2,NQ
 1230 VTIL(IJP) = 0.
 1240 CALL LOOP
 1299 CONTINUE
      CALL DONE
 1300 CALL START
      DO 1399 J=2,JP1
      DO 1389 I=1,IBAR
      IPJ = IJ + NQ
      IPJP = IJP + NQ
      ETIL(IJ) = E(IJ)+.25*(Q(IPJ)+Q(IPJP)+Q(IJP)+Q(IJ))
      ROL(IJ) = RO(IJ)
      RCSQ(IJ) = 1./(ASQ+GGM1*AMAX1(SIE(IJ),0.))
      XX = (X(IPJP)-X(IJ)+X(IPJ)-X(IJP))**2
      YY = (Y(IPJP)-Y(IJ)+Y(IJP)-Y(IPJ))**2
      DELSM(IJ) = DTB*(XX+YY)/(XX*YY)
      IJ = IPJ
 1389 IJP = IPJP
```

```
      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 00561
      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
      PP = 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
```

```
      MT = RO(IJP)/RVOL(IJP)
      PT = P(IJP)
 1530 IF (J.EQ.2    ) GO TO 1540
      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)
     1                            +R23*P23*(U23*Y32+V23*X23)
     2                            +R34*P34*(U34*Y43+V34*X34)
     3                            +R41*P41*(U41*Y14+V41*X41))
      IJ = IPJ
      IJP = IPJP
 1589 IJM = IJM+NQ
      CALL LOOP
 1599 CONTINUE
      CALL DONE
 2000 NUMIT = 0
      MUSTIT = 1
      PLMAX = EM10
 2010 CALL START
      DO 2099 J=2,JP1
      DO 2089 I=1,IBAR
      IPJ = IJ + NQ
      IPJP = IJP + NQ
      X1 = X(IPJ)
      Y1 = Y(IPJ)
      R1 = R(IPJ)
      U1 = UL(IPJ)
      V1 = VL(IPJ)
      X2 = X(IPJP)
      Y2 = Y(IPJP)
      R2 = R(IPJP)
      U2 = UL(IPJP)
      V2 = VL(IPJP)
      X3 = X(IJP)
      Y3 = Y(IJP)
      R3 = R(IJP)
      U3 = UL(IJP)
      V3 = VL(IJP)
      X4 = X(IJ)
      Y4 = Y(IJ)
      R4 = R(IJ)
      U4 = UL(IJ)
      V4 = VL(IJ)
      D = .25*RVOL(IJ)*((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)))
      S = RDT*(ROL(IJ)-RO(IJ))+ROL(IJ)*D
      RA = RCSQ(IJ)*(RDT+D)+DELSM(IJ)
      DP = -OM*S/RA
      ROL(IJ) = ROL(IJ) + RCSQ(IJ)*DP
      PLMAX = AMAX1(PLMAX,ABS(PL(IJ)))
      IF (ABS(DP).LE.EPS*PLMAX) GO TO 2080
      MUSTIT = 1
```

```
      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 = DTO2*DP                                             YAQUI1  00742
      DTO2M1 = XX*RM(IPJ)                                      YAQUI1  00743
      DTO2M2 = XX*RM(IPJP)                                     YAQUI1  00744
      DTO2M3 = XX*RM(IJP)                                      YAQUI1  00745
      DTO2M4 = XX*RM(IJ)                                       YAQUI1  00746
      UL(IPJ)  = U1+DTO2M1*R1*Y24                              YAQUI1  00747
      UL(IPJP) = U2+DTO2M2*R2*Y31                              YAQUI1  00748
      UL(IJP)  = U3-DTO2M3*R3*Y24                              YAQUI1  00749
      UL(IJ)   = U4-DTO2M4*R4*Y31                              YAQUI1  00750
      IF (J.EQ.2)   GO TO 2060                                 YAQUI1  00751
      VL(IPJ)  = V1-DTO2M1*XR24                                YAQUI1  00752
      VL(IJ)   = V4-DTO2M4*XR13                                YAQUI1  00753
 2060 IF (J.EQ.JP1) GO TO 2080                                 YAQUI1  00754
      VL(IPJP) = V2+DTO2M2*XR13                                YAQUI1  00755
      VL(IJP)  = V3+DTO2M3*XR24                                YAQUI1  00756
 2080 IJ = IPJ                                                 YAQUI1  00757
 2085 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
```

```
      AL = -AR
 3230 IF (J.EQ.2) GO TO 3290
      FB = -FT(I)
      AB = -AT(I)
 3240 FR     = DTO8*R12*((UD1+UD2)*Y21+(VD1+VD2)*X12)
      AR     = A0M*SIGN(1.,FR    )+B0*4.*FR    /(VOLR+VOLC)
      FT(I) = DTO8*R23*((UD2+UD3)*Y32+(VD2+VD3)*X23)
      AT(I) = A0M*SIGN(1.,FT(I))+B0*4.*FT(I)/(VOLT+VOLC)
      XX = AMAX1(ABS(FB),ABS(FR),ABS(FT(I)),ABS(FL))
      DTC = AMIN1(DTC,DTPOS*A0FAC/(XX*RVOL(IJ)*DTPOS*ABS(D)+EM10))
      IF (DTCSAV.NE.DTC) IDTC = I
      IF (DTCSAV.NE.DTC) JDTC = J
      DTCSAV = DTC
      MP(IJ) = RO(IJ)*VOLC
     1         +FR   *((1.-AR)    *ROL(IJ)+(1.+AR)    *ROL(IPJ))
     2         +FT(I)*((1.-AT(I))*ROL(IJ)+(1.+AT(I))*ROL(IJP))
     3         +FL   *((1.-AL)    *ROL(IJ)+(1.+AL)    *ROL(IMJ))
     4         +FB   *((1.-AB)    *ROL(IJ)+(1.+AB)    *ROL(IJM))
      ROE = RO(IJ)*ETIL(IJ)
      EP(IJ) = 1./MP(IJ)*(ROE*VOLC
     1         +FR   *((1.-AR)    *ROE+(1.+AR)    *RO(IPJ)*ETIL(IPJ))
     2         +FT(I)*((1.-AT(I))*ROE+(1.+AT(I))*RO(IJP)*ETIL(IJP))
     3         +FL   *((1.-AL)    *ROE+(1.+AL)    *RO(IMJ)*ETIL(IMJ))
     4         +FB   *((1.-AB)    *ROE+(1.+AB)    *RO(IJM)*ETIL(IJM)))
      ATR = .5*(X2*Y31-X1*Y32-X3*Y21)
      ABL =-.5*(X1*Y43+X3*Y14+X4*Y31)
      RVOL(IJ) = 3./(ATR*(R1+R2+R3)+ABL*(R1+R3+R4))
      IJ = IPJ
      IJP = IPJP
 3259 IJM = IJM + NQ
      CALL LOOP
 3269 CONTINUE
      CALL DONE
      GO TO 3300
 3280 FL     = DTO8*R34*((UD3+UD4)*Y43+(VD3+VD4)*X34)
      AL     = A0M*SIGN(1.,FL)+B0*2.*FL*RVOL(IJ)
         GO TO 3230
 3290 FB     = DTO8*R41*((UD4+UD1)*Y14+(VD4+VD1)*X41)
      AB     = A0M*SIGN(1.,FB)+B0*2.*FB*RVOL(IJ)
         GO TO 3240
 3300 CALL START
      DO 3319 J=2,JP1
      DO 3309 I=I,IBAR
      RO(IJ) = MP(IJ)*RVOL(IJ)
      E(IJ) = EP(IJ)
      IF (J.EQ.2   ) RO(IJM) = ROL(IJM)
      IF (J.EQ.JP1 ) RO(IJP) = ROL(IJP)
      IF (I.EQ.IBAR) RO(IJ+NQ) = ROL(IJ+NQ)
      IJM = IJM+NQ
      IJP = IJP+NQ
 3309 IJ = IJ + NQ
      CALL LOOP
 3319 CONTINUE
      CALL DONE
      CALL STARTD
      DO 3399 JJ=2,JP2
      J = JP4-JJ
      DO 3389 II=1,IP1
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INDEX  01/12/73                SUBROUTINE YAQUI2                                      PAGE  54
             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=I,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
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```
      VL13 = VL1+VL3
      UL24 = UL2+UL4
      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))
      FM1 = F24*RMP(IPJ)
      FM2 = F13*RMP(IPJP)
      FM3 = F24*RMP(IJP)
      FM4 = F13*RMP(IJ)
      XX = R0*4.*RVOL(IJ)/ROL(IJ)
      AL13 = A0*SIGN(1.,F13)+XX*F13
      AL24 = A0*SIGN(1.,F24)+XX*F24
      OPAL13 = 1.+AL13
      OPAL24 = 1.+AL24
      OMAL13 = 1.-AL13
      OMAL24 = 1.-AL24
      XX = UL3*OMAL24+UL1*OPAL24
      UP(IPJ)  = UP(IPJ) - FM1*XX
      UP(IJP)  = UP(IJP) + FM3*XX
      XX = UL4*OMAL13+UL2*OPAL13
      UP(IPJP) = UP(IPJP)- FM2*XX
      UP(IJ)   = UP(IJ)  + FM4*XX
      XX = VL3*OMAL24+VL1*OPAL24
      VP(IPJ)  = VP(IPJ) - FM1*XX
      VP(IJP)  = VP(IJP) + FM3*XX
      XX = VL4*OMAL13+VL2*OPAL13
      VP(IPJP) = VP(IPJP)- FM2*XX
      VP(IJ)   = VP(IJ)  + FM4*XX
      IJ = IPJ
 3599 IJP = IPJP
      UP(IJ) = UP(IJP) = UP(IJP-NQIB) = UP(IJ-NQIB) = 0.
      IF (J.NE.2)   GO TO 3620
      DO 3610 IJ=ISC2,ISCF2,NQ
 3610 VP(IJ) = 0.
 3620 IF (J.NE.JP1) GO TO 3640
      DO 3630 IJP=IJPS,LJP2,NQ
 3630 VP(IJP) = 0.
 3640 CALL LOOP
 3699 CONTINUE
      CALL DONE
 3700 CALL START
      DO 3719 J=2,JP2
      DO 3709 I=1,IP1
      U(IJ) = UP(IJ)
      V(IJ) = VP(IJ)
      RM(IJ) = RMP(IJ)
 3709 IJ = IJ + NQ
      CALL LOOP
 3719 CONTINUE
      CALL DONE
 3800 CALL START
      DO 3899 J=2,JP1
      DO 3889 I=1,IBAR
      IPJ = IJ+NQ
      IPJP = IJP+NQ
      SIE(IJ) = X(IJ)-.125*(U(IPJ)**2+U(IPJP)**2+U(IJP)**2+U(IJ)**2
     1                     +V(IPJ)**2+V(IPJP)**2+V(IJP)**2+V(IJ)**2)
      IJP = IPJP
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IMPER  01/12/73                SUBROUTINE TAQUI2                                        PAGE  54
        3889  IJ = IPJ                                                                TAQUI1  01027
              CALL LOOP                                                               TAQUI1  01028
        3899  CONTINUE                                                                TAQUI1  01029
              CALL DONE                                                               TAQUI1  01030
              IF (NPT.GT.0) CALL PARTMOV                                              TAQUI1  01031
              GO TO 100                                                               TAQUI1  01032
        C                                                                             TAQUI1  01033
        4000  FORMAT(* T=*1PE12.5*  CYC=*I5*  DT=*E12.5*  GRINDS=*E12.5*  CIRC=*      TAQUI1  01034
             1 E12.5*  DTV=*E12.5*  (DTV.JDTV=*I3*,*I3/5X*ITERS=*I4*    CP=*          TAQUI1  01035
             1 E12.5*  DTC=*E12.5*  (DTC.JDTC=*I3*,*I3)                               TAQUI1  01036
        4010  FORMAT(*0  TAPE DUMPED* AT T=*1PE12.5* CYCLE*I5)                        TAQUI1  01037
        4020  FORMAT(*0  RESTARTING FROM TD*I3)                                       TAQUI1  01038
        4030  FORMAT(3X,10HA*   T=*1PE12.5* CYCLE=*I5)                                TAQUI1  01039
        4040  FORMAT(*0 WRONG TAPE - WRONG DUMP.*)                                    TAQUI1  01040
        4050  FORMAT(1H1)                                                             TAQUI1  01041
        4060  FORMAT(*  I   J*7X*X*11X*Y*11X*U*11X*V*10X*SIE*9X*RHO*8X*VOL*10X         TAQUI1  01042
             1 *D*11X*M*11X*P*)                                                       TAQUI1  01043
        4070  FORMAT(1X,I3*,*I3,10(1X,1PE11.4))                                       TAQUI1  01044
        4080  FORMAT(5X,A10,10HA*   T=*1PE12.5* CYCLE=*I5)                            TAQUI1  01045
        4090  FORMAT(* (SORTCH(CS*)                                                   TAQUI1  01046
        4100  FORMAT(* (SORTOFARMS*)                                                  TAQUI1  01047
        4110  FORMAT(* VORTICITY*)                                                    TAQUI1  01048
        4120  FORMAT(12X* MIN=*1PE12.5* MAX=*E12.5* L=*E12.5* M=*E12.5* DQ=*          TAQUI1  01049
             1 E12.5)                                                                 TAQUI1  01050
        4130  FORMAT(*0 ITERATION LIMIT EXCEEDED - RUN WAS ABORT.*)                   TAQUI1  01051
        4140  FORMAT(* ZONES*/* DMIN=*1PE12.5* DMAX=*E12.5* DZMIN=*E12.5              TAQUI1  01052
             1 * DZMAX=*E12.5* R=*E12.5* Z=*E12.5* T=*E12.5)                          TAQUI1  01053
        4150  FORMAT(* VELOCITY VECTORS*/1X*VMAX=*1PE12.5)                            TAQUI1  01054
              END                                                                     TAQUI1  01055
```

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SINGLY REFERENCED VARIABLES
     200 -    40*     FIPYR   -R    4CO   IPXL    -I    4CO   JCEN    -I    4CO   PARPLOT -  1795U   REWIND  -    92F   RPDZ    -R    4CO
    1100 -   44R*     FIPYT   -R    4CO   IPXR    -I    4CO   JM10    -I    4CO   PARTMOV -  9925U   REZONE  -  7615U   STARTO  -  8695U
    1300 -   545*     FIXR    -R    4CO   IPYR    -I    4CO   JM14    -I    4CO   PDR     -R    4CO   REZRON  -R    4CO   THIRD   -R    4CO
    1500 -   601*     FIYT    -R    4CO   IPYT    -I    4CO   JPAR2   -I    4CO   PDZ     -R    4CO   REZSIE  -R    4CO   YAQUI2  -     15U
    2000 -   672*     FJRP    -R    4CO   ISCF1   -I    4CO   JUNF    -I    4CO   PECONV  -R    4CO   REZUE   -R    4CO   YLC1    -     2CN
    3100 -   750*     FREZ    -R    4CO   ISC3    -I    4CO   JUNFO2  -I    4CO   PXL     -R    4CO   REZVE   -R    4CO   YLC2    -     2CN
    3400 -   884*     H4020   -    145U   ITV     -I    4CO   LCM     -     2F    PXR     -R    4CO   REZVT   -R    4CO   YSC1    -     3CN
    3700 -   971*     IRP     -I    4CO   IUNF    -I    4CO   LOOPD   -  8845U    PXRP    -R    4CO   REZYO   -R    4CO   YSC2    -     4CN
    3800 -   981*     IRP1    -I    4CO   IXL     -I    4CO   LPR     -I    4CO   PYR     -R    4CO   RIBAR   -R    4CO   YSC3    -    10CN
 DATAREL -   875U     ICOLOR  -I    4CO   IXR     -I    4CO   NTE     -I    6RL   PYRM    -R    4CO   RIRP    -R    4CO
 DR      -R   4CO     IMONE3  -I    4CO   IYR     -I    4CO   NQ1     -I    4CO   PYCONV  -R    4CO   RJRP    -R    4CO
 FIRP    -R   4CO     IMONE   -I    4CO   IYT     -I    4CO   NQ12    -I    4CO   PYT     -R    4CO   ROMFR   -R    4CO
 FIPXL   -R   4CO     IN4     -I    4CO   JRP     -I    4CO   OMEM10  -R    4CO   PYTP    -R    4CO   RPDR    -R    4CO
 FIPXR   -R   4CO     IP4D    -I    4CO   JRP2    -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 -    60*    744S
   220 -    50*    774S   104    107
   290 -    66     68*
   300 -    67     69     72*
   310 -    724S   74*
   320 -    68     76*
   330 -    69     79*
   340 -    50     794S   81*
   350 -    78     80     82*
   370 -    18     92*
   380 -    96     108*
   400 -    75     1125U
   410 -    116    117*
   420 -    116    119*
   440 -    1134S  1144S  122*
   450 -    130    132    156*
   452 -    156    156    157*
   454 -    121    160*
   456 -    1184S  156    164*
   458 -    116    1174S  167*
   460 -    1154S  1234S  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 -    222    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 -   26300   285*
659 -   26200   287*
700 -   260     289*
709 -   29300   296*
719 -   29200   298*
720 -   307*    308
730 -   309*    313
735 -   300     314*
739 -   31700   318*
740 -   310     320*
750 -   322     323*
760 -   322     325*
770 -   322     327*
780 -   324     326     328*
789 -   34800   355*
799 -   34700   357*
800 -   344     358*
810 -   359     364AS   366*
820 -   366     371AS   373*    395
830 -   373     378AS   380*
840 -   365     372     379     386*
879 -   33700   343     380     385AS   396*
889 -   33300   399*
899 -   33100   400*
939 -   40300   419*
949 -   40200   421*
1000 -   67     423*
1015 -  432     436*
1020 -  435     438*
1025 -  438     442*
1030 -  441     444*
1035 -  444     448*
1040 -  447     450*
1045 -  450     454*
1050 -  453     456*
1089 -  42600   464*
1099 -  42500   466*
1130 -  531     534*
1140 -  533     537*
1199 -  47000   574*
1210 -  57700   578*
1220 -  576     579*
1230 -  58000   581*
1240 -  579     582*
1299 -  46900   583*
1389 -  58700   597*
1399 -  58600   599*
1510 -  649     652*
1520 -  652     655*
1530 -  655     658*
1540 -  658     661*
1589 -  60300   668*
1599 -  60200   670*
2010 -  675*    737
2060 -  722     725*
2080 -  706     725     728*
2089 -  67700   729*
```

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 2099 -  676DO  732*
 3000 -  735    740*
 3009 -  743DO  746*
 3019 -  742DO  748*
 3109 -  752DO  756*
 3119 -  751DO  758*
 3150 -  740    761*
 3200 -  760    762*
 3230 -  824*   851
 3240 -  827*   854
 3259 -  764DO  844*
 3269 -  763DO  846*
 3280 -  821    849*
 3290 -  824    852*
 3300 -  848    855*
 3309 -  857DO  865*
 3319 -  856DO  867*
 3389 -  872DO  883*
 3399 -  870DO  885*
 3489 -  888DO  892*
 3499 -  887DO  894*
 3599 -  898DO  960*
 3610 -  963DO  964*
 3620 -  962    965*
 3630 -  966DO  967*
 3640 -  965    968*
 3699 -  897DO  969*
 3709 -  973DO  977*
 3719 -  972DO  979*
 3889 -  983DO  988*
 3899 -  982DO  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 -  73 PR 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
AMAXI    -      30SU  189SU  202SU  206SU  295SU  315SU  535SU  592SU  705SU  831SU
AMINI    -      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   926    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    834    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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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    827=   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
GROVEL  -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  476DO   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=
IDTG    -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
IJB     -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     365     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     532     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     996     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     361     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   [illegible]  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   337DO  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   580DO  966DO
LL       -I   358=   386=   386    388    389    390    394=
LOCF     -     94SU   945U
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  580DO  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    4C0   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    4C0    58=   424    701    702
READ     -     95F    97F    98F
RETURN   -     81F   111SU
RIRJ8    -R    4C0    42
RM       ()R   5EQ    7DI   131    131    523    524    525    526    714    715    716    717    689    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    4C0    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   974=  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
SORT    -   199SU 200SU 203SU 204SU
START   -    20SU 124SU 184SU 230SU 252SU 261SU 291SU 330SU 401SU 423SU 468SU 565SU 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 YAGUI2                                          PAGE  66
U4I      =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
VFI      =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    636=   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    203    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    236
             236   267    271    275    279    353    353    353    253    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  60
   1            SUBROUTINE PARTMOV                                                    YAQUI1  01056
   2            COMMON /YSC1/ AASC(4242)                                              COMMON2 00002
   3            COMMON /YSC2/ AA(1),ANC,ASQ,A0,A0FAC,AOM,B1,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,DTA,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,IMOM ,IM1,IM6,                    COMMON2 00008
               6        IFAR,IPXL,IPXR,IPYB,IPYT,IP1,IP2,ISCF1,ISCF2,ISC2,ISC3,       COMMON2 00009
               7        ITV,IUNF,IXL,IXR,IYB,IYT,J,JAAR,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,REZJT,REZYO,RIBAR,RIBJH,RIBP,RJBP,ROMER,          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,CO,PMX,PU),(AASC(13),VTIL,     EQVREAL 00006
               5             VL,PMY,PV),(AASC(14),Q,ROL)                              EQVREAL 00007
   5            REAL LAM,LAMD,M,MR,MC,ML,MP,MPAR,MR,MT,MTE,MU,MU02,MU04               EQVREAL 00008
   6            DIMENSION X(1),XPAR(1),R(1),YPAR(1),Y(1),MPAR(1),U(1),UG(1),          DIMEN   00002
               1           DELSM(1),V(1),VG(1),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),CO(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            DIMENSION X1(4)                                                       YAQUI1  01060
   8            EQUIVALENCE (X1(2),X2),(X1(3),X3),(X1(4),X4)                          YAQUI1  01061
   9             COMMON /YSC3/ JNP                                                    YAQUI1  01062
  10            CALL START                                                            YAQUI1  01063
  11            DO 1019 J=2,JP2                                                       YAQUI1  01064
  12            DO 1009 I=1,IP1                                                       YAQUI1  01065
  13            PMX(IJ) = PMY(IJ) = PMO(IJ) = 0.0                                     YAQUI1  01066
  14      1009  IJ = IJ+NQ                                                            YAQUI1  01067
  15            CALL LOOP                                                             YAQUI1  01068
  16      1019  CONTINUE                                                              YAQUI1  01069
  17            CALL DONE                                                             YAQUI1  01070
  18            DO 1099 J=2,JP2                                                       YAQUI1  01071
  19            IEC = (J-1)*NQI                                                       YAQUI1  01072
  20            CALL ECRD (AASC,IEC,NQI,NE)                                           YAQUI1  01073
  21            IJ = 1                                                                YAQUI1  01074
  22            DO 1089 I=1,IP1                                                       YAQUI1  01075
  23            IF (X(IJ).GT.PXRP .OR. Y(IJ).LT.PYBM) GO TO 1099                      YAQUI1  01076
  24            IF (Y(IJ).GT.PYTP) GO TO 1100                                         YAQUI1  01077
  25            KI =  X(IJ)       *RPDR + OPEM10                                      YAQUI1  01078
  26            KJ = (Y(IJ)-PYB)*RPDZ + OPEM10                                        YAQUI1  01079
  27            IEC = KJ*NQI                                                          YAQUI1  01080
  28            CALL ECRD (AASC(ISC2),IEC,NQI2,NE)                                    YAQUI1  01081
  29            KIJ = (KI-1)*NQ+ISC2                                                  YAQUI1  01082
  30            KIJP = KIJ+NQI                                                        YAQUI1  01083
  31            W =  X(IJ)       -FLOAT(KI-1)*PDR                                     YAQUI1  01084
  32            H = (Y(IJ)-PYB)-FLOAT(KJ-1)*PDZ                                       YAQUI1  01085
  33            XX = RPDRDZ/RM(IJ)                                                    YAQUI1  01086
  34            HTE = PDZ-H                                                           YAQUI1  01087
  35            DO 1049 JJ=1,2                                                        YAQUI1  01088
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      WTE = PDR*W                                              YAQUI1  01089
      DO 1039 II=1,2                                           YAQUI1  01090
      XI = XX*WTE*HTE                                          YAQUI1  01091
      PMX(KIJ) = PMX(KIJ) +XI*U(IJ)                            YAQUI1  01092
      PMY(KIJ) = PMY(KIJ) +XI*V(IJ)                            YAQUI1  01093
      PMO(KIJ) = PMO(KIJ) +XI                                  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  01'39
      PVR = PV(IR)                                             YAQUI1  0.140
 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 (IMONX.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.77777777778                               YAQUI1  01190
      PV(IJ) = PV(IJ).AND..NOT.77777777778                               YAQUI1  01191
 1489 IJ = IJ + NQ                                                       YAQUI1  01192
      CALL LOOP                                                          YAQUI1  01193
 1499 CONTINUE                                                           YAQUI1  01194
      CALL DONE                                                          YAQUI1  01195
 2000 IFCP = 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
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            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
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       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,IPI
       IF (X(IJ).GT.PXRP .OR. Y(IJ).LT.PYBM) GO TO 2599
       IF (Y(IJ).GT.PYTP) RETURN
       KI =  X(IJ)      *RPDR + OPEMIO
       KJ = (Y(IJ)-PYB)*RPDZ + OPEMIO
       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
```



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 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
 B0       -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  I CF2   -I  3CO  LAMD    -R  5RL  OMCYL    -R   3CO  RON      -R   3CO
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
MULTIPLY-REFERENCED VARIABLES
  1009 -    1200   14*
  1019 -    1100   16*
  1039 -    3700   43*
  1049 -    3500   45*
  1089 -    2200   47*
  1099 -    1800   23        48*
  1100 -    24     49*
  1189 -    5200   59*
  1199 -    5100   61*
  1210 -    72*    77
  1220 -    75     78*
  1230 -    73     80*       85
  1240 -    83     86*
  1250 -    81     88*
  1289 -    6600   67        93*
  1290 -    6500   95*
  131     108*   114
  13.  -    112    115*
  1330 -    109    117*     123
  1340 -    121    124*
  1350 -    118    126*
  1389 -    10100  102       131*
  1399 -    9700   132*
  1400 -    63     133*
  1489 -    13600  139*
  1499 -    13500  141*
  2000 -    133    143*
  2010 -    145*   208
  2020 -    147*   205
  2030 -    153    157*
  2139 -    19000  199*
  2149 -    18900  200*
  2150 -    184    202*     210
  2180 -    152    209*
  2190 -    203    211*
  2539 -    23100  236*
  2549 -    22900  238*
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 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
F      ()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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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
IXI     =I    257=  259AG
IYI     =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
LPR     =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
OPEMIO  =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
PDZMW   =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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PU       ()R    4EQ    6DI    56=    58=    78     86     91=    102    115    124    129=   137=   137    169    169    169    169
                193    197=   233
PUR      =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
PVR      =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
PYR      =R     3CO    26     32     151    162    221    227    248WR  258
PYRM     =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   176=   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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WRITE   -     248F   249F
WTA     -R    127=   129    130
WTF     -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
XTF     -R    147=   150    161    171    178=   178    182
XWA     -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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INDEX  01/12/73                 SUBROUTINE REZONE                                PAGE  79
            SUBROUTINE REZONE                                                YAQUI1  01328
            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,DTB,DZ,EMI0,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,XX1,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,PYG,PYBM,PYCONV,PYT,PYTP,RDT,REZRON,REZSIZ,  COMMON2 00014
           3       REZUE,REZVE,REZVT,REZY0,RIBAR,RIBJH,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,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),PMO(1)                        DIMEN   00006
            DIMENSION UGTE(100)                                              YAQUI1  01332
            REZOMG = 0.15*RDT                                                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(FCB,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))+REZRTA*(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))+REZRTA*(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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         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   GROVEL  -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   DTB     -R   3CO   IBP     -I   3CO   IXR     -I   3CO   MUO2    -R   5RL   PYRM    -R   3CO   T20MD   -R   3CO
ASQ    -R   3CO   DZ      -R   3CO   IBP1    -I   3CO   IYB     -I   3CO   MUO4    -R   5RL   PYCONV  -R   3CO   VV      -R   3CO
AO     -R   3CO   EM10    -R   3CO   ICOLOR  -I   3CO   IYT     -I   3CO   NAME    ()I  3CO   PYT     -R   3CO   XCONV   -R   3CO
AOFAC  -R   3CO   EPS     -R   3CO   IDTO    -I   3CO   JBAR    -I   3CO   NCYC    -I   3CO   PYTP    -R   3CO   XL      -R   3CO
AOM    -R   3CO   EQUIVAL -    4F    IJPS    -I   3CO   JBP     -I   3CO   NLC     -I   3CO   REAL    -    5F    XR      -R   3CO
BO     -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   NQ1B    -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   KY:     -I   3CO   NSC     -I   3CO   RIBJB   -R   3CO   YT      -R   3CO
DTGZ   -R   3CO   FIXL    -R   3CO   IPYB    -I   3CO   LAMO    -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
AMAXI  -    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
EP     ()R   4EQ    6DI
ETIL   ()R   4EQ    6DI
FXP    -   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
GMI    -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
IPI      -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   5RL
LOGP     -     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
REZRTA   -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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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
Y'      =R     50=   51    52=   52    52    53    54    55    102=  108   109   110
Y1      =R     34=   50    50
Y2      =R     38=   50    50    8 =   90=   90    98
Y3      =R     42=   50    50
Y4      =R     46=   50    50    54    107=  108   109   110
*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*+*
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LIST OF ALL VARIABLES DEFINED IN INPUT
C MEANS VARIABLE WAS DEFINED IN COMMON IN THAT ROUTINE
D MEANS VARIABLE WAS DEFINED IN OTHER DECLARATIONS
NON-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																
ASQ	YAQUI	C	LOOP	C	FILMCO	C	YASET1	2C	PARTGEN	C	MESHMKR	C	YAQUI2	4C	PARTMOV	C	REZONE	C
F ASSIGN	YASET1	2	YAQUI2	14														
AT	YAQUI2	6D																
ATR	YASET1	2	YAQUI2	2														
AVEL	REZONE	5																
AX	YAQUI2	3																
AY	YAQUI2	3																
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																
CQ	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																

	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	T																
	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	40	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														
	EM10	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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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
GROVEL	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														
IECB	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																

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																		
ITFSTL	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																		

N	YASETI	8	YAQUI2	18														
NAME	YAQUI	C	LOOP	C	FILMCO	C	YASETI	2C	PARTGEN	C	MESHMKR	C	YAQUI2	7C	PARTMOV	1C	REZONE	C
NB	MESHMKR	4																
NR2	MESHMKR	2																
NCYC	YAQUI	C	LOOP	C	FILMCO	C	YASETI	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	YASETI	1C	PARTGEN	C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
NLI	MESHMKR	2																
NFMT	PARTMOV	4																
NPPT	PARTMOV	4																
NPS	YAQUI	C	LOOP	C	FILMCO	C	YASETI	C	PARTGEN	1C	MESHMKR	C	YAQUI2	2C	PARTMOV	C	REZONE	C
NPT	YAQUI	C	LOOP	C	FILMCO	1C	YASETI	C	PARTGEN	6C	MESHMKR	C	YAQUI2	4C	PARTMOV	2C	REZONE	C
NO	YAQUI	1C	LOOP	1C	FILMCO	1C	YASETI	8C	PARTGEN	C	MESHMKR	10C	YAQUI2	55C	PARTMOV	16C	REZONE	10C
NQI	YAQUI	C	LOOP	21C	FILMCO	C	YASETI	7C	PARTGEN	2C	MESHMKR	1C	YAQUI2	C	PARTMOV	20C	REZONE	C
NOIB	YAQUI	C	LOOP	C	FILMCO	C	YASETI	1C	PARTGEN	C	MESHMKR	C	YAQUI2	6C	PARTMOV	C	REZONE	C
NOIM	MESHMKR	2																
NOI2	YAQUI	C	LOOP	C	FILMCO	C	YASETI	C	PARTGEN	1C	MESHMKR	C	YAQUI2	C	PARTMOV	5C	REZONE	C
NR	MESHMKR	6																
NR1	MESHMKR	3																
NSC	YAQUI	C	LOOP	C	FILMCO	C	YASETI	1C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
NT	MESHMKR	5																
NT2	MESHMKR	3																
NUMIT	YAQUI	C	LOOP	C	FILMCO	C	YASETI	C	PARTGEN	C	MESHMKR	C	YAQUI2	7C	PARTMOV	C	REZONE	C
NUMTD	YAQUI	C	LOOP	C	FILMCO	C	YASETI	1C	PARTGEN	C	MESHMKR	C	YAQUI2	TC	PARTMOV	C	REZONE	C
OM	YAQUI	C	LOOP	C	FILMCO	C	YASETI	2C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
OMAL13	YAQUI2	3																
OMAL24	YAQUI2	3																
OMANC	YAQUI	C	LOOP	C	FILMCO	C	YASETI	1C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
OMCYL	YAQUI	C	LOOP	C	FILMCO	C	YASETI	1C	PARTGEN	1C	MESHMKR	2C	YAQUI2	1C	PARTMOV	C	REZONE	1C
OMEM10	YAQUI	C	LOOP	C	FILMCO	1C	YASETI	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	YASETI	1C	PARTGEN	C	MESHMKR	C	YAQUI2	C	PARTMOV	6C	REZONE	C
OUT	YAQUI	2																
S OVERLAY	YAQUI	2																
P	YAQUI	D	FILMCO	D	YASETI	D	PARTGEN	D	MESHMKR	D	YAQUI2	13D	PARTMOV	D	REZONE	D		
S PARPLOT	YAQUI2	1	PARTMOV	1														
S PARTGEN	YASETI	1	PARTGEN	1														
S PARTMOV	YAQUI2	1	PARTMOV	1														
PB	YAQUI2	3																
PC	YAQUI2	5																
PDR	YAQUI	C	LOOP	C	FILMCO	2C	YASETI	2C	PARTGEN	1C	MESHMKR	C	YAQUI2	C	PARTMOV	7C	REZONE	1C
PDRMW	PARTMOV	3																
PDZ	YAQUI	C	LOOP	C	FILMCO	2C	YASETI	2C	PARTGEN	1C	MESHMKR	C	YAQUI2	C	PARTMOV	7C	REZONE	1C
PDZMM	PARTMOV	3																
PITH	YAQUI2	5																
PIXX	YAQUI2	5																
PIXY	YAQUI2	9																
PIYY	YAQUI2	4																
PL	YAQUI	D	FILMCO	D	YASETI	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	YASETI	D	PARTGEN	D	MESHMKR	D	YAQUI2	D	PARTMOV	4D	REZONE	D		
PMY	YAQUI	D	FILMCO	D	YASETI	D	PARTGEN	D	MESHMKR	D	YAQUI2	D	PARTMOV	4D	REZONE	D		
PMO	YAQUI	D	FILMCO	D	YASETI	D	PARTGEN	D	MESHMKR	D	YAQUI2	D	PARTMOV	12D	REZONE	D		

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 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 180  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 170  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
 REZONG  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
 RIBJR   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 6   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																
	RDI	MESHMKR	7																
	ROJP2	MESHMKR	2																
	ROJI	MESHMKR	2																
	ROL	YAQUI	D	FILMCO	D	YASETI	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	YASETI	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	YASETI	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	YASETI	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	YASETI	2C	PARTGEN	C	MESHMKR	C	YAQUI2	1C	PARTMOV	C	REZONE	C
	U	YAQUI	D	FILMCO	D	YASETI	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	YASETI	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  40  YAQUI2  220  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  320  PARTMOV  3D  REZONE   D
VD1      YAQUI2   3
VD2      YAQUI2   3
VD3      YAQUI2   3
VD4      YAQUI2   3
VELIJ    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
VRANO    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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  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
  XO       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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  YBOT     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  1D   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  20    REZONE   3
  Y31      YAQUI2  13
  Y32      YAQUI2  10
  Y4       YASET1   3    YAQUI2  27    REZONE   8
  Y43      YAQUI2  10
  ZZ       YAQUI    C    LOOP     C    FILMCO   C    YASET1   1C   PARTGEN  C    MESHMKR  C    YAQUI2   1C   PARTMOV  C    REZONE   C
```


ROUTINES INDEXED


```
************************************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
**********************************************************************************************************************
```